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ABANDONED AGRICULTURAL LAND FOR RENEWABLE ENERGY USE: COMPARATIVE ANALYSIS OF LITHUANIA AND LATVIA

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Abstract. The Abandoned Agricultural Land (AAL), which has been left overgrown with bushes, trees and invasive plants, has a negative impact on the environment and socio-economic development. As Lithuania and Latvia have a significant amount of AAL and a great demand for energy supply in autumn-spring periods, both countries have been chosen for analyses. The research aim was to assess the use of AAL for Renewable Energy (RE), such as Wind Energy (WE) and Solar Energy (SE). The dynamics of AAL in Lithuania and Latvia have been evaluated. The Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis has been applied to examine the AAL's use for RE in both countries. The use of AAL for RE in both countries despite higher seasonality and low wind and solar potential, especially in territories where land abandonment is prevalent, may be a profitable option to combining these two types of RE or creating an energy mix along with other energy sources.

Keywords: abandoned agricultural land (AAL), wind energy (WE), solar energy (SE), SWOT analysis, environment, renewable energy (RE).

Introduction

Farmland abandonment [FLA] can be defined as the cessation of agricultural activities on a given surface of land. This process has been observed in many regions of Europe and at different periods, particularly on marginal land (Pointereau et al., 2008). The collapse of the Soviet system triggered the most drastic episode of land use change in the 20th century. Publicly owned land was transformed for private use. Abandonment of agricultural land in the former Soviet Union [SU] countries occurred as a result of the restructuring of the economy and the adjustment towards open market conditions (Pointereau et al., 2008; Schierhorn et al., 2013). Lithuania and Latvia as former SU countries also encountered the problem of farmland abandonment.

To be able to predict possible and effective Abandoned Agricultural Land [AAL] use methods, it is necessary to know where and why such land occurs. Several authors (Hietel et al., 2004; Ruskule et al., 2012) argue that socio-economic factors are the main drivers of land abandonment, but more often authors argue that major land cover change is related to the physical attributes of land (Hietel et al., 2004; Ruskule et al., 2012).

According to information from (IEEP & Veen, 2004; Keenleyside & Tucker, 2010), in Latvia 21.1% (44,600 hectares) of the agricultural land was categorised as abandoned in 2002. Abandonment is a major problem in the Latgale region. The main problems are poor soil, unfavourable climatic conditions and the small scale of farms. In Lithuania land abandonment affected over 10.3% of agricultural land in 1999. Poor soil and unfavourable economic conditions are mentioned as the main factors (IEEP & Veen, 2004; Keenleyside & Tucker, 2010). According to information from (Alcantara et al., 2012), in Latvia, abandoned agriculture was widespread, covering in 2005 about 39% of what was agricultural land in the 1980s. Lithuania had less AAL than Latvia (only 16% of what was formerly agricultural land was abandoned by 2005) (Alcantara et al., 2012). Problems in

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Lithuania's agrarian territories played a large part in the population decline. In some cases, it was the decline of entire villages. In sparsely populated areas, the problem of AAL use is relevant. The emergence of AAL was affected not only by nature or economic or political conditions but also by the fact that there was no one left to work the grounds (Ribokas, 2011).

The variety in statistical data concerning AAL is due to the fact that different boundary-setting methods are used and the boundaries of the AAL are changing fast. Often there is no consensus regarding what should be considered as AAL.

Lithuania and Latvia are linked by a similar historical past and similar nature and economic conditions. Taking this into account, sustainable and purposeful farmland use is important and relevant to both countries. In looking at both countries' similarities, it can be concluded that problems related to AAL are significant and their use for other purposes is very similar and can be addressed in similar ways.

The purpose of this research is to analyse distribution and dynamics of AAL in Lithuania and Latvia, to examine the strengths, weaknesses, opportunities and threats related to Abandoned Land [AL] use for the creation of Renewable Energy [RE] sources. The authors of this article want to present a scientific approach to the sustainable development of AAL use for RE (wond and sun), taking into account the social, economic and environmental aspects.

1. Materials and methods

1.1. Research area and object

As the research area, two Baltic States, the neighbours Lithuania and Latvia were selected. Research area countries presented in Figure 1. These countries were selected because of their many similarities. These countries are tied not only because of their similar history but because they both have around the same area and also have a similar population. In addition, their economic levels are around the same and that is why we can assume that both of these countries can develop the same or similar measures to create strategies for AAL use for Wind Energy [WE] and Sun Energy [SE].

Lithuania
Capital: Vilnius
Population:
2 million 794.1 thousand
(data 2020)
Surface Area:
65 286 km²

Latvia
Capital: Riga
Population:
1 million 893.2 thousand
(data 2020)
Surface Area:
64 589 km²

Figure 1. Research area countries: Lithuania and Latvia (Official Statistics Portal of Lithuania and Latvia, n.d.)

AAL in Lithuanian and Latvian territories were selected as the object of research because these territories have not been used for their intended purpose for some time and can be a great object while thinking about the goals of, WE and SE.

1.2. Methods of analysis

The Strengths, Weaknesses, Opportunities and Threats [SWOT] analysis method was chosen to develop proposals for the management of AL for RE, such as WE and SE. SWOT analysis is a complex method of strategic analysis, which includes both the inner part of the organisation/project and the environment (Igliński et al., 2016). This method identifies the strengths, weaknesses, opportunities and threats of an implemented plan and helps to understand and improve the environment in which activities will be developed. Analysis is based on internal and external factors. Internal factors can be classified as strengths or weaknesses, and external factors can be classified as opportunities or threats.

