SOUTH BALTIC FARMS
AN ESSENTIAL PART OF RENEWABLE ENERGY SYSTEMS

Interreg
South Baltic

Co-funded by
the European Union

2024

Project
DELIVERABLE

2.1 Report on policy frameworks in SBS region, stakeholder needs and challenges

Current status

Policy frameworks

Funding opportunities

Needs & challenges

www.biosolfarm.eu

Contact

www.biosolfarm.eu

contact@biosolfarm.eu

Gdańsk University of Technology
Narutowicza 11/12
80-233 Gdańsk
Poland

Preface

The project receives funding by the Interreg South Baltic Programme 2021-2027 under the project BIOSOLFarm - South Baltic Farms - an essential part of renewable systems, STHB.02.01-IP.01-0003/23-00.

Authors

Edyta Słupek, Gdańsk University of Technology

Matas Budriūnas, AgriFood Lithuania

Aleksander Karaś, Pomorski Ośrodek Doradztwa Rolniczego

Mona-Maria Narra, University of Rostock

Iwona Cichowska-Kopczyńska, Gdańsk University of Technology

Project Partners

1. Gdańsk University of Technology (GUT) — lead partner
2. AgriFood Lithuania DIH (AFL)
3. enviMV e.V. Network of environmental technologies of Mecklenburg-Vorpommern (enviMV)
4. Rietavas Tourism and Business Information Centre (RTBiC)
5. Pomeranian Agricultural Advisory Centre in Lubań (PAAC)
6. Lithuania Food Exporters Association (LitMEA)
7. University of Rostock (UROS)

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List of Abbreviations:

Abbreviation	Full Term
Mtdm	Million Tonnes of Dry Matter
BTDM	Billion Tonnes of Dry Matter
Mtoe	Million Tonnes of Oil Equivalent
GWh	Gigawatt-hour
kWh	Kilowatt-hour
2e+4	$2 \times 10^4 = 20{,}000$, 2e+4 tonnes of oil equivalent, it means: 20,000 tonnes of oil equivalent

Introduction

Energy production in the European Union currently relies mainly on fossil fuels, most of which are imported from outside the EU. Over the years, the EU has paid an average of 300 EUR billion per year for oil, coal, and natural gas imports [1]. 2022 the EU bill for imported fuels increased to approximately 720 EUR billion.

There has been a positive trend in renewable energy production, which increased by 32.6% from 2012 to 2020

The COVID-19 pandemic caused the initial increase in energy prices, but further price increases resulted from the cutting off of natural gas supplies from Russia [2]. Russia's war in Ukraine served as a crucial moment that revealed Europe's reliance on natural gas imports. From 2012 to 2022, there has been a declining trend in energy production from solid fossil fuels, oil, natural gas, and nuclear energy. Natural gas production experienced the most significant decrease (64.9%), followed by solid fossil fuels and oil and petroleum products (down 38.7% and 38.0% respectively). However, there has been a positive trend in renewable energy production, which increased by 32.6% over the same period. This growth in renewable energy sources offers hope as a potential solution to reduce reliance on fossil fuels and decrease the EU's dependence on imports. In 2024, Ember released a report titled "European Electricity Review 2024", which showed that the share of fossil fuels in the EU's electricity mix dropped by 19% in 2023 compared to the previous year, reaching less than one-third of the total electricity volume for the first time [3]. The report shows that the effects of intensifying activities to develop energy production from renewable sources are noticeable in Europe. Ensuring energy security is following Directive 2001/77/EC of the European Parliament and Council of September 27, 2001, and Directive 2009/28/EC of the European Parliament and Council of April 23, 2009, on the promotion of the production and use of energy from renewable sources. Mitigating climate change and creating energy security are the main elements of EU energy policy [4-5]. The analysis of reports, summaries, and scientific publications confirms that every year, there is an increase in the share of renewable energy sources in energy production [6]. This is because energy obtained from renewable energy sources guarantees economic stability through the use of local raw materials. The apparent continued growth in electricity production from renewable energy sources in

