

Renewable Energy Sources in the Baltic States and New Business Approach of the Sector

Karina Viskuba¹, Veronica Silinevicha²

¹ Mg.oec., Doctoral Student, University of Latvia, Raina Boulevard 19, Riga, Latvia, email: karina.viskuba@gmail.com

² Assist Prof, Mg.oec., Doctoral Student, Baltic International Academy, Lomonosova Street 1, Riga, Latvia, email: veronica.silinevicha@gmail.com

Abstract. Renewable energy sources (RES) are efficient in meeting the demand for clean and affordable energy. The need for RES is undeniable and has many advantages but there are also some challenges that need to be taken into consideration and adapted to the energy system. One of the challenges is RES volatility and its impact on electricity prices and power system operation. Europe is trending to power system decentralisation through the involvement of local authorities, active consumers and citizens in the system operation. This article provides main information about the energy sector of Latvia and RES in the Baltic countries. It proposes a methodology for the complex analysis of correlation and regression dependences of natural and price indicators of the electric power industry, based on the adaptation of the corresponding classical mathematical models.

Keywords: *renewable energy, demand response management, correlation and regression models*

Introduction

Relevance of the article

According to the European Commission, energy will play a key role in the transition to a net-zero greenhouse gas economy, which in 2018 accounted for more than 75% of all the European Union (EU) greenhouse gas emissions. RES development will reduce emissions from fossil fuels, dependence on fuel imported from third countries, will help with energy-saving, use efficiency and decouple energy costs from oil prices. The relevance of the topic is supported by the EU Renewable Energy Directive (European Commission, 2018) introduced in 2009. It stipulates that, by 2020, at least 20% of the EU's total energy must be covered by RES. On 30 November 2016, the Commission published a proposal to revise the Directive to make the EU a world leader in renewable energy and to ensure the target of at least 30% of renewable energy in the EU's final energy consumption by 2030. In general, the fossil production capacity will be reduced from 50% to 30%. On December 18, 2018, at the Republic of Latvia Cabinet meeting, the "National Energy and Climate Plan 2021–2030" project was approved for submission to the European Commission, where one of the goals is to reach a 50% share of renewable energy in gross final consumption by 2030 (The Ministry of Economics of the Republic of Latvia, 2020).

Level of problem investigation

The topic of demand response (DR) is becoming even more relevant. It has been implemented for years in many countries, for instance, America, China, Germany, Great Britain, Denmark, Finland, etc. and showed its' efficiency in energy system management and environmental benefits. In the case of the Baltic States, DR has been actively researched in the last years but practically it is applied in Estonia. The startup *FuseBox OÜ* is an independent demand response aggregator in Estonia, which has been successfully operating for several years. Lithuanian *Ignitis* started cooperation with Estonian *FuseBox* and plans to become the first independent electricity demand aggregator in Lithuania. If we turn to Latvia there is no clear vision of demand response system implementation for now but in accordance with the Cabinet of Ministers of the Republic of Latvia, a legal basis for the aggregator's operation is being developed.

Scientific problem

This article is a small step to reduce one of the most pressing problems of the energy sector – volatility of electricity production from RES and its impact on electricity prices and power system operation. As the share of electricity produced from RES increases, the fluctuations of electricity wholesale market price will also increase. The presence of additional wind and solar power on electric grids can cause coal or natural gas-fired plants to turn on and off more often or to modify their output levels more

frequently to accommodate changes in variable generation (Hale, Bird, Padmanabhan, Volpi, 2018). In order to fill the gap of the fluctuations in power system operation, it is more useful to use the DR system but not to switch on other production capacities, that are usually economically, technically and ecologically disadvantageous.

Object of the article

The object of the article- is RES, to be more precise, their development level in Baltic countries, future relevance and plans, volatility aspects, and impact on power system operation.

Aim of the article

The aim of the research is to analyse the development of RES in Baltic countries and discover other ways how to make it more adapted to the energy system. Also, to develop a methodology for a comprehensive analysis of correlation and regression dependencies of an electricity sector's natural and price indicators.

