ASSESSMENT OF SOLAR ENERGY PRODUCTION AND CONSUMPTION

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Abstract.
Purpose and aim of the study: *The present research aims to investigate and assess the production and consumption of solar energy.*
Design / Methodology / Approach: *The research employed the following methods: descriptive and logical construction were used for reviewing and analysing research papers and other information sources, as well as for scientific discussion. Statistical analysis was employed to process and analyse secondary data on trends in the use of solar panel systems in the world and in Latvia. The graphic method was applied to better represent and compare the research results.*
Main Findings: *It was concluded that the share of solar energy in the world tended to increase significantly. However, Latvia lagged far behind the neighbouring countries in terms of solar energy generation and was in last place in the entire European Union in terms of total installed capacity of solar panel systems. In Latvia, a significant increase in solar energy consumption could be observed from 2022.*
Originality: *The research examined the technology of generating solar energy and factors in the output of solar energy, summarized information on trends in solar energy consumption in Latvia and the world and identified the role of solar energy in Latvia by comparing the share of solar energy consumption with the share of consumption of other renewable energy sources and the situation in neighbouring countries and the world.*
Implications: *The present research represents the basis for further research on solar energy production and consumption*

Keywords: *electricity, photovoltaics, renewable energy, solar energy.*

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Introduction

The demand for electricity in the world tends to increase, and it is largely met by exploiting fossil energy sources. However, the fossil energy reserves are limited and the consumption of fossil energy contributes to climate change. Several countries and organizations around the world propose decreasing climate change and meeting the growing demand for electricity by renewable energy.

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In Latvia compared with other countries, the use of solar energy to produce electricity is a relatively new way of generating renewable energy. In view of the simple structure, easy installation and maintenance, solar collectors were much more widely used to obtain thermal energy in Latvia for a long period (Rivža et al., 2012).

Solar irradiance is the main source of energy for organisms living on the planet Earth. The Sun is the closest and also the most researched star. However, research on the use of solar energy for electricity generation has begun relatively recently (Bravo Hidalgo et al., 2018; Maka & Alabid, 2022).

The present research *aims* to investigate and assess the production and consumption of solar energy.

The following *specific research tasks* were set to achieve the aim:

1) to give insight into solar energy production and identify factors in the output of solar energy;
2) to examine the production and consumption of solar energy in the world;
3) to examine the production and consumption of solar energy in Latvia.

The following *research hypothesis* was put forward: the share of renewable energy, including solar energy, in total energy generation tends to increase both in Latvia and in the world.

The research employed qualitative and quantitative *methods.* The descriptive and logical construction methods were used for reviewing and analysing research papers and other information sources, as well as for scientific discussion. Statistical analysis was employed to process and analyse secondary data on trends in the use of solar panel systems in the world and in Latvia. The graphic method was applied to better represent and compare the research results.

The research was based on a review of research papers and statistical data from various institutions.

Research results and discussion

1. Solar energy production and factors in the output

Solar energy is a kind of renewable energy, and it alone is capable of meeting several hundred times the global demand for energy. Nowadays, the most common devices for producing solar energy are solar collectors and solar photovoltaic panels (Gong et al., 2019). Solar collectors are devices for producing thermal energy by using solar energy. They capture solar energy and convert it into heat by means of a heat-transfer agent. Water or air is mostly used as the heat-transfer agent. Solar collectors are relatively simple in design, easy to install and maintain, as well as relatively cheap (Tian &

Zhao, 2013; Gopalakrishna & Dey, 2022). Therefore, solar collectors were much more commonly used than solar photovoltaic panels in Latvia over a long period. Solar photovoltaic panels or solar cells (hereinafter solar panels) are devices that generate electricity from solar energy. They were invented much later than solar collectors (Fraas, 2014). Solar panels are most often placed on the ground and roofs or facades of buildings. The direct current generated by a solar panel is converted into alternating current by an inverter. The electricity generated could be immediately self-consumed, transferred to the common electricity grid or stored in batteries (Fares & Webber, 2017).

The legal framework for solar electricity production equipment in Latvia, considering the rapid progress in this field, has changed significantly over time: new legal acts have been adopted and current ones have been amended, the terminology used has been improved etc. The changes could be viewed positively, as several requirements have been eased (Ministry of Economics, 2022). The current legal acts divide solar electricity production equipment into two categories, depending on the power of the inverter: microgenerators and power plants (System Connection Rules*…,* 2021). A microgenerator is an electricity generation device that includes the production device itself (solar panels) and related devices (inverter etc.) with a capacity of up to 11.1 kW. A microgenerator is intended for alternating current generation with an operating current of up to 16 A per phase. This means that the capacity specified for the inverter may be up to 3.7 kW in single phase and up to 11.1 kW in three phases (System Connection Rules …, 2021). A power plant is an electricity generation facility, which includes a production facility (solar panels) and related equipment (inverter etc.) with a capacity of over 11.1 kW. A power plant is intended for alternating current generation with an operating current of over 16 A per phase (System Connection Rules …, 2021; 2022).