Strengths are the factors that may enhance the overall performance, whilst weaknesses may affect the efficiency, profitability and competitive advantage. Opportunities are possibilities that may add to progress, and threats are the issues that may generate problems (Kamran et al., 2020). The SWOT analysis method was primarily developed for marketing analysis and business analysis purposes and was afterwards widely adopted in many other fields for strategic planning in business and marketing purposes and research assistance, including in the energy sector (Kamran et al., 2020). Work stages of the SWOT analysis explained in Figure 2.

In order to gain a clearer understanding of the problem of use for AAL, data analysis of each country's organisations that with AL was used. In Latvia the organisation was the Rural Support Service of the Republic of Latvia and in Lithuania, the National Land Fund of Lithuania. Also, experts from Latvia University of Life Sciences and Technologies prof. Velta Parsova and prof. Anda Jankava were interviewed. Accounting of AAL and SWOT analysis were performed by analysing the national energy independence strategy resolutions, the national statistical data from official statistics portals, data from national Ministries of Agriculture, Environment and Energy, data from the National Energy Regulatory council (2022). information systems data and the scientific literature sources and legal acts of both countries, which foresee questions concerning sustainable land use, AAL use and the development of RE.

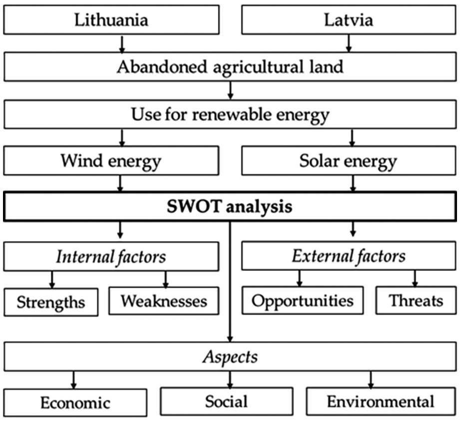

Figure 2. Work stages of the SWOT analysis of AL use for RE sources

To assess resource potential in SWOT analysis, the Global Wind Atlas data were used. The Global Wind Atlas provides freely downloadable datasets based on the latest input data and modelling methodologies. For the analysis of solar resource and photovoltaic power potential of Lithuania and Latvia, data from the Global Solar Atlas were used.

2. Results

Results of accounting of AAL in Lithuania and Latvia, comparison of AAL between both countries and SWOT analysis results of AAL use opportunities for SE and WE sources are presented in this part of work.

2.1. Accounting of abandoned agricultural land in Lithuania

In 2002, the Minister of Agriculture of Lithuania issued an order on Approval of Land Fund accounting rules (LR Seimas, 2023), in which an official definition of AAL areas was approved, and it was decided to include agricultural areas covered with woody plants identified by remote cartographic methods in the category of AAL areas.

In Table 1, the dynamics of changes of AAL in Lithuania from 2015 till the beginning of 2022 year are presented.

Table 1 data show that in Lithuania the identified AAL area is quite small, and in the beginning of 2022 only reached 1.1% of the total area of agricultural land. There is also a yearly recorded AAL decrease from 2.2% in 2015 to 1.1% in 2022. Upon looking at the results of Table 1, the question of AAL does not look like a big problem in Lithuania; however, it can be assumed that the percentages are so low only because the category of AAL areas in Lithuania was decided to include only agricultural areas covered with woody plants, which means that these territories have been abandoned for quite a long time. The distribution of AAL in Lithuania is presented in Figure 3.

Table 1. Results of AAL survey in Lithuania (National land service under the Ministry of Environment of the Republic of Lithuania (n.d.)

Year*	Total area of agricultural land, thousand ha	AAL	
		thousand ha	%, of the total area of agricultural land
2015	3,467.6	76.8	2.2
2016	3,431.5	70.0	2.0
2017	3,421.5	64.2	1.9
2018	3,411.9	62.0	1.8
2019	3,404.8	55.4	1.6
2020	3,399.1	49.1	1.4
2021	3,393.0	47.0	1.4
2022	3,386.2	37.4	1.1

* Presented data up to 1 January of the specified year

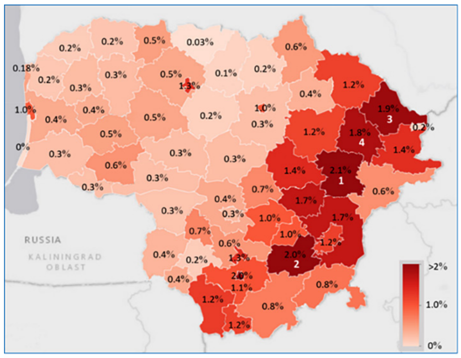

Figure 3. Distribution of AAL in Lithuania (2022, January). White numbers represent municipalities with the largest areas of AAL sites: 1 – Molėtai, 2 – Trakai, 3 – Zarasai, 4 – Utena (Land Information System of Lithuania, n.d.)

