Paikallisen energiajärjestelmän kehittäminen Pohjanmaalla
Development of the regional energy system in Ostrobothnia

T1.1 Results of energy potential on the area under consideration

Giovanna Andrea Pinilla De La Cruz
2024
Ryhmähanke R-01335

Co-funded by the European Union
Österbottens förbund Pohjanmaan liitto
esse elektro-kraft
AKTION ÖSTERBOTTEN
Vaasan yliopisto UNIVERSITY OF VAASA

TIIVISTELMÄ/ABSTRACT

This report comprises the results of task T1.1 related to the renewable energy potential of the area under consideration in this project through solar photovoltaic and wind power. The data for analysis has been obtained from public available sources. In this task, it was also considered the results of the RIPEET project in terms of the identification of renewable energy. Additionally, results of biogas potential investigated in the Digibiogashub project were used in this project to map the overall energy potential.

In terms of wind power capacity, five projects appear in planning stage, to add 693 MW of capacity to the electricity grid in the next four years. Some projects are already fully permitted but others are progressing in obtaining environmental permits and land use plans. Regarding electricity from solar photovoltaic projects, the industry in the area under consideration is still emerging. Therefore, not a significant number of projects appear as reported from publicly available sources. However, two solar photovoltaic projects in Kauhava reported in planning stage are expected to add 170 MWp to the electricity grid by 2028. As it is currently a relevant phenomenon in the country, it is expected that new solar photovoltaic initiatives arise in the area under consideration. In terms of biogas, there are opportunities for developing the production and upgrading of this fuel. However, to boost initiatives to emerge and consolidate, more efforts in research and public funding is needed due to the complex logistics of biogas value chain integration.

Overall, there are good prospects for the development of energy systems in the area under consideration in the coming years to increase the reliability and flexibility of the energy network.

Sisällys/Table of contents

1 Introduction and scope

The task investigates the renewable energy potential of the area under consideration, solar and for wind power. Aktion Österbotten has already explored renewable energy as part of the RIPEET project. These previous results are considered, but in this project the area under consideration is wider considering municipalities of Pedersöre and Kauhava. Biogas potential is explored in the Digibiogashub project, and its results are used in this project to map the total energy potential.

1.1 Scope of the analysis

This report has been prepared as part of the task of the work package 1 of the PEAK project. The project has been financed by the EU-Just Transition Fund (JTF), Regional Council of Ostrobothnia, University of Vaasa, Aktion Osterbötten and Esse Elektro-kraft.

For the analysis of the renewable energy potential of the area under consideration, data was collected from public available sources as the Renewables Finland website (formerly the Finnish Wind Power Energy Association), Motiva Oy, and the Biomass Atlas. Additional project specificities were refined based on public reports and official websites.

- Status of current wind and solar production
- Map of planned wind and solar projects and scenarios for wind power projects
- Estimation of bioenergy potential in terms of theoretical biogas

1.1.1 Area under consideration

The area under consideration in this project corresponds to the geographical delimitation of the municipalities of Pedersöre in Ostrobothnia and Kauhava in South Ostrobothnia. The decision about the geographical area corresponds to those municipalities where the largest number of users of the Esse-Elektro Kraft electrical network are concentrated. This delimitation enables us to define a specific field of action for the execution of this task and subsequent ones within this project (Figure 1).

Figure 1. Area under consideration in this project: Pedersöre and Kauhava according to the concentration of customers of Esse Elektro-Kraft

1.2 Use of results of other projects

In this task, the results of the Digibiogas hub project are used regarding the biogas potential to map the overall energy potential. As the results of Digibiogas hub are used in Chapter 5, there is a clear reference in that section related to the use of this input. Additionally, results of RIPEET projects were used in a more general way for the final conclusions of task as a reference related to the type of energy sources for the identification of the energy potential.

1.2.1 RIPEET project

According to the information published on the RIPEET project website, the RIPEET project fosters collaboration among quintuple-helix stakeholders within territorial socio-technical energy systems through the establishment of transition Labs. These labs are designed to drive a localized energy transition process (ZEI, Universiteit Leiden, ERRIN, K&I, EAE, Fundecytpctex, HIE, 2024). One of the outcomes of this project was the RIPEET Energy Vision for Ostrobothnia by 2030 (RIPEET, 2020). This analysis pointed out the need for implementing energy systems based on decentralized energy production and consumption with local solutions that lead to achieve positive impact in local communities and citizens (RIPEET, 2020).

1.2.2 Digibiogas project

The DigiBiogasHubs project aims to design and pilot an integrated system leveraging a digital platform and tools to foster the growth and collaboration of biogas hubs across various regions. This initiative also seeks to advance the development of the biogas market, enhancing its efficiency and scalability (VEBIC, 2024).

2 Contextual background

As the area under consideration comprises the municipalities of Pedersöre and Kauhava in Ostrobothnia and South Ostrobothnia where the company Esse Elektro-Kraft operates and concentrates most of its customers, therefore, it would be relevant to provide a brief description introduction on the main contextual features of this area.

2.1 Company: Esse Elektro-Kraft

Esse Elektro-Kraft is a privately-owned company that has about 350 shareholders. The current turnover of the company is about 9 millons Euros. In terms of electricity production, the company accounts for three small-scale hydropower plants and one solar photovoltaic park. The hydropower production units of Värnå, Hattar and Hanhikoski have an aggregated power capacity of 3.7 MW. Additional to the hydropower capacity, the company recently embarked on a solar project to diversify the renewable energy sources that feed the electricity grid (Esse Elektro-Kraft, 2024).

2.2 Municipality of Pedersöre

The municipality of Pedersöre, in Ostrobothnia, was mentioned for the first time in an official publication in 1348. In 1977, Esse, Purmo and Pedersöre were merged into one larger municipality (Figure 2). Later in 1983, Pedersöre officially becomes a bilingual municipality (the proportion of Finnish-speakers exceeds eight per cent) (Pedersöre, 2023). In 1989, Pedersöre's Finnish-language name becomes Pedersören kunta. This municipality is made up of small and large villages. The largest village in Pedersöre has just over 2,000 inhabitants (Pedersöre, 2023).

Figure 2. Map of the Pedersöre municipality. Graph from Pedersöre (2023)

2.3 Municipality of Kauhava

The municipality of Kauhava is located in the northern part of South Ostrobothnia. The city was formed in 2009 with the merger of the municipalities of Alahärmä, Kauhava, Kortesjärvi and Ylihärmä (Figure 3). This city is recognized as to be one of the most industrialized areas in Southern Ostrobothnia given the developments in terms of metal and wood industries. The population of Kauhava at the end of 2023 was around 15.000 people (Kauhava, 2023).

Co-funded by the European Union

Figure 3. Map of Kauhava. Graph from Kauhava (2023)

3 Wind power capacity

According to Statistics Finland (2023), renewable energy sources accounted for more than half of Finland's electricity production in 2022. Among the renewable energy sources in the country, electricity generated from wind power experienced significant growth, increasing over 40% to reach 11.6 TWh during 2022. In particular, wind power in Finland is one of the most important renewable energy sources as covering around 18 % of the country electricity consumption according to the report of Wind power in 2023 in Finland by Suomen Tuulivoimayhdistys (2023). As presented in the same report, the current cumulative wind power capacity in the country is around 7000 MW with a cumulative number of installed capacity of 1601 WTG (Suomen Tuulivoimayhdistys, 2023).