A simplified sequence of steps to be taken by owners of solar energy microgenerators and power plants is shown in Figure 1.

As shown in Figure 1, the requirements for solar power plant owners to generate electricity and transfer it to the common electricity grid are much more time-consuming, complex and resource-intensive than those for solar microgenerator owners.

The amount of electricity generated by solar panels is affected by several factors. The main one is solar irradiance. This variable largely depends on geographical location and meteorological conditions.

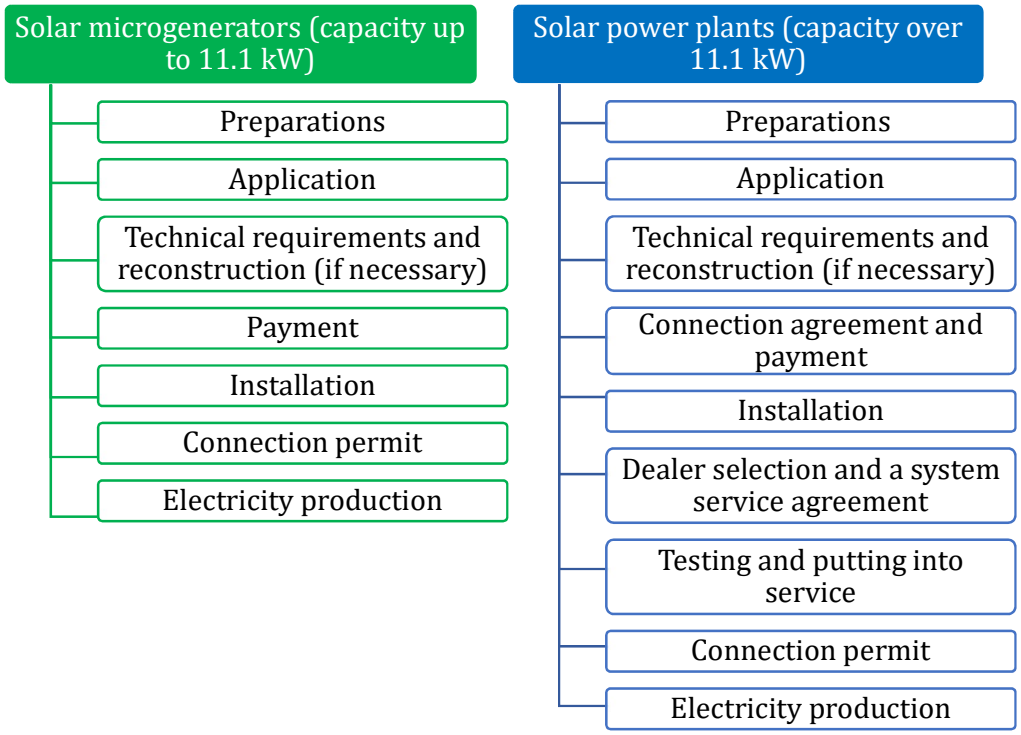

Fig.1 Comparison of the steps to be taken by owners of solar microgenerators and power plants to start generating electricity for the electricity grid (authors' construction based on Sadales tīkls, 2023a; 2023b)

Southern Europe has higher potential for the use of solar energy for electricity production; however, under ideal conditions in Latvia, on average, 1000 kWh of electricity could be generated by 1 m^2 of solar panels per year. However, this amount of electricity is only theoretical because in that case the efficiency of solar panels should be 100%, whereas at the beginning of 2023, the efficiency of solar panels available on the market did not exceed 25% (Aydin et al., 2020; Solargis, 2021; Jude, 2023).

The amount of electricity generated by a solar panel is also significantly affected by the position of the solar panel relative to the azimuth of the Sun and the angle of the solar panel itself to the horizon (Yoon et al., 2023). Solar panels can generate the most electricity if they are placed directly perpendicular to the Sun (Hafez et al., 2017; Abdallah et al., 2020). However, the Sun's angular height above the horizon is a variable. It depends on the geographical location, the time of day and the season, as the angular height of the Sun above the horizon is lower in winter and higher in summer. For example, in Latvia, the lowest angular height of the Sun above the horizon is at the winter solstice, on 22 December, when it does not exceed 11° at noon. In contrast, the Sun has its highest angular elevation above the horizon at the summer solstice, 21 June, when it exceeds 55° at noon (Suncalc, 2023).