The Figure 3 shows that territories with the most AAL areas are marked with a dark burgundy colour. The lighter the colour, the smaller the recorded AAL area is. The largest areas of AAL sites exist in Molėtai District Municipality 2.1%, Trakai District Municipality – 2.0%, Zarasai District Municipality – 1.9% and Utena District Municipality – 1.8%. The smallest areas of AAL sites for many years are in Joniškis District Municipality – only 0.03%. In Neringa Municipality, AAL sites are not seen at all.

2.2. Accounting of abandoned agricultural land in Latvia

In Latvia the term and definition of AAL or unfarmed agricultural land was introduced in 1997 with the adoption of the law "On Immovable Property Tax". The law provided an additional real estate tax for AAL in the amount of 1.5%. AAL is land which is not used for producing or growing agricultural products, including crop harvesting, grazing and keeping animals for agricultural purposes, or the land is not maintained in a good agricultural and environmental state. Maintaining the agricultural land in a good agricultural and environmental state means that mowing, grass harvesting or crushing and dispersal have been carried out at least once before 1 September of the current year (LIKUMI LV, n.d.). The survey, inspection and determination of the area of uncultivated agricultural land were conducted by the Rural Support Service of Latvia. Information was obtained via satellite images and an on-site survey too. Results of the AAL survey in Latvia are presented in Table 2.

Table 2. Results of AAL survey in Latvia (Rural Support Service Republic of Latvia, 2022)

Year	Surveyed agricultural land, thousand ha	AAL	
		thousand ha	% of surveyed land
2010	1,978.2	366.4	18.5
2013	2,305.8	342.1	14.8
2014	2,291.9	345.5	15.0
2017	2,252.0	225.2	12.4
2018	2,239.7	256.6	11.5
2019	2,228.8	256.2	11.5
2020	2,216.5	240.2	10.8
2021	2,200.6	227.4	10.3

Results of the agricultural land survey show a positive trend regarding AAL: its area in the last 10 years has decreased by 7%. According to the data of the Rural Support Service and Central Statistical Bureau, the situation varies widely in municipalities. For example, only 3% of the total area of agricultural land is abandoned in Bauska municipality. However, the proportion of AL in some municipalities of Latvia is high. In Ludza it is 19%, in Rezekne, 17%, in Balvu, 15% and in Aluksne, 15% (Figure 4).

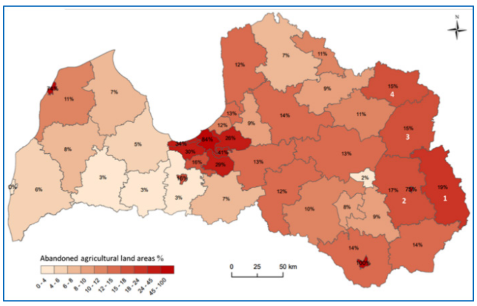

Figure 4. Results of AAL in the municipalities of Latvia in 2021, % (Rural Support Service of Latvia, 2021). White numbers represent municipalities with the largest areas of AAL sites: 1 – Ludza, 2 – Rezekne, 3 – Balvu, 4 – Aluksne

A survey of agricultural land shows that AAL mainly is located in the eastern part of Latvia, far from Riga, in places of low land productivity. At the same time, a high proportion of unfarmed land is located around Riga, but their agricultural land has actively been used as building sites and urban development areas (Rural Support Service Republic of Latvia, n.d.).

Administrative responsibility for land on which processing of agricultural land has not been undertaken or is not being continued could be one of instruments to promote the involvement of agricultural land in farming. In the long term, other solutions have also been introduced to make land use sustainable and efficient in Latvia, such as:

- a land credit programme for the purchase of agricultural land has been established;
- land stock of Latvia has been established;
- in cooperation with organisations representing the interests of farmers, specific criteria for the purchase of agricultural land and conditions of the land market have been established;
- landowners selling agricultural land to farmers has been exempted from income tax;
- a double real estate tax rate has been introduced for AAL, etc. (Ministry of Agriculture Republic of Latvia, n.d.).

2.3. Comparison of abandoned agricultural land between Latvia and Lithuania

The driving forces of land abandonment in both countries are quite similar. The major reasons are natural and economic conditions:

- inefficient land management due to its low quality (soil fertility) and terrain peculiarities;
- population density in the regions;
- lack of financial resources;
- lack of time and willingness to manage the land by landowners;
- many landowners have inherited agricultural land, but the land is not used for agricultural purposes.

Although both countries have many historical and geographical similarities, as well as similar causes of land abandonment. From Figures 3 and 4, it is obvious that the percent of AAL in Latvia is much larger than in Lithuania. This may be due to the different definitions attributed to the AAL category. In Lithuania the stage when agricultural land is not used for its intended purpose but not yet covered with woody plants is not included in the category of AAL and is not reflected in the statistics. This may be why the statistics regarding AAL in Lithuania are significantly better than in Latvia.

2.4. SWOT analysis of abandoned agricultural land use opportunities for solar and wind renewable sources

This analysis attempts to explore the possibilities and to identify the key problems in adapting AAL for the development of WE and SE RE sources in Lithuania and Latvia. This part of the paper presents the SWOT analysis, taking into account the principles of sustainable development as well as the social, economic and environmental aspects.