recent years primarily reflects the intensified development of wind and solar energy across Europe, with the total electricity generated from renewable sources being 36.5% and 13.3%, respectively. Among the EU Member States, the highest energy generated from renewable sources was recorded for Germany at 47.6%; in Lithuania and Poland, the energy consumption was at a similar level of 26.5 and 21%, respectively [7]. Figure 1 shows the energy distribution from renewable sources in the total energy production for all EU Member States. Although there is an apparent increase in the share of renewable energy in individual countries, there are significant differences among them. Countries such as Sweden, Finland, Lithuania, and Denmark have achieved the highest share of energy derived from renewable sources due to their sustained pro-environmental policies for many years [8]. Germany and France are considered pioneers in pro-environmental policies [9]. However, their share of energy from renewable sources is similar to that of countries like Greece and Spain. This fact can be attributed to various factors such as a region's population, area, level of education, and degree of industrialization. Moreover, the availability of renewable resources, investment in renewable energy technologies, and the political will to transition to renewable energy all influence the share of renewable energy in a country's energy mix [10] (Table 1). As a result, household electricity consumption varies significantly across European Union member states. The average consumption amounts to 1,671 kWh/year for Europe, with much higher values recorded in Poland and Lithuania. In contrast, Germany's per capita electricity consumption is much lower, at 1,671 kWh per year [11].

General information on obtaining renewable energy for Europe and countries such as Germany, Lithuania, and Poland. Table 1

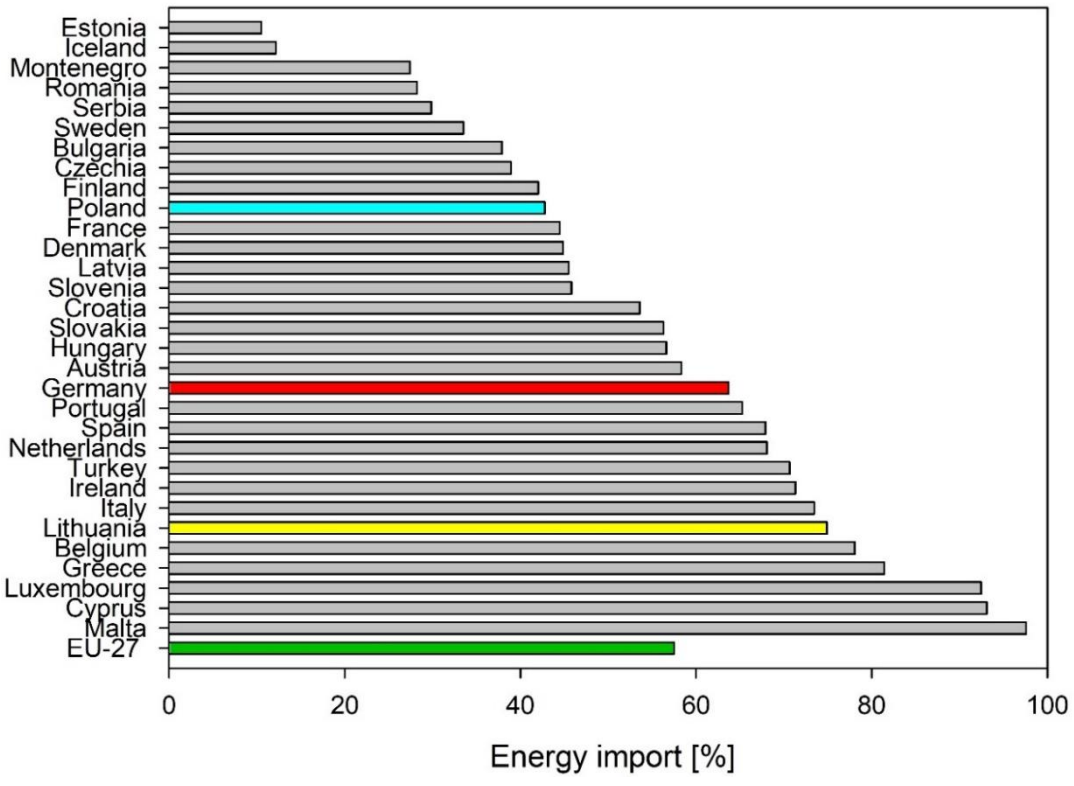
Name of region	Europe	Germany	Lithuania	Poland	Ref.
Land area [Thousand Hectares]	41,425	35,330	6,264	30,724	[12]
Farmland area [Thousand Hectares]	156,66	16,715	2,925	14,406	[12]
RES share in energy mix per region [%]	37.0	14.8	25.6	11.3	[13,14]
The share of energy from RES [%]	23.02	20.8	29.6	16.9	[7]
Share of energy from renewable sources in gross electricity consumption [%]	41.2	47.6	26.5	21.0	[7]
The share of energy from biogas [%]	5.1	13.0	4.5	4.2	[15]
The share of wind energy [%]	36.5	51.2	46.3	54.4	[15]
The share of solar energy [%]	13.3	19.2	3.8	6.7	[15]
Per capita electricity demand in the region [KWh/year]	1,671	1,403	21,290	27,290	[11]