Various obstacles and their shadows on solar panels can significantly reduce the amount of electricity generated because the solar panels are connected to each other in series and, in some cases, in parallel, yet their cells are connected to each other in series. Therefore, even a small amount of shading on the surface of a single solar panel can significantly reduce the total output power of the system (Sathyanarayana et al., 2015; Satpathy et al., 2022). Sathyanarayana et al. (2015) found that bird-shape shading, which covered only 4% of the surface of solar panels, reduced their efficiency by more than two-fold. Coşgun and Demir (2022) established that the efficiency of solar panels was affected by dust. In meteorological conditions in Latvia, dust is effectively cleaned by rain.

No less important factor that affects the efficiency of solar panels is temperature because when the solar panel cells heat up, output power losses occur. A research study conducted in Latvia by Stanka et al. (2020) concluded that when solar panels heated up above 25 °C, their output power decreased by 0.4% per degree Celsius. Consequently, an output power loss of 11.4% or 12.63 W/m^2 was observed when solar panel cells heated up to 53.5 °C.

2. Production and consumption of solar energy in the world

Mitigating climate change and meeting the high demand for energy are the main goals of energy policy. Renewable energy has high potential to solve the problems caused by achieving the goals in the nearest future. However, such a solution requires coordinated and coordinated action, as well as several significant changes in the energy policies of various organizations and countries (Olabi & Abdelkareem, 2022).

Several countries and organizations around the world have set various goals to achieve the objectives stated by the Paris Agreement. For example, in 2018, the EU adjusted its 2014 target by 5%, so that by 2030 the share of renewable energy in the total consumption of energy in the EU would reach 32% (Frank et al., 2016; Quintana-Rojo et al., 2020). However, Denmark has set an even more ambitious goal to fully meet the country's demand for energy by renewable energy by 2030 (Goldbergs, 2022).

Despite the efforts made by countries and organizations to increase the share of renewable energy, still about 78% of the total demand of energy is met by fossil energy. Unfortunately, it is the consumption of fossil fuels that contributes to global warming and other ecological problems, as well as the depletion of limited fossil reserves (REN21 Secretariat, 2023).

The latest statistical data reveal that the share of renewable energy, incl. solar energy, tends to increase from year to year. The output of electricity has increased very significantly. During the last decade, the demand for electricity has increased by almost 20%, and in 2021 compared with 2011,

the share of renewable electricity increased by 7.9% (REN21 Secretariat, 2023) (Figure 2).

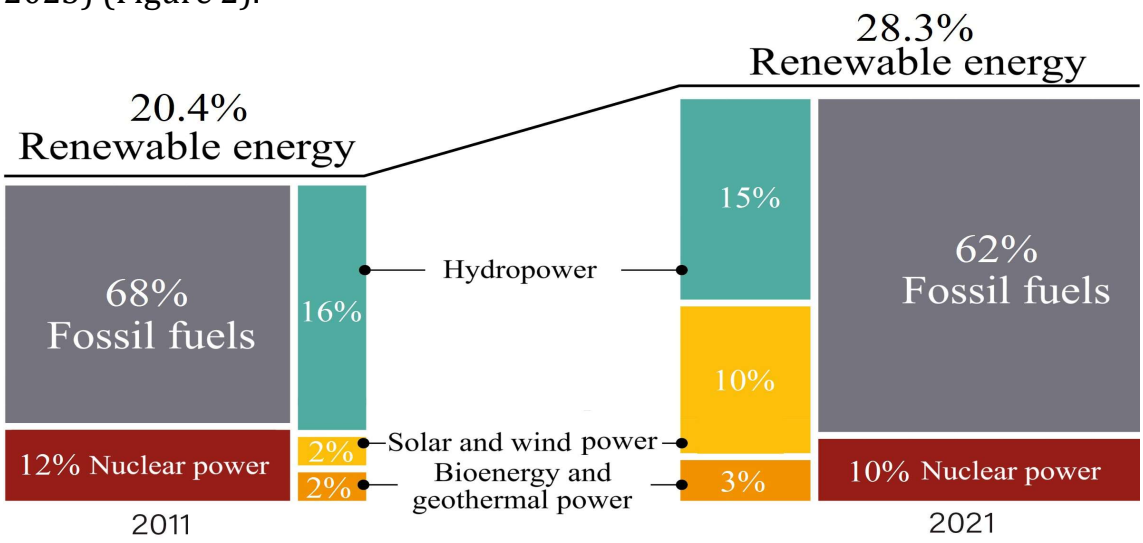

Fig. 2 Share of renewable energy capacity in total generation in 2011 and 2021, % (authors' construction based on REN21 Secretariat, 2023)

As shown in Figure 2, the demand for electricity increased, whereas the share of fossil and nuclear energy decreased. Of all renewable energy sources, the largest amount of electricity was generated by hydroelectric power plants using water flow energy, or hydropower, yet the amount of electricity from solar and wind energy has increased very significantly from 2% in 2011 to 10% in 2021.