Because applying the SWOT analysis method compared two countries Lithuania and Latvia, this method was appropriate to evaluate differences and similarities in their AAL use opportunities for WE and SE sources. Some aspects such as environmental or investment decisions because of similarities between the countries were common to both countries. The analysis was carried out focusing on the territories with the largest areas of AAL sites. The results of the SWOT analysis are presented in chapter 2.4.1. concerning WE and in chapter 2.4.2. – on SE.

2.4.1. Wind energy

1) Resource potential – wind speed.

Lithuania. Weaknesses. The mean wind speed is a measure of the wind resource (Global Wind Atlas, n.d.). Average wind speed potential in 100 m height in Lithuania is 7.24 m/s. However, in the eastern part of country, where agricultural land abandonment is greatest, the mean wind speed is lower than the average mean wind speed of the country and in some places is only about 6 m/s in 100 m height (Figure 5a).

Latvia. Strengths. Average wind speed potential in 100 m height in Latvia is 7.01 m/s. However, the greatest agricultural land abandonment is in the eastern part of country, and in this part the mean wind speed in some places is higher than the average mean wind speed of the country and in some places is more than 8 m/s in 100 m height (Figure 5b).

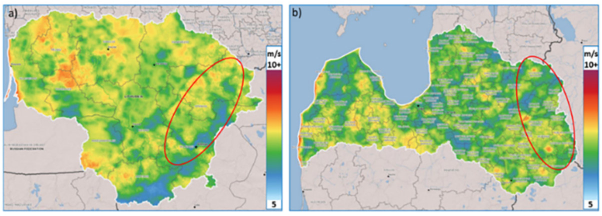

Figure 5. Mean wind speed satellite-based map m/s in 100 m height: a) Lithuania, b) Latvia. Red ovals – the territories with the largest areas of AAL sites (Global Wind Atlas, n.d.)

2) Resource potential – wind power density.

Lithuania. Weaknesses. Mean wind power density gives a more accurate indication of the available wind resource (Global Wind Atlas, n.d.). Country mean wind power density is 354 W/m^2 in 100 m height. In the eastern part of the country, mean power density is lower and in some parts is only 200 W/m^2 in 100 m height (Figure 6a).

Latvia. Strengths. Country mean wind power density is 331 W/m^2 in 100 m height. In the eastern part of the country, the mean power density is quite favourable and in some parts is up to 500 W/m^2 in 100 m height, but there are places where the mean power density is low and varies about 200 W/m^2 (Figure 6b).

3) Resource potential – wind stability.

Lithuania. Strengths. Not only wind speed but also wind stability is important factor. Mean wind speed in the eastern part of country, where agricultural land abandonment is greatest, varies from 6.5 to 7.8 m/s in 100 m height. Wind speed variation in the eastern part of the country is insignificant (Figure 5a). Wind stronger than 15 m/s becomes a dangerous meteorological phenomenon, but the highest probability of such winds is at the seaside (60–70 days per year) and the lowest in the southwest of Lithuania (about 10 days per year).

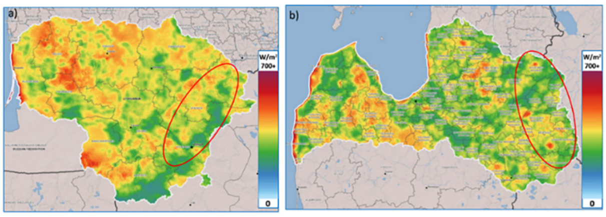

Figure 6. Mean wind power density map m/s in 100 m height: a) Lithuania, b) Latvia (red oval – the territories with the largest areas of AAL sites) (Global Wind Atlas, n.d.)

Latvia. Strengths. Mean wind speed in the eastern part of Latvia, where agricultural land abandonment is greatest, varies from 6.0 to 8.3 m/s in 100 m height. Mean wind speed variation in the eastern part of the country is insignificant (Figure 5b).

4) Roughness.

Lithuania. Strengths. In the lower layers of the atmosphere, wind speeds are affected by the friction against the surface of the earth. Roughness is the roughness length of the terrain surface. Anywhere on the earth, roughness has a major impact on wind. The more pronounced the roughness of the earth's surface, the more the wind will be slowed down (Global Wind Atlas, n.d.). From Figure 7a it is clear that the roughness length is largest in the south-eastern and eastern parts of Lithuania, where the largest areas of AL are located. The wind rose is useful for siting wind turbines too (Figure 8). A wind rose gives information on the relative wind speeds in different directions, each of the three sets of data (frequency, mean wind speed and mean cube of wind speed). Most of the WE comes from the southwest of Lithuania (Figure 8a) and obstacles in other directions are not as important since much less WE comes from those directions.

Latvia. Strengths. From Figure 7b obvious that the roughness length in Latvia is less permanent than in Lithuania. In in Eastern part of Latvia, where agricultural land abandonment is largest, roughness is similar

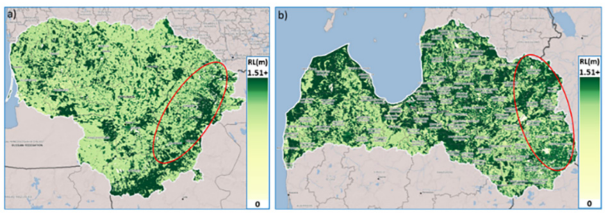

Figure 7. Roughness: a) Lithuania, b) Latvia. Red ovals – the territories with the largest areas of AAL sites (Global Wind Atlas, n.d.)