The wind power industry in Finland has progressed toward maturity and consolidation in recent years. Between 2011 and 2023, the average capacity of installed wind turbines has grown significantly, resulting in a substantial increase in annual wind power production (Suomen Tuulivoimayhdistys, 2023). In terms of the current share of cumulative capacity by the end of 2023 shows important players in the market as: Taaleri Energi, EPV Tuulivoima Oy, Neoen, Exilion Tuuli Ky and Ilmatar, among others. These five players together account 38% of shares of the Finnish wind power cumulative capacity (Suomen Tuulivoimayhdistys, 2023). Notably, Finland's business environment fosters the growth of wind power, supported by one of the most stable electricity grids in the world. Ongoing investments consistently enhance the grid's capacity, ensuring robust infrastructure to accommodate the expanding wind power sector (Business Finland, 2020).

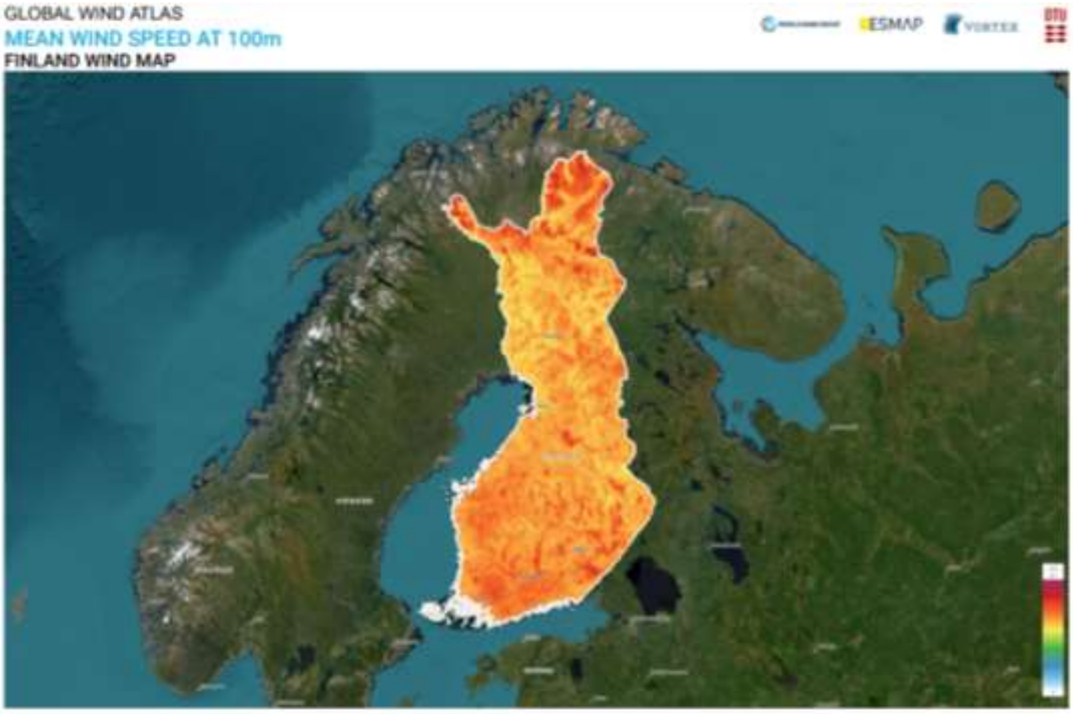

Figure 4. Wind map of Finland at mean wind speed at 100 m. From the Global Wind Atlas (WAsP, 2024)

Furthermore, Finland offers suitable conditions for exploiting wind power potential as the country's geographical location and movement of low-pressure systems from the Atlantic Ocean leads to large-scale average wind speed (Työ-ja elinkeinoministeriö, Laitos, & Oy, 2010). Average wind speed in Finland ranges from 9 to 9.5 m/s according to the 'Soumen Tuuli Atlas', corresponding to higher numbers in comparison with some locations as Southern Europe, but lower than regions in the North Atlantic in Europe (Työ-ja elinkeinoministeriö et al., 2010). These results are consistent with the graphs of wind speed in Finland at 100 m and 200m of altitude from the Global Wind Atlas, as it is possible to observe in Figures 4 and 5 where the spectrum of wind speed is shown in colors from white and blue (lowest) to red and purple (highest) (WAsP, 2024).

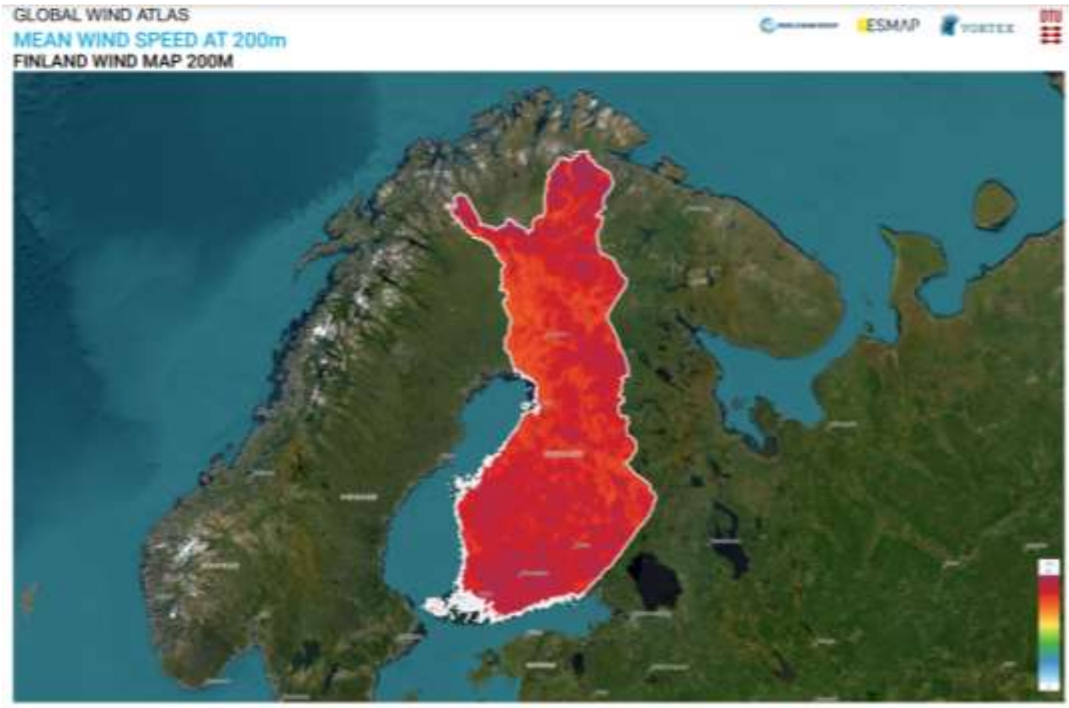

Figure 5. Wind map of Finland at mean wind speed at 200 m. From the Global Wind Atlas (WAsP, 2024)

3.1 Wind power profile of the area under consideration

The area under consideration covers two municipalities of Ostrobothnia and South Ostrobothnia in Western Finland. Currently, the regions of Ostrobothnia and South Ostrobothnia are on the top of the distribution of wind turbine generators in Finland with other two regions as North Ostrobothnia and Lapland (Suomen Tuulivoimayhdistys, 2023). By the end of 2023, around 16% of wind turbine generators were in Ostrobothnia, and 12% in South Ostrobothnia (Suomen Tuulivoimayhdistys, 2023). At the same time, the cumulative capacity for these two regions in the Finnish wind power landscape is related to 18% for Ostrobothnia and 12% for South Ostrobothnia (Suomen Tuulivoimayhdistys, 2023).