By analyzing comprehensive data on the level of energy dependence of EU countries on external energy sources, one can see the scale of this phenomenon. Currently, the average energy dependency rate for EU-27 is 57.5%. Among the countries with the highest export rates are Malta and Cyprus, at 98% and 93%, respectively [16]. The export rates show that many EU countries are at risk of a sudden reduction or complete blocking of imported energy supplies, highlighting the crucial need for strategic planning and long-term solutions.

Figure 1 shows the supply values of the individual EU countries, which show differences in how well they implement pro-environmental standards and sustainable development solutions. These measures aim to reduce greenhouse gas emissions by using renewable energy sources for energy production.

Using bioenergy from renewable sources is essential in combating climate change, but it's important to remember that renewable energy sources alone cannot wholly decarbonize the entire energy system. Achieving and maintaining sustainable development is crucial for meeting current and future needs in environmental, economic, and social aspects. Therefore, a thorough analysis of each EU country's energy resources can lead to a more effective use of national resources. In some countries, lower exports may be due to underutilization of their potential for energy generation from renewable sources.

This report analyzes the potential for energy resources in Europe, focusing on countries bordering the Baltic Sea, such as Germany, Lithuania, and Poland. It will emphasize the feasibility of producing bioenergy using biogas plants, wind, and solar technologies.



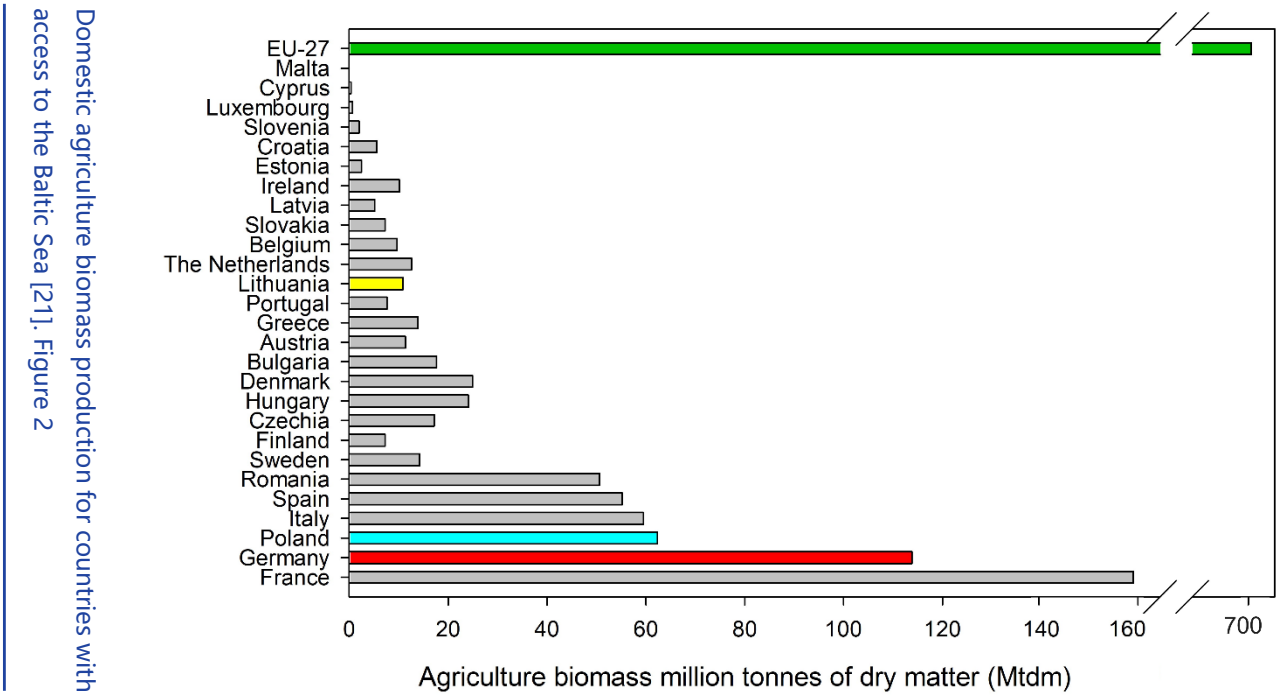
Energy import dependency in the European Union (EU-27) in 2020 [17]. Figure 1