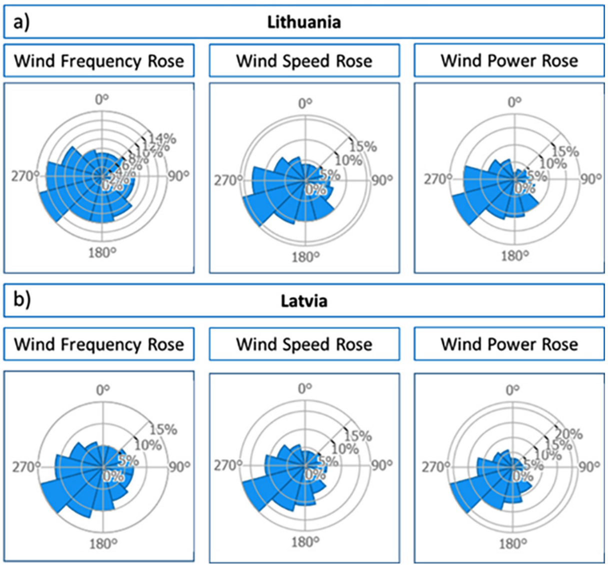

Figure 8. Wind roses: a) Lithuania, b) Latvia (Global Wind Atlas, n.d.)

as in other parts of country. Most of the WE comes from the southwest of Latvia (Figure 8b). The roughness in this direction is slightly more favourable than in the whole country.

5) Small population density.

Lithuania. Strengths. In the eastern part of country, where agricultural land abandonment is greatest, population density is low and varies from 11 to 30 people per km^2 (Figure 9a). Lithuania is sparsely inhabited compared to the Western European heartland.

Latvia. Strengths. In the territories with the largest areas of AAL sites, in Latvia the population density is lower than in Lithuania and varies from 4 to 19 people per km^2 (Figure 9b).

6) Environmentally friendly – emission free.

Lithuania and Latvia. Strengths. One of the best solutions to reduce climate change is RE. Wind is the most efficient renewable source. Greenhouse gas (GHG) emissions from wind power are 8–20 g/kWh, which is only 2.2% of the emissions generated by coal (Alcantara et al., 2013). Using electricity generated from wind turbines in Lithuania, less than 0.7 Mt CO_2 per year is emitted into the environment. CO_2 footprint of wind turbine over its

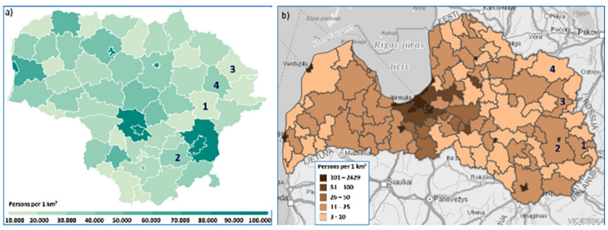

Figure 9. Population density person per km^2: a) Lithuania (data 2020) (Official Statistics Portal of Lithuania, n.d.), b) Latvia (data 2021) (Official Statistics Portal of Latvia, n.d.). Black numbers – the territories with the largest areas of AAL sites

25–30 year of life cycle is only 10–11 g CO_2/kWh (Lithuania Wind Power Association LVEA, 2021).

7) High initial investment and long pay-off period.

Lithuania and Latvia. Weaknesses. The weakness of the high capital investment cost of wind farms is considered to be a big obstacle to the development of WE (Kamran et al., 2020). For example, it is estimated that the payback period of the wind park "Pagėgiai13", which is in western part of Lithuania, will be about 12 years. Estimating that in the western part of country the wind is stronger, it is possible to assume that in the eastern part of country, the payback period of wind parks will be longer than 12 years. Evaluating that the standard life of a wind turbine is 20–25 years, (Lithuania Wind Power Association LVEA, 2021), the payback period is long but economically pays off.

8) Unfavourable plot configuration and size.

Lithuania and Latvia. Weaknesses. Small parcels far from the farm are more likely to be abandoned than easily accessible and large plots due to high transportation and labour costs (Terres et al., 2013). From Figure 10, it is evident that AL parcels often are small and have unfavourable configurations.

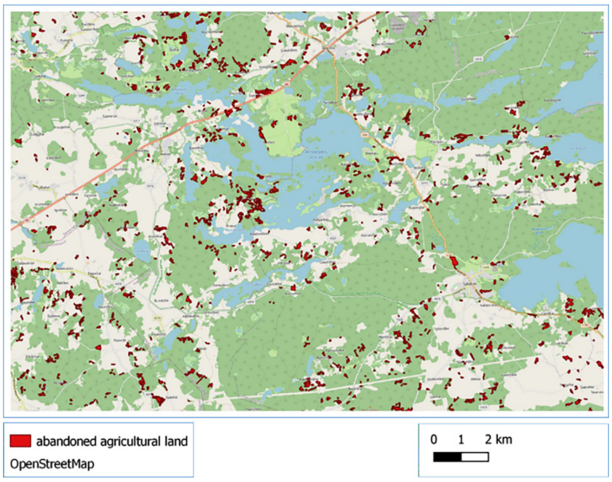

Figure 10. Fragment of spatial data of AAL in Lithuania

9) Energy independence of the country.