As it was discussed in previous sections, the wind speed conditions in Finland are suitable for the wind power industry. In terms of the area under consideration in this particular project, according to the Global Wind Atlas (WAsP, 2024), the data for the 10% windiest areas in Pedersöre and Kauhava indicate that it could reach 9.42 m/s at 200 m of altitude. However, there is a high seasonal variability to consider when planning wind power projects.

3.2 Status of wind power in the area under consideration

In this section the wind power projects in the area under consideration are presented in various stages of development. Only projects over 1 MW of capacity have been considered in this study. The data was obtained from the website of Renewables Finland (2024b). First, a description of projects that are currently in the productive stage is presented. Secondly, the set of wind projects in the planning stage is presented. Finally, the summary of wind power capacity in the area under consideration is shown with some scenarios for projects in planning stage.

3.2.1 Wind power projects in production and under construction

This section presents the projects related to the increase of capacity in wind power that take place in the area under consideration. According to information published by Renewables Finland (previous The Finnish Wind Power Association), there are two projects in the operational phase in the area under consideration. No projects under construction were found according to the source consulted by the time of writing this report. Below is a graph with the location of the wind power projects in operation. In Figure 6, the projects that are currently in production and under construction was created based on the interactive map available on the Renewables Finland website (Renewables Finland, 2024b).

Figure 6. Wind power projects in production phase and under construction. Based on Renewables Finland website (Renewables Finland, 2024b)

As mentioned before, at the moment of writing the present report there are no projects under construction in the area, but two projects in production over 1 MW of capacity (Table 1). Both projects are located in Kauhava. These projects came online in 2010 and 2014 by the companies Tuuliveikot Oy and HP-Energia. It is possible to note the significant difference between the number of turbines generators and capacity in comparison to current projects in the planning stage.

Table 1. Wind power projects in production and under construction >1MW

Stage	Project	Municipality	Number of turbines	Capacity (MW)	Owner	Coming online
In production	Isonnevamäki	Kauhava	1	3	Tuuliveikot Oy	2014
In production	Vuoren-syrjänkallio	Kauhava	2	1	HP-Energia	2010

3.2.2 Wind power projects in planning stage

In terms of the wind power projects in planning stage located in the area under consideration, five projects appear in the information available on the website of Renewable Finland (Renewables Finland, 2024b). As shown in Figure 7, these projects are in the process of land use proposal, land use plan done, EIA (Environmental Impact Assessment) process, and fully permitted.

Figure 7. Wind power projects in planning stage in the area under consideration. From the website of Renewables Finland (Renewables Finland, 2024b)

Concerning those projects that already obtained their environmental permits, with great possibilities to come online in the coming years, two projects appear in Kauhava (Table 2). It is expected to a combined added capacity of 71 MW to the grid with both projects when they come online in 2025 and 2026,

Table 2. Wind power projects in planning stage: fully permitted

Stage	Project	Municipality	Number of turbines	Capacity (MW)	Owner	Coming online
Fully permitted	Suolineva	Kauhava	4	28	Windfellows Oy	2025
Fully permitted	Salo-Ylikoski	Kauhava	7	43	OX2	2026

Regarding wind power projects in planning stage, specifically in land use plan or with STR done – Suunnittelutarveratkaisu (Need for planning decision), there is one project located in Pedersöre, with an expected capacity of 42 MW with six turbine generators (Table 3). The company Esse Vind Ab is planning to develop this project called 'Mastarbacka' in the area located between Lappfors and Purmo. According to Pedersöre (2024), the total height of the power plant will be 270 meters. This wind park will be connected to either Fingrid's or Herrfors' electricity grid. Moreover, besides wind turbines, service infrastructure is under development in the area in terms of roads and underground cables (Pedersöre, 2024).

Table 3. Wind power projects in planning stage: land use or plan STR done

Stage	Project	Municipality	Number of turbines	Capacity max (MW)	Owner	Coming online
Land use plan or STR done	Mastarbacka	Pedersöre	6	42	Esse Vind Ab	N/A

On the other hand, in relation to the planning projects that are in process of developing the land use plan proposal, there one relevant project in Pedersöre called 'Purmo'. This project is expected to come online in 2026 by the company ABO Wind Oy (Table 4). The expected added capacity to the grid with this project is around 430 MW with 43 turbine generators. The area of this project is around 5100 hectares located in the southwestern part of the municipality of Pedersöre.

As this project add a significant capacity to the grid, there is a need to share the information about the plan with the community located in the surrounding areas, not limited to the specific wind power infrastructure but about the service infrastructure, including power station, underground cables and internal road network. According to Pedersöre (2024), there will be some public events connected to this information at the end of 2024.

Table 4. Wind power projects in planning stage: land use plan proposal

Stage	Project	Municipality	Number of turbines	Capacity max (MW)	Owner	Coming online
Planning: Land use plan proposal	Purmo	Pedersöre	43	430	ABO Wind Oy	2026

Related to the projects in the process of obtaining environmental permits (Environmental Impact Assessment – EIA), there is one project called 'Dalalandet' located in Kauhava and Nykarleby. This project will have around 11 to 15 turbines, adding 150 MW to the grid (Table 5). This project is developing by PROKON Wind Energy Finland Oy.

Table 5. Wind power projects in planning stage: EIA process ongoing

Stage	Project	Municipality	Number of turbines	Capacity max (MW)	Owner	Coming online
EIA in process	Dalalandet	Nykarleby and Kauhava	11-15	150	PROKON Wind Energy Finland Oy	N/A

3.3 Summary of wind power capacity of the area under consideration

Overall, wind power projects of 1 MW and above located in the area under consideration correspond to the following: 4 MW as combined capacity in operation in Pedersöre and Kauhava (Table 6). No projects were found under construction in the area under consideration. Regarding planned projects, combined capacity reaches 693 MW (Table 7). However, the development of these projects is linked to relevant factors as the enact of environmental permits, reaching acceptance of projects by communities located in the surrounding areas, financial factors and supporting electricity infrastructure, among others (Spoof-tuomi, 2024b).

Table 6. Summary of wind power projects in operation and under construction in the area under consideration

Project stage	Number of projects	Capacity (MW)
In operation	2	4
Under construction	0	0
Total	2	4

Table 7. Summary of planned wind power projects in the area under consideration

Project stage	Number of projects	Capacity max (MW)
Fully permitted	2	71
EIA in progress	1	150
Plan draft	0	0
EIA done	0	0
Land use plan proposal	1	430
Land use plan / STR done	1	42
Total	**5**	**693**

Particularly, in Figure 8, it is possible to observe the relevance of current projects in the process of developing land use proposal and obtaining environmental permits as Purmo and Dalalandet. However, the size and scale of projects may also change during the project development.