An important indicator for analysing trends in the consumption of renewable energy is not only the amount of electricity generated but also the capacity. Statistical data (International Renewable Energy…, 2022) on the percentage share of renewable energy capacity in total generation in 2021 in the world show that of all renewable energy resources, hydropower had the largest capacity in total generation in the world (40.13%), followed by solar (28.01%) and wind energy (26.78%), while a relatively low percentage was reported for bioenergy (4.59%), geothermal energy (0.48%) and marine energy (0.02%). It could be concluded that in the world, the use of renewable energy for electricity production is well diversified because, for example, at night when solar energy does not generate electricity, it could be offset by wind energy or hydropower, and vice versa.

The latest available data show that a particularly significant increase in renewable energy capacity occurred in recent years (Figure 3).

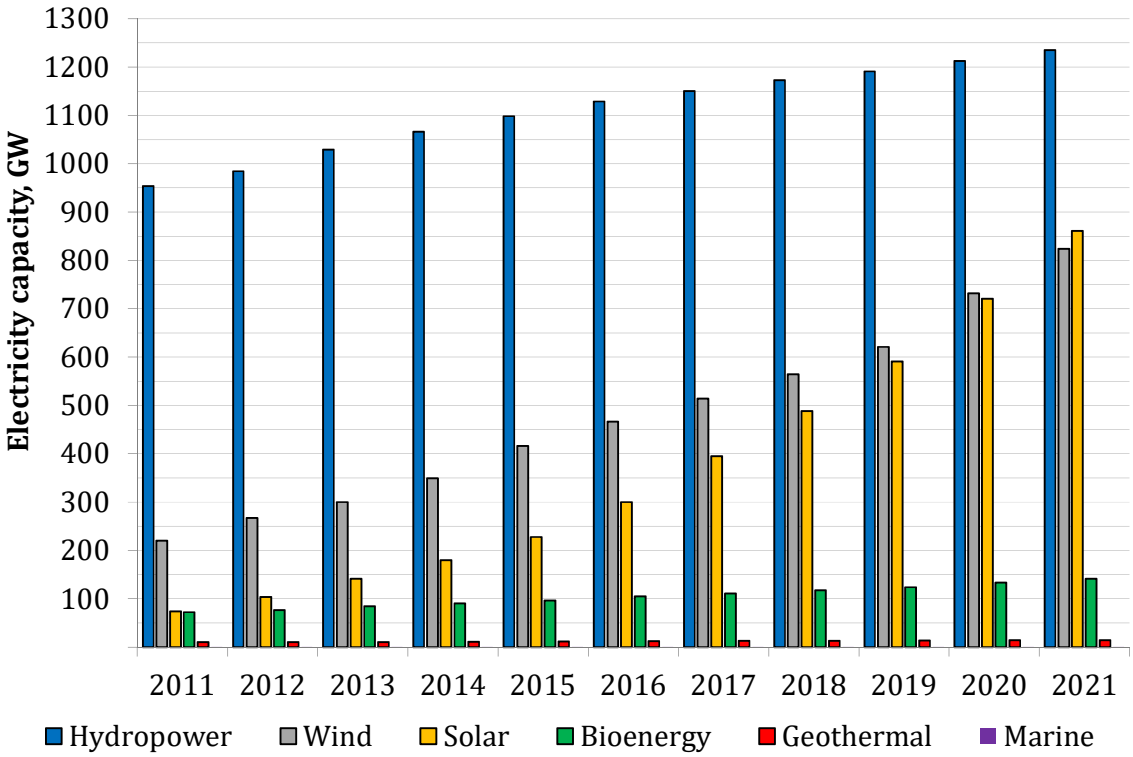

Fig. 3 Renewable electricity capacity in the world from 2011 to 2021, GW (authors' construction based on International Renewable Energy… 2022)

As shown in Figure 3, the total capacity of all renewable energy resources tended to increase, while the total capacity of wind and solar energy increased particularly significantly. Since 2021 in the world, the total capacity of solar energy has exceeded the total capacity of wind energy. In 2011, the total capacity of solar energy used for electricity generation was 74 GW, while in 2021 it was more than 10 times larger at 862 GW.