Lithuania. Opportunities. Alternative energy opens the door to energy independence (Bužinskienė, 2018). In 2030, it is estimated that the majority of electricity – no less than 45% of the electrical power consumed in Lithuania – will be produced from RES, and no less than 53% could come from wind power (National Energy Independence Strategy of Lithuania, 2018).

Latvia. Opportunities. Latvia has pledged to reach 50% RE of its total energy consumption by 2030. In Latvia in 2030 compared to 2017, the amount of electricity produced in wind power plants will increase due to the installation of a total capacity of approximately 1100 MW (Latvia's National, 2020). In 2020, wind power plants in Latvia produced 177 GWh, which is 14.9 % or 23 GWh more electricity than a year earlier (Official Statistics Portal of Latvia, n.d.).

10) Environmental hazards.

Lithuania and Latvia. Threats. Wind turbines induce mortality and present a disturbance risk to birds (Dai et al., 2015). Noise is one of the major environmental hindrances to the development of the wind power industry (Dai et al., 2015). Shadow flicker, an effect caused by the movement of the turbine blades through the sunshine, becomes a human impact when a number of parameters converge, including distance from the turbine, operational hours and interactions with the sunlight (Harding et al., 2008). Besides the flickering shadows, the negative visual impact of wind farms on landscapes is another factor that makes people have a negative opinion of the WE industry (Dai et al., 2015; Wolsink, 2005). Although the electromagnetic field of a wind turbine itself is extremely weak and is confined to a small range, it can still create electromagnetic interference (Dai et al., 2015). Wind turbines destroy natural ecosystems. In the wind parks, for one megawatt, about 20 ha of land is needed (Bužinskienė, 2018).

2.4.2. Solar energy

1) Resource potential – PVOUT.

Lithuania. Weaknesses. Photovoltaic electricity potential (PVOUT) (expected output from a PV system) simulates the conversion of the available solar resource to electric power, considering the impact of air temperature, terrain horizon and albedo, as well as module tilt, configuration, shading, soiling and other factors affecting the system performance. PVOUT is the amount of power generated per unit of installed PV capacity over the long term (the specific yield), measured in kilowatt hours per installed kilowatt peak (kWh/kWp) (Global Photovoltaic Power Potential by Country, 2020). PVUT in Lithuania varies from a min. of 2.76 kWh/kWp to a max. of 3.05 kWh/kWp. In 90.5% of the territory, it varies from 2.8 to 3.0 kWh/kWp. In territories where agricultural land abandonment is greatest, PVUT varies from 2.8 to 2.9 kWh/kWp, and only a small part does not reach 2.8 kWh/kWp (Figure 11a).

Latvia. Weaknesses. PVUT in Latvia varies from a min. of 2.76 kWh/kWp to a max. of 3.05 kWh/kWp. In 86.4% of the territory, it varies from 2.8 to 3.0 kWh/kWp. In territories where agricultural land abandonment is greatest, PVUT varies from 2.8 to 2.9 kWh/kWp, and only a small part does not reach 2.8 kWh/kWp (Figure 11b).

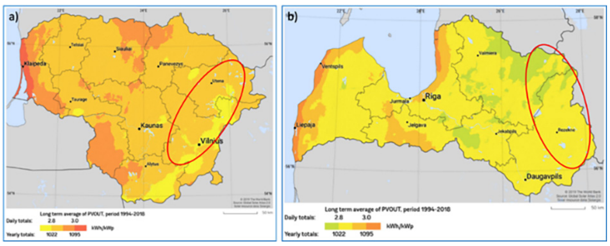

Figure 11. Photovoltaic power potential (PVOUT) from 1994 to 2018: a) Lithuania, b) Latvia. Red ovals – the territories with the largest areas of AAL sites (Global Solar Atlas, n.d.)

2) Resource potential – Global horizontal irradiation (GHI).

Lithuania. Weaknesses. Global horizontal irradiation (GHI) is the most important parameter for energy yield calculation and performance assessment of flat-plate photovoltaic (PV) modules, which is presently the most widely adopted technology. The solar resource map provides a summary of the estimated SE available for power generation and other energy applications (Global Photovoltaic Power Potential by Country, 2020). Figure 12a shows the multi-year mean (1994–2018) data for GHI in kWh/m^2 verifying the availability of solar potential in Lithuania. Results of GHI daily totals in Lithuania vary from 2.76 to 2.96 kWh/m^2. In 73.3% of Lithuania's territory, GHI is more than 2.8 kWh/m^2; in 23.7%, it is less than 2.8 kWh/m^2. The most favourable place for SE development is in the western part of the country, where the number of sunny days is the greatest. Agricultural land abandonment in this part of country is, however, very insignificant. Parts of eastern of Lithuania, which has the largest areas of AAL sites, have a GHI lower than 2.8 kWh/m^2 (lower than the average potential of the country), and other parts have higher than 2.8 kWh/m^2 (Figure 10a).

Latvia. Weaknesses. Figure 12b shows the multi-year mean (1994–2018) data for GHI in kWh/m^2 verifying the availability of solar potential in Latvia. Results of GHI daily totals in Latvia are lower than in Lithuania and vary from 2.69 to 2.94. In 18.8% Latvia's territory, GHI is more than 2.8 kWh/m^2, and in 81.2%, it is less than 2.8 kWh/m^2. The eastern part of Latvia, which has the largest areas of AAL sites, has a GHI lower than 2.8 kWh/m^2 (Figure 12a). This result is the same as the average potential of the country but lower than in Lithuania.