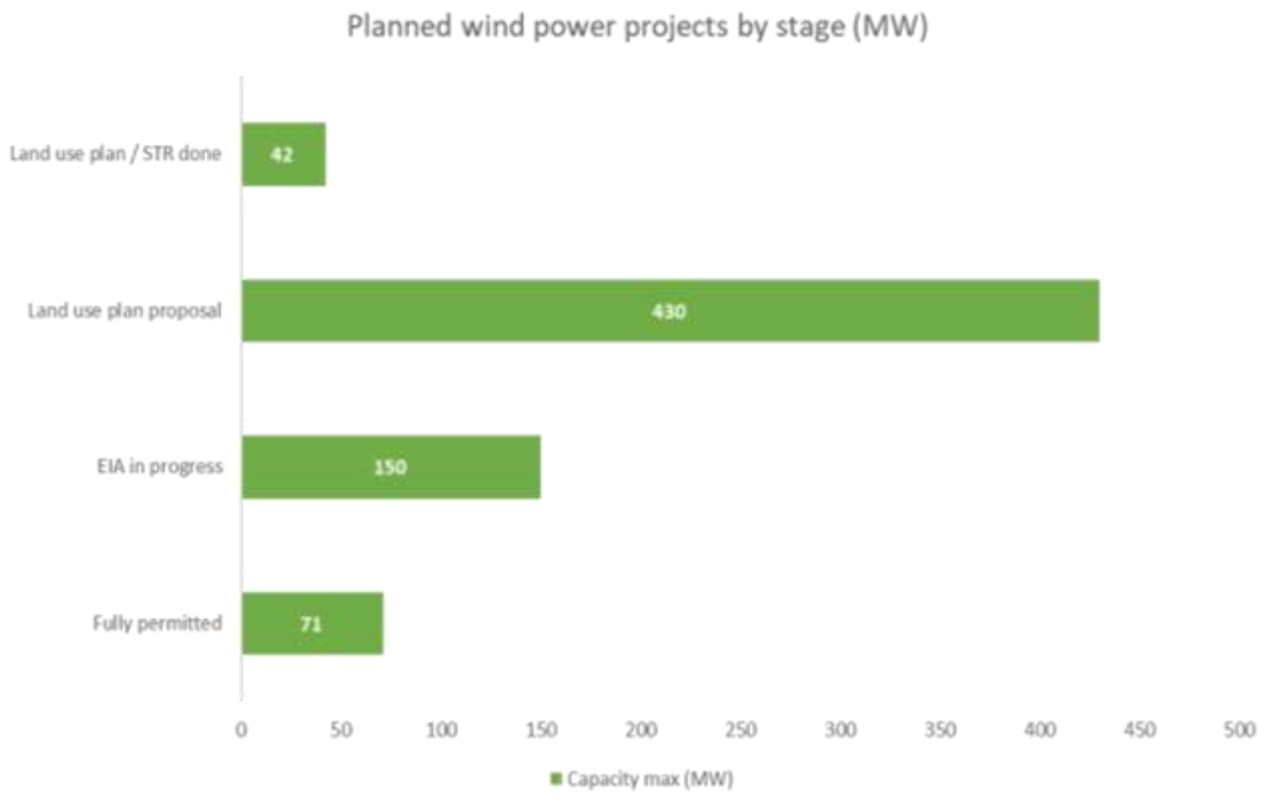

Figure 8. Graph of wind power projects in planning stage located in the area under consideration (MW)

3.4 Scenarios for wind power capacity in the area under consideration

For the purpose of providing a realistic landscape of wind power in the next years, it is presented a set of three scenarios for wind energy production in 2030 based on the existing reported wind power projects (Table 8):

- The first scenario consists of the projects in operation/under construction + 50% of projects in fully permitted + 30% of projects in EIA phase + 10% of projects in land use
- The second scenario corresponds to the projects in operation/under construction + 70 % of projects in fully permitted + 50% of projects in EIA phase + 30% of projects in land use phase.
- The third scenario is related to the projects in operation/under construction + 100% of projects in fully permitted + 70% of projects in EIA phase + 50% of projects in land use phase.

Table 8. Description of scenarios for wind power capacity

Max output	Capacity (MW)	Scenario I	Scenario II	Scenario III
Operation/under construction	4	100 %	100 %	100 %
Fully permitted	71	50 %	70 %	100 %
EIA phase	150	30 %	50 %	70 %
Land use plan / STR done + Land use plan proposal	472	10 %	30 %	50 %

With the above-mentioned scenarios in consideration, below are presented three scenarios for electricity production (Table 9). It is important to mention that the capacity factor employed for this estimate corresponds to 31% based on the studies conducted by Spoof-tuomi (2024) and the report by FCG Finnish Consulting Group Oy (2021).

Table 9. Scenarios for wind power by 2030 in the area under consideration (electricity production)

Wind power 2030 (Pedersöre+Kauhava)	**Scenario I**	**Scenario II**	**Scenario III**
In operation + under construction 2024 (MW)	4	4	4
Fully permitted	35.5	49.7	71
EIA phase	45	75	105
Land use plan / STR done + Land use plan proposal	47.2	141.6	236
Wind power capacity in 2030 (MW)	131.7	270.3	416.0
Capacity factor*	0.31	0.31	0.31
Hours per year	8760	8760	8760
Total TWh/y	**0.4**	**0.7**	**1.1**

4 Solar photovoltaic capacity

The global growth trend in the solar photovoltaic industry is anticipated to drive the rapid development of Finland's solar energy sector in the coming years (Renewables Finland, 2024a). The solar industry in Finland is still emerging. Studies, such as the Solar Cluster Study conducted by Gaia Consulting Oy (2021) for Business Finland, stated that installed solar capacity connected to the electricity grid in Finland in 2019 was around 200 MW. In the same report, the Finnish solar photovoltaic value network, identifying around 55 organizations involved in the sector, including both established and newer companies that generate more than 500 jobs (Gaia Consulting Oy, 2021). Major companies have started implementing significant solar projects nationwide, with a growing number of projects in the planning stages (Motiva Oy, 2024). As it is possible to observe in Figure 9, most solar photovoltaic projects in Finland are currently in planning stage. There is a significant concentration of projects in the West Coast of Finland as well as in the Southeast.