Objectives of the article

1. To analyse RES in Baltic countries. 2. To develop a methodology for a comprehensive analysis of correlation and regression dependencies of an electricity sector's natural and price indicators. 3. To make conclusions and recommendations for future research.

Methods of the article

This study is based on legislative documents, literature, statistical data review, empirical research, comparative analysis, comprehensive analysis of correlation and regression dependencies. The results were presented in tables and diagrams.

1. Brief theoretical introduction

The topic of RES can be considered from different angles, one of them is environmental problems, other – energy-producing and delivery technical issues, another side is investment and business and also political and legislative difficulties.

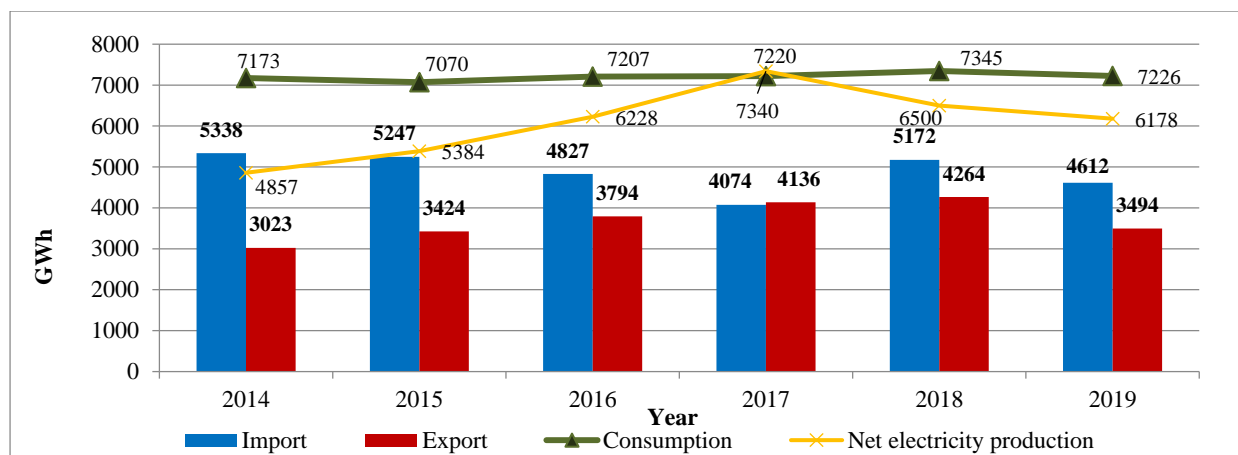
In the energy sector, the development of clean technology is one of the main streams but it is difficult to implement it without new business approaches. In world practice, the main solution for involving consumers in the retail electricity market for demand response systems is the creation of demand management aggregators. The future of an energy sector business model (supply either demand) is inactive consumers. Active consumers are electricity consumers that not only produce, use, store or sell electricity but also take part in energy efficiency schemes and in-demand management systems. (Wohlfarth, Worrell, & Eichhammer, 2020), (Cappers, Mills, Goldman, Wiser, & Eto, 2011) Aggregator is a merchant whose commercial activity is the provision of a demand response service. The demand response system is a hardware and software platform itself, which connects users to the cloud for energy monitoring and responsive control. The mechanism is designed to promote energy users to reduce their electricity consumption in response to wholesale market price signals (Bird, Milligan, & Lew, 2013). Demand response is becoming more topical for the Baltic region, not only because of the plans to increase the share of RES in total electricity generation, which will cause certain wholesale electricity price volatility because of changing supply due to RES generation variability but also because of the electricity networks synchronisation process of all the Baltic countries with Western Europe, which will increase the need for capacity maintaining the system frequency (Broka, Baltputnis, Sauhats, Sadovica, and Junghans, 2018).