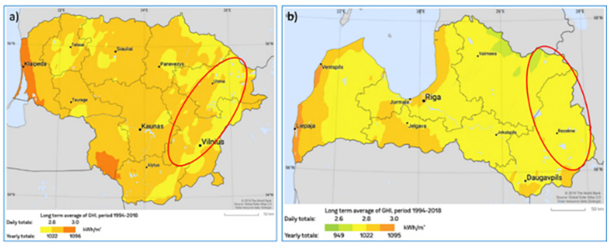

Figure 12. Global horizontal irradiation (GHI) from 1994 to 2018: a) Lithuania, b) Latvia. Red oval – the territories with the largest areas of AAL sites (Global Solar Atlas, n.d.)

3) Seasonality.

Lithuania. Weaknesses. The seasonality index provides an indication of the seasonal variability. The seasonality index is calculated as a ratio between the highest and the lowest average monthly potential values in an average year. Regular weather cycles, or seasons, determine the yearly pattern of PV power generation. The high-potential countries tend to have low seasonality (below 2.0), which represents very stable electricity production throughout the year and vice versa (Global Photovoltaic Power Potential by Country, 2020). The PVOUT seasonality index (country/region MEAN value) in Lithuania exceeds 7.

Latvia. Weaknesses. The PVOUT seasonality index (country/region mean value) in Latvia exceeds 8. High seasonality exacerbates the difficulties because the highest demand for energy is during cold winters.

4) Air temperature.

Lithuania. Weaknesses. Air temperature is the significant geographical factor, as it affects PV conversion efficiency (Global Photovoltaic Power Potential by Country, 2020). Average air temperature at 2 m above ground in Lithuania is 7.3 °C; maximum 8.3 °C, minimum 6.6 °C.

Latvia. Weaknesses. Average air temperature at 2 m above ground in Latvia is 6.7 °C; maximum 8.1 °C, minimum 5.8 °C.

5) Increasing private investors.

Lithuania. Strengths. The installation of power plants requires substantial investment; therefore, it is very important that support is provided for the installation of solar power plants, and this support in Lithuania could reach one third of the price of solar power plants (Ministry of Environment of Lithuania, n.d.). In recent years interest in solar power plants in Lithuania has strongly increased. Such demand is related to the rising prices of electricity and is due to its convenient energy production, use and storage infrastructure and compensations. At the beginning of 2022, in Lithuania an average of 200 new self-energy-producing consumers are established each month (Ministry of Energy of Lithuania, n.d.).

Latvia. Weaknesses. Latvia's potential for RE resources – wind and solar – are being exploited to a negligible extent. In 2020, solar power plants in Latvia produced 5 GWh of electricity, which is 66.7% (2 GWh) more than a year earlier (Official Statistics Portal of Latvia, n.d.).

6) Favourable natural conditions.

Lithuania. Strengths. Lithuania is a low-lying plain country. The highest point in Lithuania is only 294 m above sea level.

Latvia. Strengths. Latvia is essentially an undulating plain, with fairly flat lowlands alternating with hills. The eastern part of the country, where the land abandonment is greatest, is more elevated.

7) Environmentally friendly – emission free.

Lithuania and Latvia. Strengths. SE technologies and power plants do not produce air pollution or greenhouse gases when operating and use no finite fossil fuel resources (EIA U.S., n.d.).

8) Initial investment costs and payback time.

Lithuania and Latvia. Strengths. Over the last decade, the solar power sector has seen installation costs fall dramatically and global installed capacity rise massively. The solar PV module prices have fallen 80% in the last decade, while installed capacity has grown from 40 GW to over 600 GW in the same period (Global Photovoltaic Power Potential by Country, 2020). The approximate payback period for solar power plants is about 5–6 years after receiving support which is up to 30% of the investment (Energy distribution, 2022). To determine the lifetime of solar modules exactly is complicated because it depends on various factors: quality, maintenance, exploitation conditions, etc. For this reason, estimated lifespan of a solar modules varies from 15 to 30 years. PV systems can produce the equivalent amount of energy that was used to manufacture the systems within 1 to 4 years (EIA U.S., n.d.).

9) Unfavourable land plots and configurations.

Lithuania and Latvia. Weaknesses. AAL areas are often small, have an inconvenient shape, are in unfavourable areas, and are therefore difficult to use. SE is volatile because it depends on meteorological conditions and daytime; the technology is expensive, and it requires a lot of space (Bužinskienė, 2018). When a solar power plant is installed on the ground, it is estimated that to install 1 kW a territory of about 10 m² is required (Ministry of Environment of Lithuania, n.d.)

10) Energy independence of the country.

Lithuania. Opportunities. It is estimated that the majority of electricity (no less than 45% of the electrical power consumed in Lithuania) will be produced from RE sources (RES) in 2030. No less than 22% could come from SE (National Energy Independence Strategy of Lithuania, 2018).

Latvia. Opportunities. In 2030 share of energy produced from RES in gross final energy consumption (%) in Latvia will be 50%. Large capacity electricity generation from SE has currently not been developed in Latvia. However, Latvia might have a similar potential as other European countries where such production has been developed (Latvia's National, 2020).