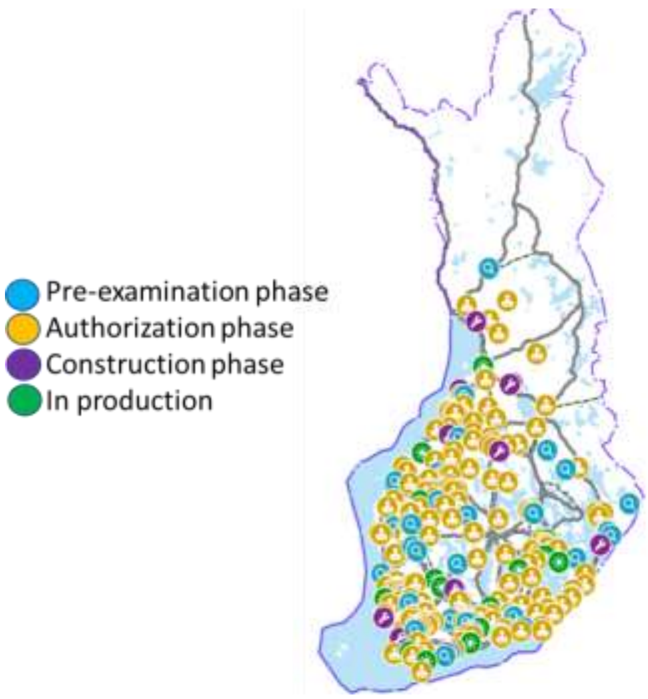

Figure 9. Solar photovoltaic projects in Finland in different stages. From the interactive map developed by Motiva Oy (Motiva Oy, 2024)

According to the interactive map of the Global Solar Atlas developed by the World Bank Group (World Bank, 2024), the direct normal irradiation in Finland is around 951.4 kWh/m^2 (Figure 10). The highest values of solar direct irradiation in the country are associated to the summer season from March till August.

Figure 10. Direct normal radiation per year in Finland. Graph from the Global Solar Atlas online app World Bank (2024)

According to the Global Solar Atlas online app, the potential specific photovoltaic power output that is possible to exploit in the country could reach approximately 943.2 kWh/kWp (yearly and monthly averages values of solar photovoltaic electricity by a photovoltaic system and normalized to 1 kWp – PVOUT specific) (World Bank, 2024). The average hourly profiles of the country based on the Global Solar Atlas are presented in Figure 11 (World Bank, 2024). The concentration of higher values of direct irradiation are located between 8 am and 2 pm from March till August.


Average hourly profiles

Direct normal irradiation [Wh/m²]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1												
1 - 2												
2 - 3												
3 - 4												
4 - 5					22	48	22					
5 - 6				5	136	179	118	29				
6 - 7				142	253	256	192	137	16			
7 - 8			98	259	346	326	260	212	117			
8 - 9		14	302	338	395	386	334	271	180	81		
9 - 10		179	384	399	421	402	368	309	221	142	34	
10 - 11	75	236	401	425	421	396	366	328	234	145	92	18
11 - 12	215	249	412	400	401	382	352	320	215	141	75	118
12 - 13	199	251	397	373	378	347	323	298	210	147	71	131
13 - 14	171	243	366	358	367	328	312	290	198	127	77	67
14 - 15	73	211	329	338	353	317	301	277	188	120	43	1
15 - 16		168	305	312	326	293	282	254	174	75		
16 - 17		31	257	292	329	286	271	238	153	5		
17 - 18			104	276	325	294	267	223	97			
18 - 19				187	288	282	257	175	13			
19 - 20				14	205	230	195	44				
20 - 21					46	136	96					
21 - 22						24	4					
22 - 23												
23 - 24												
Sum	733	1,583	3,383	4,117	5,025	4,914	4,320	3,408	2,017	983	394	335

Figure 11. Average hourly profiles of direct normal irradiation in Finland (Wh/m^2). Graph from the Global Solar Atlas online app World Bank (2024)

4.1 Profile of solar photovoltaic potential of the area under consideration

4.1.1 Pedersöre

Notably, there is great potential for the development of the solar photovoltaic industry in Pedersöre. According to the interactive map of Photovoltaic Geographical Information System (PVGIS) related to the solar irradiation and potential for photovoltaic system performance managed by Joint Research Centre (2024), the yearly in-plane irradiation in Pedersöre is related to 1089.6 kWh/m². From these values of solar direct irradiation, the potential yearly energy output from fix-angle PV system that could be exploited in the city 872.8 kWh (Figure 12).

In recent reports by the Österbottens Förbund (2022) and Gaia Consulting (2023), it is highlighted the relevance of further investigating suitable locations for solar energy production in Ostrobothnia.

However, it is crucial to prioritize brownfield sites to minimize environmental impacts. Large-scale industrial solar farms should be established in treeless, underused areas, such as former peat production sites, abandoned fur farms, or low-productivity farmland.

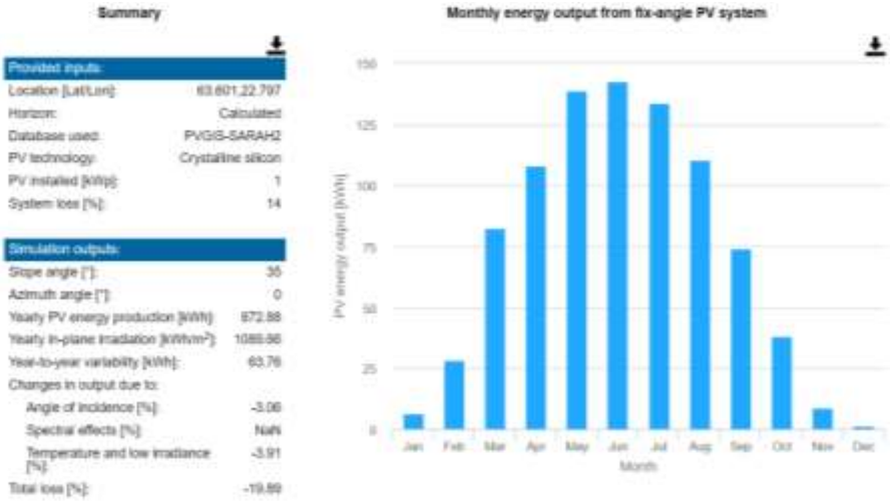

Figure 12. Profile of Pedersöre solar PV potential (Joint Research Centre, 2024)

4.1.2 Kauhava

As in Pedersöre, Kauhava also accounts with important values in terms of solar direct irradiation. According to the same source as before, the yearly in-plane irradiation in the city reaches 1081.39 kWh/m^2 (Joint Research Centre, 2024). The potential yearly energy output from fix-angle PV system that could be exploited in Kauhava is around 859.4 kWh (Figure 13). A study by FCG Finnish Consulting Group Oy (2023) outlined a preliminary identification of potential solar energy sites in South Ostrobothnia. The suitability for solar photovoltaic projects of these areas was evaluated based on several factors, including proximity to high-voltage lines and transformer stations, accessibility by surrounding roads, and land cover quality. Findings of that study indicate that open, wide, and undeveloped areas were considered the most favorable for solar power. The study emphasized environmental permits and the potential use of abandoned peat production areas for solar energy development (FCG Finnish Consulting Group Oy, 2023).