In accordance with the Decree of the Cabinet of Ministers of the Republic of Latvia, dated 04/02/2020, a legal basis for the aggregator's operation is being developed, which determines its relationship with other participants of the electricity market and power system (Legal acts of the Republic of Latvia). An important aspect of aggregator implementation is to conduct a more in-depth analysis and identify the relationship of natural and pricing indicators of the industry.

2. Overview of Renewable Energy Sources in the Baltic States

The authors show basic indicators of the sector in Latvia for the past few years, basing the information on statistical data analyses. The average contribution of the energy industry to the national GDP has not particularly changed and is 2.11% during the 2013–2019 period (Stecenko, Silinevicha, Viskuba, 2020). Latvia is one of those countries that are strongly relying upon imported energy resources from other countries because Latvia is not able to fully meet the necessary electricity consumption. The data of

Latvian total electricity demand, net electricity production, import and export for the period 2014–2019 is shown in Figure 1. There have been no significant fluctuations in final energy consumption over the last decade, moreover, the usage of electricity in 2020 decreased due to the coronavirus crisis (in mid-March, in the Baltic States was declared a state of emergency to limit the spread of the Covid-19 pandemic, which affected electricity demand, especially in the segment of legal entities). In conjunction with the generation increase, the export of electricity has also mostly increased (the correlation of net electricity production and export is notable on the graph). The electricity import is volatile, during the researched period, however, it is partly relating to export changes. It should be noted that Latvia's export exceeded imports in 2017. That year, Latvian domestic electricity production covered 101% of consumption.



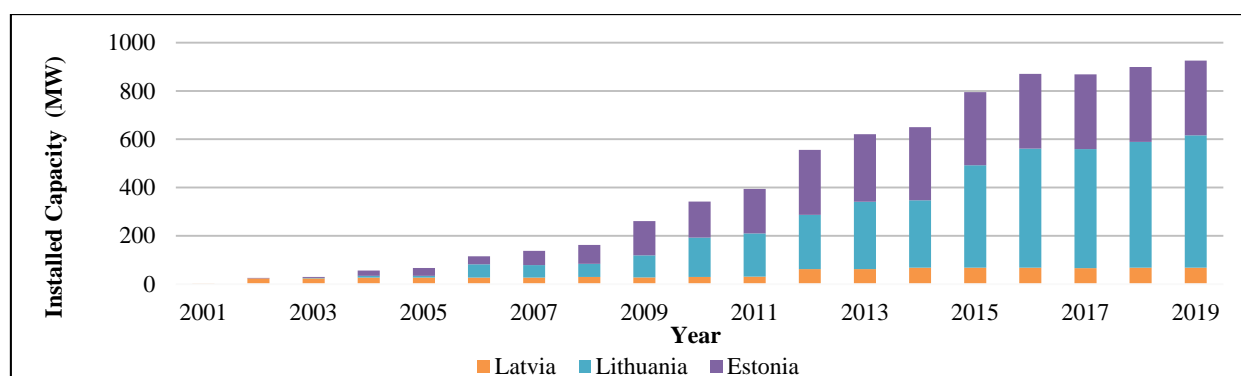
Source: created by the authors, using (Central Statistical Bureau of Latvia) dates.

Fig 1. Latvia's Electricity Import, Export, Consumption and Net Electricity Production in 2014–2019 years, GWh

In 2017, compared to 2016, import fell by 15.6%, export increased by 9%, consumption grew by 1.7%. The main reason for such an export increase was the increase in electricity generation at the Daugava HPP. It has been driven by a larger inflow of water into the Daugava, and thus electricity generation in 2017 has been the largest since 1998, as well as the third-largest in the history since 1966. Hydropower plant production increased by 74% in 2017, because of it, the production of fossil fuel power stations decreased by 36%. In 2019, Latvia's total net electricity production was 5% lower than in 2018, logically followed by a decline in exports. Moreover, the decrease was also observed in total consumption and import of 2019. It can be explained by the active implementation of energy efficiency policy, as well as, climate changes (Fig.1)