Current status of selected green energy sources use

BIOMASS

Europe has an estimated total agricultural land area of 157 million hectares. Farms more prominent than 100 hectares comprise 52% of this land, while smaller farms with less than 5 hectares (known as small farms) use approximately 6% of the total land. The total biomass source in Europe is about 1 billion dry tons (BTDM), with a utilization of 1.2 (BTDM). Currently, the demand for biomass throughout Europe is higher than its production. Seventy percent of the used biomass comes from the agricultural sector, including food, harvested residues, and grazed biomass, while the remaining portion comes from crops and crop residue [18]. The distribution of agricultural biomass in each EU member state is depicted in Figure 2. The data demonstrates that Germany is the second-highest producer among all EU countries and is a leader compared to countries with access to the Baltic Sea. Germany annually produces approximately 113.78 million tons of dry biomass (Mtdm), which accounts for roughly 16% of the total biomass production in Europe. Different sources of biomass streams are utilized, including wood and wood waste, agricultural biomass, municipal organic waste, and energy crops. The majority of this fraction comes from agricultural and forestry residues. Biomass from the agricultural sector 113.78 (Mtdm) contributes to 77%, whereas the remaining 23% comes from forestry 34.44 (Mtdm). It should be mentioned that the dominant biomass feedstock from the agricultural sector utilized for biomass production in Germany is green maize [19]. Poland ranks second among countries with access to the Baltic Sea, producing about 62.30 (Mtdm), including corn silage, cereal crops (straw, cereals, and by-products), slurry, animal excrements (cattle, pigs, poultry), energy crops (miscanthus, sorghum), agricultural residues (corn, sugar beet pulp, fruit, and vegetable waste), legumes and mown grass. Meanwhile, Lithuania has the most minor agricultural biomass production at 10.84 (Mtdm). The primary source of biomass in Lithuania is agriculture, which accounts for about 76–80 percent of the total domestic biomass production, followed by wood biomass, which accounts for about one-fifth of the total biomass production in the country. Produced biofuel is mainly used for heating and conversion to electricity [20]. Biomass in Europe is a locally sustainable and cost-effective energy source that ensures energy security. Biomass also plays a crucial role in diversifying energy sources and achieving climate goals, making it a key player in the fight against climate change. Agricultural farms in the EU, especially those with access to biomass sources such as agricultural raw materials, agriculture by-products, liquid or solid animal excrements, waste or residues from processing agricultural or forest products, or plant biomass from non-registered areas, have great potential for

biogas production. The most common technology for energy production in Baltic Sea countries is anaerobic fermentation, where microorganisms break down organic matter to produce biogas. This biogas can be used for electricity generation, heating, or as vehicle fuel (biomethane) [22].