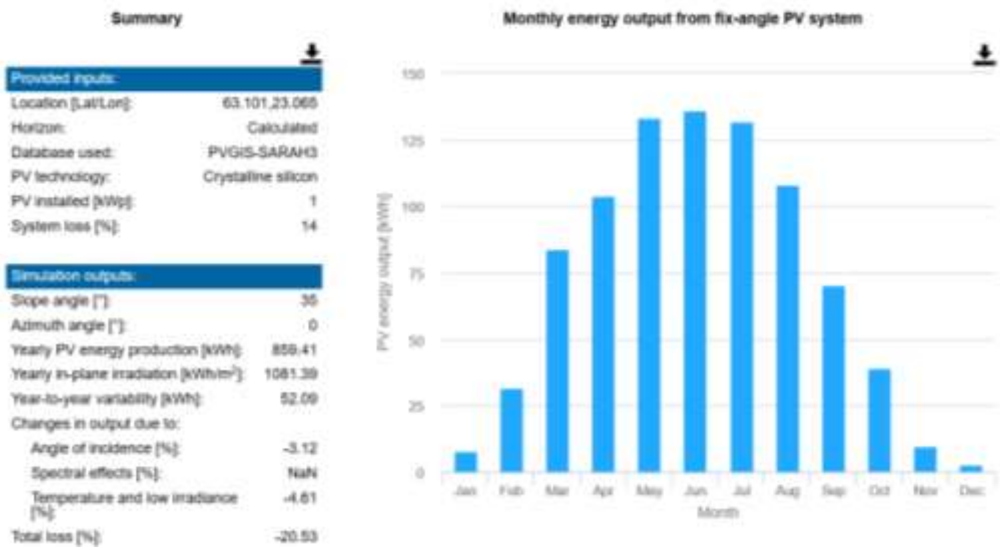

Figure 13. Profile of Kauhava solar PV potential (Joint Research Centre, 2024)

Furthermore, according to the report by Etelä-Pohjanmaan Liitto (2024), approximately 25 sites in South Ostrobothnia have been identified as suitable for industrial-scale solar energy projects. However, the region holds significant additional potential for solar energy development. For instance, former peat production areas transitioning to alternative land uses offer promising opportunities. To fully harness this potential, strategic planning for the development of the solar photovoltaic industry in the region, including the city of Kauhava, must be detailed, dynamic, and continuously updated. This process should involve close collaboration and engagement with stakeholders across the solar energy value chain.

4.2 Solar power capacity in the area under consideration

In this report, solar PV projects with a peak capacity of 1 MW or above in Pedersöre and Kauhava have been considered. Information from official sources such as Motiva Oy indicate that there are no solar PV projects in production in the area under consideration (Motiva Oy, 2024). However, some projects in operation are expected to be registered in the official database for data public access, for example, the solar park where the company Esse Elektro-Kraft participates.

4.3 Solar power projects in planning stage

According to the information available on the website of Motiva Oy, there are two projects in planning stage in Kauhava (Table 10). These projects are currently in the planning stage (authorization phase) (Motiva Oy, 2024). One of these projects, called 'Haisuneva' is expected to reach an annual production capacity of 95 GWh/y with 100 MWp. The developer company is EPV Aurinkovoima Oy. It is important to highlight that the 'Haisuneva' solar PV park is close to other three relevant solar photovoltaic projects in Lapua being developed also by EPV Aurinkovoima Oy. Therefore, this area may concentrate in the next years a significant amount solar PV capacity for the region (Figure 14).

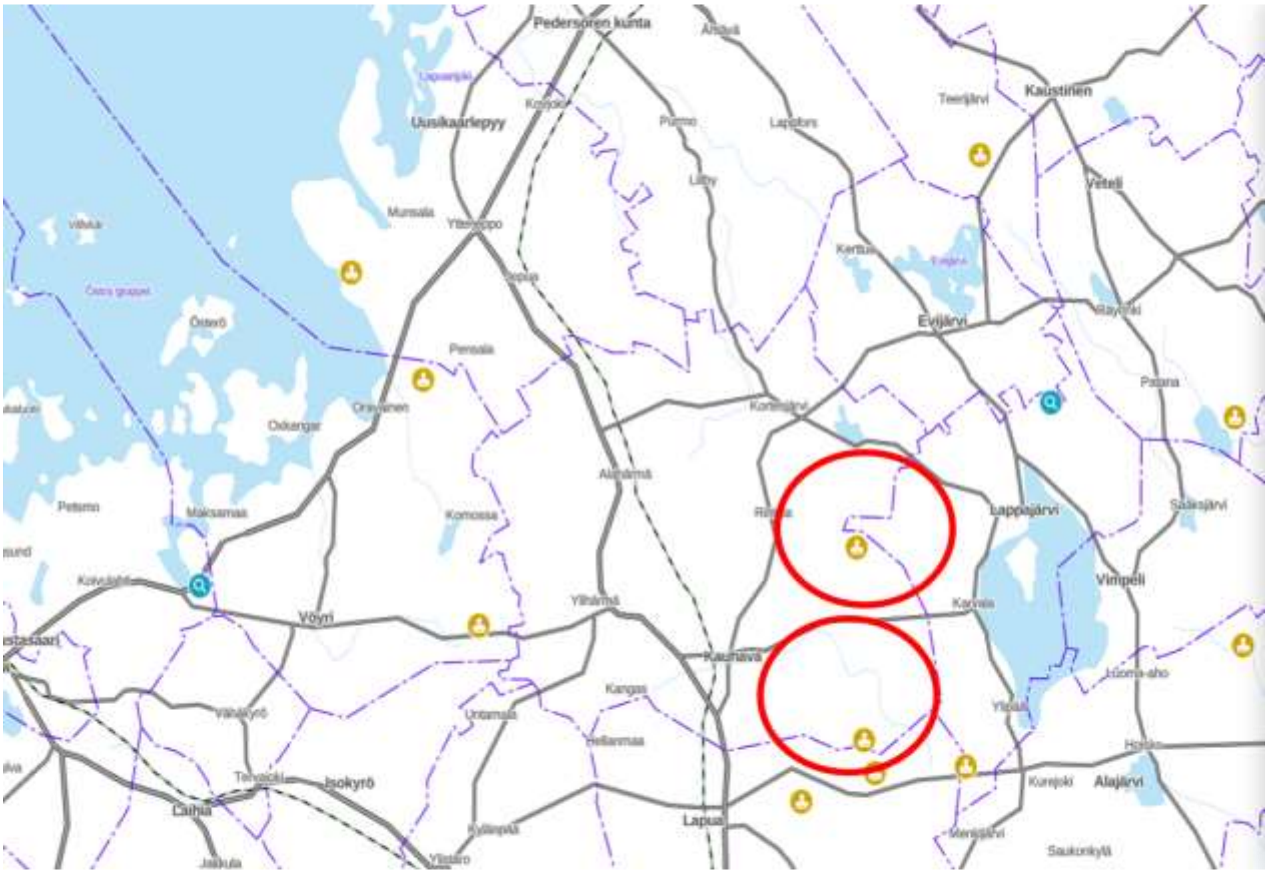

Figure 14. Map of solar photovoltaic projects in the area under consideration. Graph from Motiva Oy (2024)

Concerning the second solar photovoltaic project in planning phase in Kauhava is called 'Ohraneva'. According to the information reported on the Motiva Oy' website, this project developed by EPV Aurinkovoima Oy (Motiva Oy, 2024).