An advantage of solar panels is that electricity is generated during the day when electricity consumption is the highest and electricity prices are the highest at the electricity exchange (Kannan & Vakeesan, 2016; Albertus et al., 2020). However, solar panels do not produce electricity during the night hours and produce it in small amounts on cloudy days. Establishing large solar panel parks requires a large land area. For example, solar panel systems with a capacity of 1 MW require about 1 ha of land (Goldbergs, 2022), while in some cases even more – 1.6 ha of land (Kabir et al., 2018). Kannan and Vakeesan (2016) and Kabir et al. (2018) pointed out that the share of renewable energy would only increase, considering the high demand for energy as well as climate change mitigation goals. The share of solar energy will continue increasing at a high rate.

3. Trends in the consumption of solar energy in Latvia

In Latvia, the use of solar panels began mostly only during the last decade. In 2012, according to JSC "Sadales tīkls" data, there were 36 microgenerators connected to the common electricity grid (Sadales tīkls, 2023c), and only in 2018 the total capacity of solar panel systems reached 1 MW (CSB, 2022). At the same time, in Estonia and Lithuania, this figure reached tens of MW (Figure 4) (International Renewable Energy …, 2022).

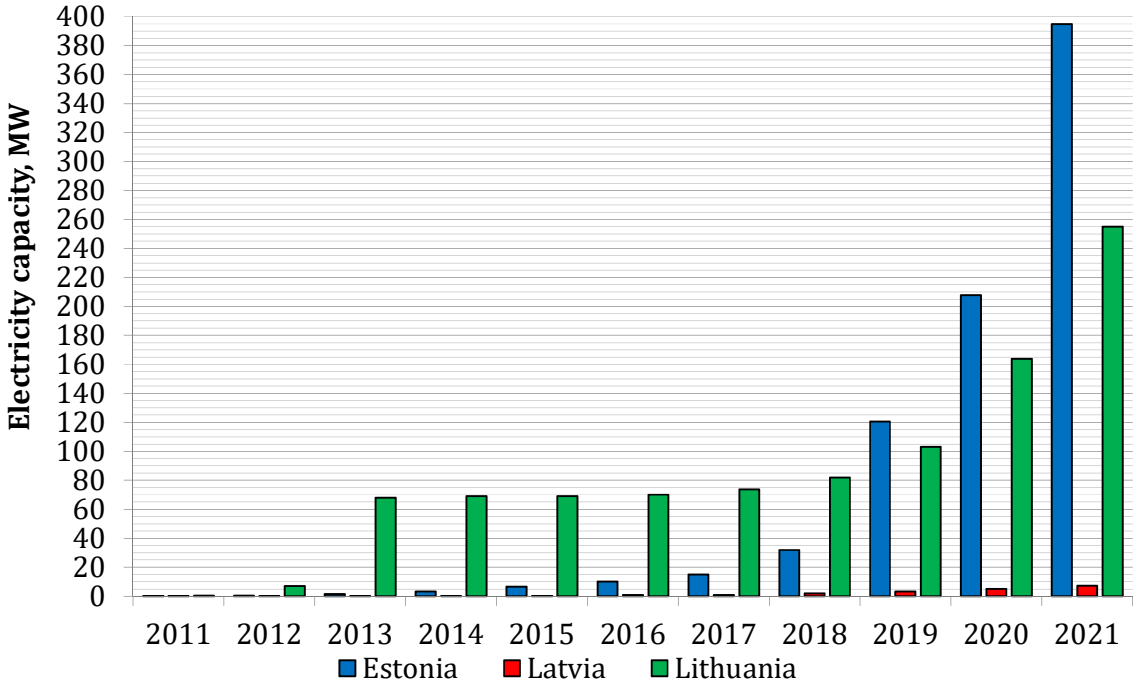

Fig. 4 Solar electricity capacity in the Baltic States from 2011 to 2021, MW (authors' construction based on the CSB, 2022; International Renewable Energy …, 2022)

As shown in Figure 4, during the last 10 years the total capacity of solar panel systems has significantly increased in Estonia and Lithuania, whereas a minimal increase has been reported in Latvia. Data for 2021 show that the total installed capacity of solar panels in Estonia was 394.77 MW, 255.00 MW in Lithuania, whereas in Latvia only 7.16 MW (CSB, 2022; International Renewable Energy …, 2022). This means that in Estonia, which is a smaller country and geographically located further north, where the level of solar irradiance is lower, the total installed capacity of solar panel systems in 2021 was more than 50 times larger than that in Latvia.

According to the 2021 data, Latvia was in last place in terms of solar panel use not only among the Baltic countries but also in the entire EU. In addition, the total capacity of solar panel systems in Ireland, which was in

second last place, was almost 20 times larger than that in Latvia with 135.32 MW (International Renewable Energy …, 2022).