The main types of RES in the Baltics are hydropower, wind, solar, biomass, and waste. The authors consider that an installed capacity is showing a full clean potential of each country, which, in opposite to total generation, is not influenced by short-term technical issues, market volatility, water inflow and so on. According to the ENTSO-E, the total installed capacity of Latvia's HPP was 1537 MW in 2015, it increased by 2 MW in 2017 and remains the same until 2019. The low increase can be explained by a long, technically difficult and financially expensive work process. Daugava HPP is the largest hydropower plant in the country, which provides a high share of renewable energy and is one of the most important reasons that allow Latvia to be among the greenest countries in the EU for a long time. Lithuania's hydropower total installed capacity in the explored time period has not changed and is 1028 MW in 2019. Lithuania has two main hydropower generation sources – the first is hydro pumped storage plant Kruonis with 900 MW installed capacity and Kaunas hydroelectric plant with 101 MW installed capacity. The work of these two plants is connected because the Kaunas reservoir is acting as the lower reservoir for the Kruonis HPSP. Estonia's total installed capacity is only 8 MW, which can be explained by the geographical area of Estonia, the rivers are short and mostly have small discharge.

The situation with wind power plants capacity is different and not only in total Baltic volumes but in volumes of each country. In 2001 installed capacity of wind power plants was only 2 MW but in the following next two years it substantially increased to 24 MW. The next leap when installed capacity increased rapidly to 62 MW in total was in 2012. It can be explained with the start of the exploitation period of several wind farms, for instance, 20,07 MW of installed capacity by producer Ltd. *Winergy*. Latvia's total installed capacity of wind turbines in 2019 was about 68 MW. In contrast, in Estonia, the installed capacity in 2019 was 310 MW, which is 4.5 times higher than Latvia's. However, Lithuania is the absolute leader of the Baltic countries with 548 MW installed. (Fig. 2) According to the "National Energy and Climate Plan for 2021–2030", which was prepared by the Ministry of Economics of the Republic of Latvia, Latvia plans to increase the share of RES in electricity generation by increasing the installed capacity of wind generators and solar photovoltaics, taking into account the capacity of Latvia's electricity transmission network, which currently allows increasing the amount of electricity transferred to the network by 800MW. Taking into account the considerations of maritime spatial planning, it is planned to develop joint offshore wind farm projects (with a maximum capacity of 800 MW) on the Latvian-Estonian border and the Latvian-Lithuanian border. (The Ministry of Economics of the Republic of Latvia, 2020) The partnership process has already started in September 2020, when the Minister of Economics of the Republic of Latvia and the Minister of Economic Affairs and Infrastructure of the Republic of Estonia have electronically signed a Memorandum of Understanding on the joint project of the Latvian and Estonian offshore wind farm for energy production from renewable energy sources.



Source: created by the author, using "The Wind Power database" dates.

Fig 2. Total Installed Capacity of Latvia's, Lithuania's and Estonia's Wind Turbines in 2001–2019, MW

Other renewable energy types are not that well developed. The group of other RES in each country is different, it contains summarised installed capacities of different types of renewable energy sources (in Latvia 126 MW, Lithuania 199 MW, Estonia 221 MW of total installed capacity in 2021). According to ENTSO-E, in Latvia other RES consists only of biomass but data of JSC AST shows the presence of biogas and slightly solar energy. The volumes are gradually growing, however, in obedience to the "National Energy and Climate Plan for 2021–2030", Latvia does not plan to increase biomass and biogas capacity for electricity generation. Other Lithuanian RES consist mostly of solar and biomass. In the researched time period, the installed capacity of other Lithuanian RES was fluctuating but saved the leading position between Baltic countries, however, the situation changed in 2019, when installed solar energy capacity rapidly increased in Estonia. Other Estonian RES are solar, biomass and waste.