Table 10. Solar photovoltaic projects in Kauhava

Project	Municipality	Number of panels	Capacity (MWp)	Expected annual production (GWh/y)	Developer	Coming online
Haisuneva	Kauhava	200000	100	95	EPV Aurinkovoima Oy	2028
Ohraneva	Kauhava	100000	70	60	EPV Aurinkovoima Oy	2027
Total			**170**	**155**		

On the other hand, according to the public information available provided by Motiva Oy, there are no solar photovoltaic projects in this area of the municipality of Pedersöre. However, on the north side of Åsbackavägen in Ytteresse a solar park has been built where the electricity company Esse Elektro-Kraft has an important participation (Esse Elektro-Kraft, 2024). When writing this study, that solar park did not appear on the website of Motiva Oy. According to the information reported in the Esse Elektro-Kraft, the project was built on a site formerly utilized as a fur farm. It encompasses a service building and spans an area of 11 hectares. Currently, this solar park is currently in operation phase. The facility complements the company's hydropower production, which typically experiences reduced output during the summer due to low water flow in the Esse River. The aim is to enhance the reliability of our electricity supply and reduce our customers' climate impact through innovative solutions (Esse Elektro-Kraft, 2024).

5 Biogas potential

This chapter presents estimates of the theoretical biogas potential for the geographic areas of the municipalities of Pedersöre and Kauhava. For this, the results of the Digibiogas project were taken into consideration. Additionally, a biogas estimation was made based on a specific type of biomass as a suitable feedstock for anaerobic digestion.

Notably, biogas is produced through anaerobic digestion from the decomposition of biomass, coming for example from the agricultural industry, livestock, or treatment plants, in the form of agricultural or livestock waste, sludge, among others. To produce biomethane from biogas, a purification process would be required to eliminate carbon dioxide, volatile organic compounds, among other components (Repsol, 2024).

5.1 Results of biogas potential from the Digibiogas project

In the Digibiogas project, one of the main activities was the analysis of biogas production and use potential and emission calculation of biogas production and use in the region of Ostrobothnia (Spoof-tuomi, 2024a). According to the partial report of this project TP2, the total energy from biomass in Pedersöre corresponds to 77473 MWh/y. This theoretical yearly estimation is based on the following feedstock: fallow-grasses, protection zone grasses, surplus- straw, green manure lawn early harvest, beef slurry manure, pigs slurry manure, egg laying chickens dry manure, broilers, turkey and other poultry manure, sheep and goats dry manures, horses dry manures, and fur-animals manures (Spoof-tuomi, 2024a).

5.2 Estimation of theoretical biogas

5.2.1 Feedstock and parameters

To estimate the theoretical potential of biogas in the area under consideration in this report, the information published in the Biomassa-Atlas by Luke (2024b) was used as a main source of the amount of biomass. For Pedersöre and Kauhava, the amount of field biomass and wet and dry manure was calculated directly in the Biomass Atlas. Subsequently, the theoretical biogas potential was calculated using as reference values of the biogas calculator developed by Luke (2024a), and insights from Digibiogas hub project. The feedstock considered in this estimation for biogas theoretical potential were:

- Cattle slurry
- Beef cattle slurry ex housing
- Dry cattle manure
- Beef cattle solid manure ex housing
- Slurry from pigs
- Sow & piglets slurry ex housing
- Manure from laying hens
- Broiler, turkey, other poultry manure
- Sheep and goat manure
- Dry horse manure
- Fur animal dung

The theoretical biogas potential was estimated as follows:
Biogas production [(m3/y)/t]: biomass [ton/ year] * (total solids [TS] % in biomass) * (volatile solids [VS] %) *(theoretical methane potential in one cubic meter [m^3 CH_4/tVS]). Then, the total theoretical biogas is estimated for the set of selected feedstocks considering the methane density of 0.717 kg/m^3 at standard conditions and the methane energy density 13.9 kWh/kg (Kannonlahti & Peura, 2022; Spoof-tuomi, 2024a).

5.2.2 Pedersöre

In Table 11, it is presented the estimation of theoretical biogas for Pedersöre, using the data set from Biomassa Atlas by Luke (2024), in terms of the specific types of feedstock and parameters described above. From 156.720 annual tonnes of biomass, it is possible to obtain 48.413 MWh/y of biogas (Table 11).

Table 11. Estimation of theoretical biogas in Pedersöre

Feedstock	Dry matter content (TS, Total Solids)	Organic dry matter (VS, Volatile Solids)	CH4 production potential	CH4 theoretical	Amount biomass	CH4 theoretical	CH4 theoretical
	%	%	m3 CH4/tVS	(m3/y)/t	ton/y	m3/y	MWh/y
Cattle slurry	9%	80%	200	14.4	56902	819388.8	8166.3
Beef cattle slurry ex housing	9%	80%	200	14.4	27113	390427.2	3891.1
Dry cattle manure	30%	85%	200	51.0	24978	1273878.0	12695.9
Beef cattle solid manure ex housing	30%	85%	200	51.0	33992	1733592.0	17277.5
Slurry from pigs	8%	82%	320	21.0	907	19039.7	189.8
Sow & piglets slurry ex housing	8%	82%	320	21.0	2993	62829.1	626.2
Manure from laying hens	35%	75%	260	68.3	34	2320.5	23.1
Broiler, turkey, other poultry manure	68%	85%	155	89.6	0	0.0	0.0
Sheep and goat manure	25%	80%	100	20.0	329	6580.0	65.6
Dry horse manure	35%	85%	160	47.6	2245	106862.0	1065.0
Fur animal dung	33%	79%	235	61.3	7227	442758.5	4412.7
Total				0	**156720**		**48,413**
						Dry biogas	31,038
						Wet biogas	17,375

5.2.3 Kauhava

For Kauhava, the estimation of theoretical yearly biogas production is presented in Table 12. As for Pedersöre, the raw data was obtained from Biomass Atlas by Luke (2024), in terms of the specific types of feedstock and parameters described above. From 200.194 annual tonnes of biomass, it is possible to obtain 61.419 MWh/y of biogas (Table 12).

Table 12. Estimation of theoretical biogas in Kauhava

Feedstock	Dry matter content (TS, Total Solids)	Organic dry matter (VS, Volatile Solids)	CH4 production potential	CH4 theoretical per ton	Amount biomass	CH4 potential	CH4 potential
	%	%	m3 CH4/tVS	(m3/y)/t	ton/y	m3/y	MWh/y
Cattle slurry	9%	80%	200	14.4	59115	851256	8,484
Beef cattle slurry ex housing	9%	80%	200	14.4	27826	400694.4	3,993
Dry cattle manure	30%	85%	200	51.0	25639	1307589	13,032
Beef cattle solid manure ex housing	30%	85%	200	51.0	30714	1566414	15,611
Slurry from pigs	8%	82%	320	21.0	29255	614120.96	6,121
Sow & piglets slurry ex housing	8%	82%	320	21.0	5556	116631.552	1,162
Manure from laying hens	35%	75%	260	68.3	5	341.25	3
Broiler, turkey, other poultry manure	68%	85%	155	89.6	3883	347877.97	3,467
Sheep and goat manure	25%	80%	100	20.0	1773	35460	353
Dry horse manure	35%	85%	160	47.6	6158	293120.8	2,921
Fur animal dung	33%	79%	235	61.3	10270	629186.415	6,271
Total					**200194**		**61,419**
						Dry biogas	31,565
						Wet biogas	29,855

6 Overall energy potential

The potential for renewable energy development in the area under consideration encompasses wind, solar, and bioenergy, as outlined below:

- **Wind Power**

  The region has significant potential for wind energy, with five projects currently in the planning stage. These projects are expected to contribute an additional 693 MW of capacity to the electricity grid over the next four years. While some of these projects have already secured full permits, others are still obtaining environmental clearances and land-use approvals.