A similar situation could be observed in Latvia regarding wind energy. This could largely be explained by already the high share of renewable energy in total electricity generation. The share of renewable energy made up more than half (51.4%) of the total electricity consumption in 2021 (CSB, 2023), while the EU average was only 37.5% (Eurostat, 2023). In 2021 in the EU, only Austria (76.2%), Sweden (75.7%), Denmark (62.6%), Portugal (58.4%) and Croatia (53.5%) had a higher share of renewable energy in total electricity consumption than Latvia (*Eurostat, 2023*).

Besides, the share of renewable energy in the total consumption of energy was 42.1% in Latvia in 2021 (CSB, 2023), which was far above the EU average of 21.8% (Eurostat, 2023) and the 32% target set by the Paris Agreement by 2030 (Quintana-Rojo et al., 2020). In 2021 in the EU, this figure was higher only in Sweden (62.6%) and Finland (43.1%) than that in Latvia (Eurostat, 2023). Consequently, Latvia has not had the motivation to increase and support other kinds of renewable energy production, including wind and solar energy.

In Latvia, the high share of renewable energy in total electricity generation was largely provided by hydropower. In 2021 in Latvia, the total capacity of hydroelectric power plants (HPP) was 1587 MW. The plants generated 2708 GWh of electricity, which accounted for 72.8% of the total renewable electricity generated in Latvia (CSB, 2022). Most of the renewable energy capacity in Latvia was hydropower (87.05%), which was provided by the three largest hydroelectric power plants in the country: the Plavinas HPP (908 MW), the Riga HPP (402 MW) and the Kegums HPP (248 MW). In 2021, their total capacity was 1558 MW, making up 98.2% of the total capacity of hydroelectric power plants in Latvia (CSB, 2022; Latvenergo, 2023).

The capacity of other renewable energy sources in Latvia was relatively small. In 2021 in Latvia, the share of bioenergy capacity in total renewable energy capacity for electricity generation was 8.32%, 4.23% for wind energy and only 0.39% for solar energy (CSB, 2022).

It should be pointed out that in 2022, the situation regarding solar energy consumption improved significantly. At the end of 2021 in Latvia, more than 2000 households had installed solar panel systems, while at the end of 2022, more than 11000 households had them (Vilciņš, 2022). At the end of 2022, according to JSC "Sadales tīkls" data, almost 12 thousand microgenerators were connected to the common electricity grid. A significant increase in the number of microgenerators was reported in 2022. In 2022 compared with 2021, the total number of households having microgenerators increased by 448% (Sadales tīkls, 2023c). This could be explained by high electricity prices in 2022, support measures and relaxed

requirements for installing solar panel systems and connecting them to the common electricity grid (Regulations regarding the Support Programme…, 2021; Vilciņš, 2022; Ministry of Economics, 2022).

According to an electricity supply report by the JSC "Sadales tīkls" for the 1st quarter of 2023, the number of microgenerators exceeded 13 000 at the end of the 1st quarter, while their total capacity exceeded 100 MW. In addition, the total capacity of solar microgenerators and power plants was approximately 140 MW at the end of Q1 2023 (Sadales tīkls, 2023d).

At the beginning of 2023, the JSC "Sadales tīkls" stated that several solar power plants with a total capacity of approximately 900 MW were at the stages of design, contract conclusion as well as construction and putting into service. In addition, the declaration of solar microgenerators and the connection to the grid was still actively ongoing (Sadales tīkls, 2023d).

The potential of solar energy for generating electricity is very large, and the total capacity of solar panel systems tends to increase rapidly in the world. Latvia is no exception, and since the beginning of 2022, the capacity of solar panel systems has increased several times. However, Latvia is still significantly behind the rest of EU Member States in terms of solar energy use.

Conclusions and suggestions

The amount of electricity generated by solar panels is affected by solar irradiance, which depends on geographical location and meteorological conditions. The amount of electricity generated by a solar panel is also significantly affected by the position of the solar panel relative to the azimuth of the Sun and the angle of the solar panel itself to the horizon, various obstacles and their shadows on the solar panel as well as temperature because power losses occur when the solar panel cells heat up.

The requirements for solar power plant owners to generate electricity and transfer it to the common electricity grid are much more time-consuming, complex and resource-intensive than those for solar microgenerator owners.

The share of solar energy in total electricity generation increases rapidly in the world. In 2021 compared with 2011, the total capacity of solar panel systems increased more than 10 times. Since 2021 in the world, the total capacity of solar energy used for electricity generation has exceeded the total capacity of wind energy, reaching 28.01% of the total renewable energy capacity.