Summarising analyses in the Baltic states, it is worth mentioning that countries are using their geographical, nature potential, implementing rational maintenance and are working on modernisation and reconstruction for a sustainable future of energy systems. The capacities of wind and solar installations are growing not only in the Baltics but all around Europe. The Baltic countries have not used all the potential, which in combination with the EU target of carbon-neutral by 2050, investments, support schemes and auctions, smart strategy and implementation can lead us to sharply increasing RES, especially of wind and solar capacities.

3. Mathematical Models for the Analysis of the Electricity Sector Indicators

Research methodic

The aim of the research is to develop a methodology for a comprehensive analysis of correlation and regression dependencies of an electricity sector's natural and price indicators, based on the adaptation of the corresponding classical mathematical models.

Objectives of the research:

1. To analyse Latvian total electricity production, import, wind power production and price.
2. To adapt classical mathematical models for the analysis of correlation and regression dependences of natural and price indicators of the electricity sector.
3. To make conclusions and recommendations for future studies about the model.

Research methods. Statistical data review, comprehensive analysis of correlation and regression, using the *MATHCAD* programming language.

The research data analysis and the discussion of the results

There have been developed mathematical models for the analysis of the electricity sector's natural and price indicators of electricity production and imports in the period 2014–2019, average hourly electricity consumption and the price of one MWh of wind power in 2019, as well as similar indicators for hours of peak consumption from 8:00 to 12:00 GTM+2 (Table 1, 2, 3). All the calculations were carried out by using the *Mathcad* programming language.

Table 1

Indicator, MWh	2014	2015	2016	2017	2018	2019
Net electricity production	4857	5384	6228	4401	6500	6108
Import	5338	5247	4827	4074	5172	4612

Source: created by the authors based on "Central Statistical Bureau of Latvia" data

Table 2

Indicator	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average hourly wind power production (MWh)	171	219	222	141	135	89	122	58	161	159	183	224
Average wind power price (EUR/MWh)	56	47	40	44	44	45	49	39	49	47	45	39

Source: created by the authors based on (Nord Pool) data

Table 3

Average hourly calculated natural and price indicators of wind energy during the peak hours (from 8:00 to 12:00 GTM+2) in Latvia, 2019

Indicator	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average hourly peak wind power production (MWh)	174	211	230	118	123	76	96	47	149	153	181	213
Average peak wind power price (EUR/MWh)	64	50	43	52	57	66	61	60	67	56	48	42

Source: created by the authors based on (Nord Pool) data

The calculated average per diem and peak hours indicators differ insignificantly in volume (6%) and significantly in price (18%), moreover, during peak hours, the average of wind power is less but the average hourly price is higher. As the next step, the authors developed a regression model that describes the dependence of the indicators in Table 3 and 4 from month number i . (Adams, Bloomfield, Booth, & England, 1993) The modified regression model is:

$$Y_i = \beta_0 + \beta_1 \sin\left(\frac{i-c}{6}\pi\right) + \beta_2 x_{i,2} + Z_i, i = 1, \dots, 12, \quad (1)$$

Model (1) assumes that the maximum and minimum outliers have the same average deviations from the total average. If this is not the case, then additional related variables should be introduced to identify the maximum and minimum outliers and the regression model will be:

$$Y_i = \beta_0 + \beta_1 \sin\left(\frac{i-c}{6}\pi\right) + \beta_2 x_{i,2} + \beta_3 x_{i,3} + Z_i, i = 1, \dots, 12. \quad (2)$$

Next, the authors considered a regression model that approximates both tables at once. To do this, the authors will introduce an additional related variable identifying the table under consideration, and the estimation will be carried out on all data from both Tables 2 and 3.

The calculated covariance for the net electricity production and import is 5.772×10^4 and the correlation coefficient is 0.17. These indicators are positively correlated but the degree of correlation is low. The covariance for the two presented indicators is 5.25 for Table 2 and -308 for Table 3. The corresponding correlation coefficients are 0.021 and -0.626. It can be stated that the statistical characteristics of these two tables are mostly different.