Domestic agriculture biomass production for countries with access to the Baltic Sea [21]. Figure 2

Furthermore, the digestate by-product of this process can be used as fertilizer. This solution increases energy efficiency, improves waste management, and reduces pollution discharge into the Baltic Sea. Additionally, large farm areas provide substantial potential for installing photovoltaic and wind power systems. However, to meet peak energy demands, it is crucial to develop energy storage systems [23]. There are 19,419 biogas facilities across Europe, and the total energy production from biomass in 2022 was 102.2 Mtoe (Table 2). From biogas, 15,712 Mtoe was obtained, with 13,237 Mtoe produced through anaerobic fermentation. This resulted in 80,000 GWh of electricity and 7,000 kWh of heat energy. The increasing use of biomass suggests that energy from biogas production could reach 31,000-40,000 Mtoe in 2030 and even 150,000 Mtoe by 2050 GWh of electricity and 7,000 kWh of heat energy were obtained. The continuous increase in biomass use indicates energy from biogas production may reach 31,000-40,000 Mtoe in 2030 and even 150,000 Mtoe by 2050 [24].

However, it is worth noting that there is currently no uniform model for biogas market development in the EU countries. This is mainly due to variations in the availability of raw materials in terms of quantity and the financial capabilities of each country. When constructing a new biogas plant, it is essential to establish its primary purpose on the farm. One approach involves improving the

efficiency of farms by building micro and small biogas plants with capacities not exceeding 50 kW and 200 kW, respectively. Another option is to create medium or large-sized biogas plants with capacities not exceeding 500 kW and 1 MW, respectively. The construction of medium and large-sized biogas plants aims to develop new farm revenue opportunities. In this case, farms must have the capability to gather sufficient organic biomass, and the energy produced must be sold at market prices. There is more interest in micro-biogas plants in Europe than in other installations, mainly because of the simplified investment path for plants with 200,000 m^3 of biogas [25]. Germany is the leading producer of biogas in Europe, where dominant types include agricultural, industrial, small-scale, and municipal biogas plants. Germany is home to 60 % of Europe' s biogas plants. Industrial biogas plants use by-products from various industrial activities, including slaughterhouse waste and food processing waste, among others, to generate bioenergy. Small-scale biogas plants are purposely built for small farms or rural areas using locally generated organic waste as feedstocks. Municipal biogas plants utilize municipal organic waste, sewage sludge, etc., as the raw materials [26]. In the Polish model, most installations were biogas and agricultural micro-biogas plants. However, the main biogas plants in Lithuania are in the agricultural sector.

Information on accessing renewable energy from biomass in Europe, focusing on Germany, Lithuania, and Poland [25,27-29].

Table 2

Region	Number of biogas plants	Large-scale biogas plant	Total energy obtained from biomass [Mtoe]	Total energy obtained from biogas [Mtoe]	Total energy production from anaerobic fermentation biogas [Mtoe]	Gross electricity production from pure biogas [GWh]	Total heat consumption from biogas [Ktoe]	Potential
Europe	19,419	Micropower 10-50 kW Small - up to 200 kW Medium - power up to 500 kW Large – over 500 kW	102.2	15,712	13,237	80,000	7,000	It is estimated that in the coming years, there will be a tenfold increase in energy obtained from biogas.
Germany	9,909	Micropower 10-50 kW Small - up to 200 kW Medium - power up to 500 kW Large – over 500 kW	14.38	7,631	7,015	31,805	1,650	Germany aims to increase its renewable energy share to 65% by 2030. Biogas and biomethane production are estimated to increase elevenfold to contribute to this target significantly.
Lithuania	38	Medium - power up to 500 kW Large - power up to 1 MW and above in what biogas scale does Lithuania include	1.3	41.8 [Ktoe]	n.d.	158.7	13.5	Increase in biogas capacity by 20-40 MW over the coming years.
Poland	383	Micropower >50 kW Small – < 50kW >1 MW	8.68	288.3	133.4	1,394.2	127.7	The goal is to achieve an installed capacity of 800 MW by 2030.