In terms of solar energy use, Latvia was not only in last place among the Baltic States but also in the entire EU. A rapid increase in the number of solar panel systems in the household sector could be observed in Latvia in 2022.

At the beginning of 2022, 2145 households had solar microgenerators, while at the end of 2022, their number had increased several times, reaching 11764 households.

At national level, the Ministry of Climate and Energy should contribute to significantly increasing the share of other renewable energy resources, except for hydropower. The diversification by increasing the share of wind and solar energy can provide electricity even in periods when hydroelectric plants do not generate enough electricity.

References

1. Abdallah, R., Natsheh, E., Juaidi, A., Samara, S., & Manzano-Agugliaro, F. (2020). A multi-level world comprehensive neural network model for maximum annual solar irradiation on a flat surface. *Energies*, 13(23), paper No. 6422.
2. Albertus, P., Manser, J.S., & Litzelman, S. (2020) Long-duration electricity storage applications, economics, and technologies. *Joule*, 4(1), 21 – 32.
3. Aydin, E., Allen, T.G., Bastiani, M., Xu, L., Ávila, J., Salvador, M., Kerschaver, E., & Wolf, S. (2020). Interplay between temperature and bandgap energies on the outdoor performance of perovskite/silicon tandem solar cells. *Nature Energy*, 5(11), 851 – 859.
4. Bravo Hidalgo, D., Jiménez Borges, R., & Valdivia Nodal, Y. (2018) Applications of solar energy: history, sociology and last trends in investigation. *Produccion & Limpia*, 13(2), 21 – 28. https://doi.org/10.22507/pml.v13n2a3
5. CSB (2022). *Electrical capacity and produced electricity from renewables 1990 - 2022 1990–2021* https://data.stat.gov.lv/pxweb/lv/OSP_PUB/START__NOZ__EN__ENA/ENA040
6. CSB (2023). *Share of renewable energy resources 2004 - 2021.* https://data.stat.gov.lv/pxweb/lv/OSP_PUB/START__NOZ__EN__ENA/ENA020
7. Coşgun, A.E., & Demir, H. (2022). The experimental study of dust effect on solar panel efficiency. *Politeknik Dergisi*, 25(4), 1429 – 1434.
8. Minsitry of Economics (2022). *Atvieglo būvniecības procesu saules paneļu uzstādīšanai.* https://www.em.gov.lv/lv/jaunums/atvieglo-buvniecibas-procesu-saules-panelu-uzstadisanai
9. Eurostat (2023) *Renewable energy statistics.* https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Renewable_energy_statistics#Share_of_renewable_energy_more_than_doubled_between_2004_and_2021
10. Fares, R.L., & Webber, M.E. (2017). The impacts of storing solar energy in the home to reduce reliance on the utility. *Nature Energy*, 2(2), 1 – 10.
11. Fraas, L.M. (2014). History of solar cell development. *Low-Cost Solar Electric Power*, 1 – 12.
12. Frank, S., Böttcher, H., Gusti, M., Havlík, P., Klaassen, G., Kindermann, G., & Obersteiner, M. (2016). Dynamics of the land use, land use change, and forestry sink in the European Union: the impacts of energy and climate targets for 2030. *Climatic Change*, 138, 253 – 266.