Table 4

Actual and smoothed monthly data for model (1) and indicators of Table 2

i	1	2	3	4	5	6	7	8	9	10	11	12
Y_1	171	219	222	141	135	89	122	58	161	159	183	224
\hat{Y}_i	158.57	220.91	213.53	138.40	136.42	68.68	143.81	81.47	158.57	163.98	165.96	233.7
Y_2	56	47	40	44	44	45	49	39	49	47	45	39
\hat{Y}_2	47.25	44.59	43.58	44.48	43.74	45.38	43.74	46.39	45.93	46.51	47.25	45.61

Source: created by the authors.

Table 5

Actual and smoothed monthly data for model (14) and indicators of Table 3

i	1	2	3	4	5	6	7	8	9	10	11	12
Y_1	174	211	230	118	123	76	96	47	149	153	181	213
\hat{Y}_i	167.55	217.36	202.93	128.22	117.56	53.32	117.56	67.75	142.55	156.98	167.55	231.79
Y_2	64	50	43	52	57	66	61	60	67	56	48	42
\hat{Y}_2	55.45	46.88	47.34	56.70	57.04	66.06	57.04	65.60	56.24	55.78	55.45	46.23

Source: created by the authors.

The next step is a repeat of the calculations for the case of introducing two additional related variables identifying the maximum and minimum outliers.

Table 6

Actual and smoothed monthly data for model (2) and indicators of Table 2

i	1	2	3	4	5	6	7	8	9	10	11	12
Y_1	171	219	222	141	135	89	122	58	161	159	183	224
\hat{Y}_i	159.36	219.90	212.64	139.54	137.60	67.22	144.85	79.78	159.36	164.67	166.62	232.46
Y_2	56	47	40	44	44	45	49	39	49	47	45	39
\hat{Y}_2	49.01	42.00	41.22	46.94	46.36	41.61	46.36	42.39	47.71	48.49	49.06	42.78

Source: created by the authors.

Actual and smoothed monthly data for model (2) and indicators of Table 3

i	1	2	3	4	5	6	7	8	9	10	11	12
Y_1	174	211	230	118	123	76	96	47	149	153	181	213
\hat{Y}_1	167.10	218.00	203.51	127.51	116.91	54.26	116.90	68.74	142.00	156.49	167.10	232.45
Y_2	64	50	43	52	57	66	61	60	67	56	48	42
\hat{Y}_2	56.77	45.00	45.63	58.49	58.95	63.31	58.95	62.68	57.86	57.23	56.77	44.37

Source: created by the authors

The comparison of the two explored models for the purpose of their practical use leads to the following recommendations: if we proceed from the formal criterion, the sum of squares of deviations, then the preference should be given to the model (2). However, expert analysis shows that the results provided by model (1) are more logically justified. In this regard, model (1) is recommended for practical use.

Conclusions

1. In Baltics, renewable energy sources are becoming more topical, developed, as well as accessible for even more individuals, making them an active part of the energy system.
2. Latvia, in cooperation with Estonia and Lithuania, has great ambitions in the field of renewable energy production, committing to produce at least 50% of electricity from RES by 2030. Wind will also make a significant contribution, increasing production capacity from 66 MW to 800 MW in ten years.
3. In the developing process of a methodology for statistical analysis of wind energy yearly and monthly (2019) data, it was established that analysis methods should be applied for practical use that give not only good quality criteria but also the values of the considered indicators corresponding to the logical meaning.
4. Testing of polynomial regression models for the analysis of monthly statistical data gave unsatisfactory results, therefore, it is recommended to use the model of sinusoidal dependence of the corresponding indicators.
5. The developed models are recommended to be used as analytical tools for the electricity aggregator development in Latvia.

Summarising, the authors believe the EU is on the right way to achieve carbon neutrality by having clear policy vision and goals, natural, human, finance, etc. resources, growing electricity market decentralisation and integration, as well as building up a background and rising experience and society education level.

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