WIND POWER PLANTS

In 2023, the wind power industry in the European Union experienced a significant increase in energy production, generating a record 475 TWh, a 13% increase from the previous year. This surpassed the energy production from gas (452 TWh) and coal (333 TWh) for the first time. Additionally, 17 GW of wind technologies were installed in the EU in 2022, compared to 16 GW in 2021 [30]. Stationary wind farm technologies are currently at the commercialization stage and are the most advanced. The largest onshore wind farm in Europe is the Fântânele-Cogealac Wind Farm in Romania, with a total capacity of 600 MW. Another notable wind farm is the Whitelee Wind Farm in Scotland, with a total capacity of 539 MW and 215 turbines. However, the capacity achieved was much lower than that expected. EPowerEU's energy strategy assumes that by 2030, the energy obtained from wind should be 420 GW. To

achieve the targets, an increase in capacity of 31 GW per year should be recorded. Because of its underlying objectives, Europe must strengthen and expand its wind energy supply chain [31].

The largest offshore wind farm in Europe is the Atlas Wind Farm, located in UK territorial waters, with 175 turbines providing a total capacity of 630 MW. The second largest offshore wind farm in Europe, located in Dutch territorial waters, is the Gemini Wind Farm, with a total capacity of 600 MW achieved by constructing 150 wind turbines [32]. This year has witnessed the highest-ever annual increase in power obtained from wind technology, indicating impressive growth and development in wind power. However, EU countries must intensify their efforts to meet the targets by 2030. The rate received must be almost double to more than and achieve a value of 30 GW per year.

Denmark, an EU member, leads in the share of wind energy in the national energy mix, which reached 54% of the electricity produced with wind technology in 2022. We anticipate a further increase in 2023, with the share of wind energy reaching 58%. Lithuania is the second-largest producer of wind energy, accounting for 46% of its electricity mix. However, by 2023, Lithuania is expected to fulfill only 44% of its energy needs through domestic production, with the remainder obtained from imports [30]. Lithuania's significant increase in the share of wind energy in its electricity mix results from several strategic actions and initiatives, including the country' s investment, supportive government policies, energy independence goals, EU funding, and public and private sector collaborations. Of the 27 European Union countries, 21 achieved their highest share of wind power in the energy mix in 2022. Lithuania, the Netherlands, Germany, and Belgium posted the most significant annual percentage increase. Germany currently has 61GW of onshore wind power installed from approximately 28,700 turbines. The country' s projection is to reach a total installed capacity of 115 GW by 2030. To achieve this, Germany strives to build about five new turbines daily. The German Offshore Wind Energy Act projects that by 2030, the installed wind offshore power to the grid should be increased to 30GW. To achieve this, areas for future expansion are already being allocated [33,34]. In Poland, for the past ten years, wind power development has been blocked by the Distance Law, which prevented wind farms from being located in more than 99% of Poland's territory [35,36]. In addition, the Polish government did not facilitate the development of wind farms, as it introduced a law on the increased taxation of wind farms and maintained the values of green certificates (support systems for RES generation) at an undervalued level. In 2016, support systems, in the form of green certificates, were changed to auctions. However, these changes did not significantly accelerate the development of wind farms.

Only in 2018, after the liberalization of the 10H rule and the reduction of taxes on units using renewable energy sources, was the intensification of the development of wind farms offered in 2023 [37]. The minimum distance between wind farm locations and buildings is 700 m. However, this is still more than the announced 500 m, unlocking another 47% of onshore wind power expansion potential [38]. Research on a support system for offshore wind energy, which is only now getting a chance to develop, has also been conducted for many years. The Polish power system aims to construct offshore wind farms with a capacity of up to 11 GW by 2040. These will be responsible for nearly 20% of electricity consumption in Poland [39].