13. Goldbergs, J. (2022). "Latvijai vajadzīgos saules un vēja parkus var uzbūvēt ātri", *Dienas Bizness*, 2022. gada 11. oktobris, 28. – 31. lpp.
14. Gong, J., Li, C., & Wasielewski, M.R. (2019). Advances in solar energy conversion. *Chemical Society Reviews*, 48(7), 1862 – 1864.
15. Gopalakrishna, M., & Dey, S. (2022). Study and Modelling of Solar Energy and Solar Power Tower. *Journal of Interdisciplinary Cycle Research*, 14(4), 360 – 365.
16. Hafez, A.Z., Soliman, A., El-Metwally, K.A., & Ismail, I.M. (2017). Tilt and azimuth angles in solar energy applications – A review. *Renewable and Sustainable Energy Reviews*, 77, 147 – 168.
17. International Renewable Energy Agency (2022). *Irenastat online data query tool.* https://pxweb.irena.org/pxweb/en/IRENASTAT/IRENASTAT__Power%20Capacity%20and%20Generation/ELECCAP_2022_cycle2.px/
18. Jude T. (2023). *8 most efficient solar panels.* https://www.architecturaldigest.com/reviews/home-improvement/most-efficient-solar-panels
19. Kabir, E., Kumar, P., Kumar, S., Adelodun, A.A., & Kim, K.H. (2018). Solar energy: Potential and future prospects. *Renewable and Sustainable Energy Reviews*, 82, 894 – 900.
20. Kannan, N., & Vakeesan, D. (2016). Solar energy for future world: A review. *Renewable and Sustainable Energy Reviews*, 62, 1092 – 1105.
21. Latvenergo (2023). *Par mums: Ražošana.* https://latvenergo.lv/lv/par-mums/razosana
22. Maka, A.O., & Alabid, J.M. (2022). Solar energy technology and its roles in sustainable development. *Clean Energy*, 6(3), 476-483.
23. *Noteikumi par atbalsta programmu viena dzīvokļa dzīvojamo māju atjaunošanai un energoefektivitātes paaugstināšanai*. (11/02/2021). MK noteikumi Nr. 103. https://likumi.lv/ta/id/321021-noteikumi-par-atbalsta-programmu-viena-dzivokla-dzivojamo-maju-atjaunosanai-un-energoefektivitates-paaugstinasanai
24. Olabi, A.G. & Abdelkareem, M.A. (2022). Renewable energy and climate change. *Renewable and Sustainable Energy Reviews*, 158, paper No. 112111.
25. Quintana-Rojo, C., Callejas-Albiñana, F.E., Tarancón, M.Á., & Martínez-Rodríguez, I. (2020). Econometric studies on the development of renewable energy sources to support the European Union 2020–2030 climate and energy framework: A critical appraisal. *Sustainability*, 12(12), paper No. 4828.
26. REN21 Secretariat (2023). *Renewables 2022: Global status report*. https://www.ren21.net/wp-content/uploads/2019/05/GSR2022_Full_Report.pdf
27. Rivža, P. (sci. ed.) (2012). *Atjaunojamā enerģija un tās efektīva izmantošana Latvijā: Monogrāfija*. Jelgava: LLU, 392 lpp.
28. Sadales tīkls (2023a). *Mikroģeneratora pieslēgšana.* https://sadalestikls.lv/lv/mikrogeneratora-pieslegsana
29. Sadales tīkls (2023b). *Elektrostacijas pieslēgšana.* https://sadalestikls.lv/lv/elektrostacijas-pieslegsana
30. Sadales tīkls (2023c). *Sadales tīkls: Elektroapgādes apskats 2022.* https://prezi.com/i/view/Zch8VEUQH6cyiqp2ny10/
31. Sadales tīkls (2023d). *Sadales tīkls: Elektroapgādes apskats 2023. gada janvāris – marts.* https://sadalestikls.lv/lv/elektroapgades-apskats
32. Sathyanarayana, P., Ballal, R., Sagar, P.L., & Kumar, G. (2015). Effect of shading on the performance of solar PV panel. *Energy and Power*, 5(1A), 1 – 4.

33. Satpathy, P.R., Aljafari, B., & Thanikanti, S.B. (2022). Power losses mitigation through electrical reconfiguration in partial shading prone solar PV arrays. *Optik*, 259, paper No. 168973.
34. *Sistēmas pieslēguma noteikumi elektroenerģijas ražotājiem*. (14/04/2022). Sabiedrisko pakalpojumu regulēšanas komisijas padomes lēmums Nr. 1/8. https://likumi.lv/ta/id/323728-sistemas-piesleguma-noteikumi-elektroenergijas-sadales-sistemai
35. *Sistēmas pieslēguma noteikumi elektroenerģijas sadales sistēmai*. (03/06/2021). Sabiedrisko pakalpojumu regulēšanas komisijas padomes lēmums Nr. 1/8. https://likumi.lv/ta/id/323728-sistemas-piesleguma-noteikumi-elektroenergijas-sadales-sistemai
36. Solargis (2021). *Global Horizontal Irradiation.* https://solargis.com/maps-and-gis-data/download/europe
37. Stanka, N., Aboltins, A., & Palabinskis, J. (2020). Impact of high temperature and other factors on PV module efficiency on small farms in Latvia in *Engineering for Rural Development*: proceedings of the international scientific conference, 19., 472 – 480.
38. Suncalc (2023). *Solar data for the selected location.* https://www.suncalc.org/#/56.9474,24.1069,5/2023.06.21/13:26/1/3
39. Tian, Y., & Zhao, C.Y. (2013). A review of solar collectors and thermal energy storage in solar thermal applications. *Applied Energy*, 104, 538 – 553.
40. Vilciņš, A. (2022). "Viens izdevīgākais piedāvājums neeksistē", *Dienas Bizness*, 2022. gada 8. novembris, 28. – 32. lpp.
41. Yoon, S., Park, J., Lee, C., Kim, S., Choi, Y., Kwak, S., Kim, H., & Kim, J. (2023). Optimal orientation of solar panels for multi-apartment buildings. *Mathematics*, 11(4), paper No. 938.