- **Solar Photovoltaic (PV) Power**

  The solar PV industry in the region is in its early stages of development. According to publicly available sources, the number of projects remains limited. However, two planned solar PV projects in Kauhava are expected to add 170 MWp to the electricity grid by 2028. Given the growing interest in solar energy across the country, it is anticipated that new solar PV initiatives will emerge in this area in the coming years.

- **Bioenergy**

  Theoretical estimates suggest that Pedersöre and Kauhava have the potential to generate 109,832 MWh/year of biogas. This highlights opportunities for the development and enhancement of biogas production in the region. However, realizing this potential requires addressing challenges in the biogas value chain, which involve complex logistics. Increased research efforts and public funding will be essential to support and accelerate the growth of biogas initiatives.

This analysis underscores the region's substantial opportunities for advancing renewable energy, while also emphasizing areas that require further support and development.

7 Conclusions

With the growing push for electrification in Finland and the need to expand capacity in regions like Ostrobothnia and South Ostrobothnia, renewable energy sources such as solar photovoltaic, wind power and biogas are becoming increasingly relevant. Especially in terms of wind power, there is a set of projects in the area under consideration with a significant capacity that will be added to the grid when coming online between 2025 to 2028 (Renewables Finland, 2024b).

Concerning solar photovoltaics, the industry in Finland is process of deployment with high expectations. Particularly, in the area under consideration, a few projects have been identified, all in Kauhava, with an important addition in capacity to the grid. However, as these projects are still in the planning phase, it is expected that they will progress through environmental permitting and other regulatory processes. Notably, there are significant opportunities for solar photovoltaic in the area under consideration, however, it is necessary to develop specific studies for the identifying potential sites for solar PV development on unused land. There is especially a significant opportunity to build solar photovoltaic parks in brownfield areas, such as former peat production sites, abandoned fur farms, or low-productivity farmland (Gaia Consulting, 2023; Österbottens Förbund, 2022).

In terms of biogas, the theoretical estimations could appear as valuable inputs to start developing roadmaps for the exploration and exploitation of the bioenergy potential in Ostrobothnia and South Ostrobothnia, including the area under consideration in this project. Particularly, it is important to raise the awareness among citizens about untapped opportunities in the bioenergy spectrum from agricultural biomass, and the implications in logistics to take advantage of bioenergy resources.

Overall, the results of the energy potential in the area under consideration indicate great possibilities to add capacity to the current energy market with renewable energy sources. Sources and technologies explored in this study present distinctive characteristics, which is a positive aspect when added to the grid to increase reliability and flexibility.

References

Business Finland. (2020). A strong tailwind powers growth. Helsinki, Finland. Retrieved from www.businessfinland.fi

Esse Elektro-Kraft. (2024). Esse Elektro-Kraft. Retrieved from https://eekab.fi/

Etelä-Pohjanmaan Liitto. (2024). *Maakuntakaava- luonnoksen kuulemisvaiheen palautekooste: Etelä-Pohjanmaan maakuntakaava 2050*. Retrieved from www.epliitto.fi

FCG Finnish Consulting Group Oy. (2021). *Åbackin tuulivoimaosayleiskaava Yhteystiedot*. Helsinki, Finland.

FCG Finnish Consulting Group Oy. (2023). *Etelä-Pohjanmaan aurinkoenergiaselvitys:* Helsinki, Finland.

Gaia Consulting. (2023). *Ökade investeringar i den gröna omställning i Österbotten*.

Gaia Consulting Oy. (2021). *Solar Cluster Study*. Retrieved from www.businessfinland.fi/en

Joint Research Centre. (2024). Photovoltaic Geographical Information System (PVGIS). Retrieved from https://joint-research-centre.ec.europa.eu/photovoltaic-geographical-information-system-pvgis_en

Kannonlahti, J., & Peura, P. (2022). *Uusiutuvan energian potentiaali Kaustisen seutukunnassa , sekä sen hyödyntämisen vaikutukset ympäristöön*.

Kauhava. (2023). Welcome to Kauhava. Kauhava. Retrieved from www.kauhava.fi

Luke. (2024a). Biogas Tool. Retrieved from https://biokaasulaskuri.luke.fi/

Luke. (2024b). Biomassa-Atlas. Retrieved from https://biomassa-atlas.luke.fi/

Motiva Oy. (2024). Solar Power Plants. Retrieved from https://aurinkosahkovoimalat.fi/

Österbottens Förbund. (2022). Pohjanmaan maakuntakaava 2050 – aurinkoenergiaselvitys: Aurinkoenergian Tuotanto Maankäytön Ja Aluesuunnittelun Kysymyksenä Pohjanmaalla. Vaasa, Finland.

Pedersöre. (2023). Pedersöre: Kommun och näringsliv. Retrieved from www.pedersore.fi

Pedersöre. (2024). Partial general plan of the Purmo wind power park. Retrieved from https://www.pedersore.fi/fi/asuminen-ja-ymparisto/kaavat-ja-kartat/purmon-tuulivoimapuiston-osayleiskaava

Renewables Finland. (2024a). Solar Power. Retrieved from https://suomenuusiutuvat.fi/en/solar-power/about-solar-power-in-finland/

Renewables Finland. (2024b). Wind Power. Retrieved from https://tuulivoimayhdistys.fi/en/wind-power-in-finland

Repsol. (2024). Qué es el biometano y para qué sirve: Metano de origen renovable, un paso más hacia la sostenibilidad. Retrieved from https://www.repsol.com/es/energia-futuro/movilidad-sostenible/biometano/index.cshtml

RIPEET. (2020). *Territorial transition pathways: Deliverable No.4.1*. Retrieved from https://ripeet.eu/our-resources

Spoof-tuomi, K. (2024a). *Biokaasun tuotanto- ja käyttöpotentiaalin selvitys sekä biokaasun tuotannon ja käytön päästölaskenta - Pohjanmaan maakunta*.

Spoof-tuomi, K. (2024b). *Tuulivoimalla Tuotetun Sähkön Kokonaispotentiaali Vuoteen 2030 Mennessä Sisältö*. Vaasa, Finland.

Statistics Finland. (2023). Production of electricity and heat. Retrieved from https://stat.fi/en/publication/cl8mo29omxf8t0dukky5aa8i1

Suomen Tuulivoimayhdistys. (2023). *Wind power in 2023 in Finland*. Retrieved from www.businessfinland.fi

Työ-ja elinkeinoministeriö, Laitos, I., & Oy, M. (2010). *Suomen Tuuli Atlas: Summary report*. Helsinki, Finland. Retrieved from tuuliatlas.fmi.fi

VEBIC. (2024). DigiBiogasHubs: Digital platforms as enablers of flexible and scalable biogas operations. Retrieved from https://sites.uwasa.fi/digibiogashubs/fi/etusivu/

WAsP. (2024). Global Wind Atlas. Retrieved from https://globalwindatlas.info/en/

World Bank. (2024). Finland: global solar atlas. Retrieved from https://globalsolaratlas.info/map

ZEI, Universiteit Leiden, ERRIN, K&I, EAE, Fundecytpctex, HIE, R. C. of O. (2024). RIPEET: Responsible Energy Transition. Retrieved from https://ripeet.eu/