11) Environmental hazards.

Lithuania and Latvia. Threats. There are environmental hazards related to the use and production of SE technologies. SE technologies require use of materials (as glass and metals), that are energy intensive to make. The environmental hazards related to the production of these materials could be associated with SE systems when conducting life-cycle environmental analysis. There are hazardous chemicals used to make photovoltaic (PV) cells and panels and it is important to avoid its release to the environment. Some types of PV cell and panels technologies use heavy metals and these types of cells and panels may require special handling in the end of their useful life. Some solar thermal systems use potentially hazardous fluids to transfer heat, and leaks of these materials could be harmful to the environment (EIA U.S., n.d.). According to forecasts, by 2040, the total weight of dismantled photovoltaic cells in European countries will exceed 33 thousand tons (ESFC, n.d.). Both SE and WE are associated with toxic and radioactive waste (Bužinskienė, 2018).

12) Modernisation and renewal.

Lithuania and Latvia. Threats. The efficiency of solar power plants highly depends on technological progress, but innovations rely on large financial resources. The consequences of refusing to undertake the planned modernisation of a solar power plant can often be failures and accidents, an increase in investment costs and decrease in energy production. Aging equipment with a decrease in its parameters increases costs in repair and maintenance (ESFC, n.d.).

13) Destruction of natural ecosystem.

Lithuania and Latvia. Threats. Solar power plants can affect the environment at or near their locations. Clearing land for construction and the placement of the solar power plant may have long term effects on the habitats of native animals and plants (EIA U.S., n.d.).

Conclusions and discussion

Obvious statistical data differences concerning the AAL areas in Latvia and Lithuania arise due to the fact that there is no common consensus regarding what should be considered AAL, different boundaries setting methods are used, and the boundaries of the AAL are changing fast. But the most important factor in deciding the huge differences in the use of AAL in Lithuania (2021 – 1.1%) and Latvia (2021 – 10.3%) is that in each country the data are collected differently.

Even though from analysing the statistical data concerning the use of AAL in Lithuania and in Latvia an insignificant yearly drop in AAL can be seen, the real situation in this field will only be evident if EU subsidies, which are now received by all landowners who look after their land, are lowered or removed.

Results of the SWOT analysis show that after comparing the countries as a whole the wind potential in Lithuania is more favourable than in Latvia, but the results of areas where the abandonment of AL is largest are more favourable for Latvia. The use of modern technologies allows to install wind parks not only in territories where the wind is strong. However, in order to use AAL areas in the eastern part of Lithuania for wind parks, the height of the wind turbines must be higher than 100 m. Higher wind turbines will be more efficient, and at a higher height, the wind usually is stronger.

Not only wind speed but also wind stability is an important factor for WE. In both countries, wind potential is not strong, but it is stable. Wind turbines create some environmental hazards, but by following all the requirements for wind turbines installation and given that in both countries the population density in the territories with the largest areas of AAL sites is very low, it is possible to use them for WE. Low population density can positively improve the development of WE because wind turbine noise, flickering shadows and electromagnetic fields have an impact on people living near wind parks. The payback period for wind parks is quite long, especially in territories where the wind is not strong, but they do pay off economically because the life of wind turbines is long. Although the AAL plots often are of an unfavourable configuration and size, they can still be used for WE and to contribute to the energy independence of both countries, especially for Latvia because AL abandonment exceeds 10% there.

Solar radiation is essentially a free resource available anywhere on earth, to a greater or lesser extent. In Lithuania and Latvia PVOUT expected output from a PV system is low and mainly varies from 2.8–2.9 kWh/kWp. However, in such countries as Lithuania and Latvia, despite higher seasonality and lower PVOUT values, solar PV may be a profitable option especialy combining energy with other energy sources.

The theoretical PV power potential GHI is not fully proportional to practical potential PVOUT. The distribution of air temperature often counteracts the distribution of GHI. Places with below average solar radiation may benefit from cooler air temperatures year-round, and vice versa, high air temperatures may hinder the PV power output in regions with high solar resources (Global Photovoltaic Power Potential by Country, 2020). GHI potential in areas with the largest AL abandonment in Lithuania is not high but is more favourable than in Latvia, therefore Lithuania can more widely to exploit the solar resources, especially in AL.

Upon evaluation of the solar modules' installation investment costs and payback time in the SWOT analysis, these aspects are assigned to strengths because when compared with wind parks' capital investment costs and payback time, the solar modules have an advantage.

Data from Eurostat (European Commission, n.d.) show that Latvia had the EU's third-highest share of RE sources in its energy consumption mix. More than 60% of electricity produced in Latvia is green, being produced by hydroelectric plants, but Latvia's potential for WE and SE is being exploited to a negligible extent and significantly lags behind Lithuanian efforts.

High seasonality challenges countries like Lithuania and Latvia, where the highest demand for energy is during the winters. At the same time, short daylight periods and low sun angle limit PVOUT generation. To address the use of AAL for RE in both countries and the fact that wind and solar potential are low in territories where land abandonment is prevalent, a profitable option may be to combine these two types of RE. The strongest winds blow in November–January, and the weakest are in May–September. The intensity of solar radiation is highest in May–August. So, one potential source would compensate for the other when its power decrease, would save network connection and infrastructure preparation costs.

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