Information on accessing renewable energy from wind in Europe, focusing on Germany, Lithuania, and Poland [40]. Table 3

Region	Number of wind plant	Large-scale wind plant	Installed wind power capacity [MW]	Onshore wind energy capacity [MW]	Offshore wind power capacity [GW]	Gross electricity production from wind [TWh]	Electricity consumption (TWh)	Total electricity capacity from wind plant [GW]	Potential
Europe	Offshore (5,402) Baltic Sea (2,219)	Micro - up to 100 W Small - power up to 50kW Large - power above 50kW	257 111,000	201,144	34.0	475.0	2,549	255	Increased capacity from wind power plants to about 25.2 GW (7.7 GW offshore wind and 17.5 GW onshore wind) by the coming years.
Germany	Onshore (28,677) Offshore (1,566)	Micro: 0 – 5 kW Mini: 5 – 30 kW Medium: 30 – 100 kW Large: power above 100 kW	66,206	3,567	8.5	125.29	137.8	91	Increased capacity to 115 GW from onshore wind power and 30 GW from offshore wind power by 2030.
Lithuania	Onshore (226)	Large - power above 50kW	493.0	946	n.d.	1.51	11.19	1.0	The country is planned to see an increased capacity from wind power plants to about 5 GW (1.4 GW offshore wind and 3.6 GW onshore wind) by the coming years.
Poland	Onshore (1,517)	Micro up to 100 W Small – up to 100 kW. Large - above 100 kW.	8,129.5	9307	n.d.	23.2	12.24	9.4	The country plans to increase wind power plant capacity from about 21.3 GW to 26.6 GW (12.7-18 GW onshore and 8.6 GW offshore) by 2030.

PHOTOVOLTAICS

Solar energy, particularly photovoltaic (PV) panels, is currently the fastest-growing renewable energy source in the European Union. In 2023, there was a 37% increase in PV power generation in the electricity mix across Europe (Table 1). Over the past two years, the most significant increase in PV-acquired energy was recorded in 2022 at 48 TWh relative to 2021. A lower increase of only 36 TWh was achieved in 2023 compared with the previous year. The total electricity capacity from solar photovoltaics in Europe is 215,906 GWh, while the annual increase in energy obtained from new PV is currently at 239,000 MW (Table 4) [41]. Due to the growing popularity of photovoltaics in Europe, many countries have significantly reduced their need for gas imports, enhancing their energy security and independence from high-energy prices. Between 2022 and 2023, PV installations saved 15 billion cubic meters of gas, substantially contributing to EU energy security. Additionally, the PV sector generates substantial employment opportunities, providing approximately 650,000 jobs. Residential installations are an essential part of the growth in the installed capacity at the European level. According to the latest survey, residential installations reached more than 40 GW in 2021 and are estimated to exceed 70 GW by 2027. More than 1 million households in Europe have solar batteries [34]. The latest Ember report presented a new ranking of countries that are the current leaders in producing energy obtained from PV in the national energy mix. The first place was Greece, which generated 19% of its electricity from PV. Just behind Greece, Hungary (18%) and Spain (17%). Overall, EU countries achieved a record share of PV in the national electricity mix in 2023. Exceptions were Latvia, Slovakia, and Slovenia. Spain recorded the most significant increase in energy production (9.4 TWh; +26%). On the other hand, Germany had the highest photovoltaic capacity at 14 GW. The country's total photovoltaic capacity is estimated to be approximately 82 GW [24]. The growth of Germany's solar sector can be attributed to the involvement of the private sector and the increase in the capacity of commercial roof-top and ground-mounted installations. To establish 215 GW of installed solar capacity by 2030, an estimated 19 GW of new solar capacity is needed every year in the country [35]. In Poland, energy derived from PV had a difficult start. In 2016, a feed-in tariff system for consumers producing energy from RES came into effect. The schemes and amendments to laws introduced by the government did not encourage investment in micro installations [36]. The development of PV energy in Poland was not observed until mid-2018. At that time, the Czyste Powietrze and Mój Prąd programs only led to realizing subsidies and tax credits. Consequently, larger PV power plants began to be built in Poland [37]. In Poland, the increase in energy production from PV was 3.9 TWh in 2023. This is a 47% increase in the acquired PV energy compared with the previous year [30]. The rapid growth of photovoltaic installations in Poland is due to several factors working

together, such as government support, lower technology costs, increased environmental awareness, favorable financial conditions, and stable legal regulations. The combination of these elements has created ideal conditions for the advancement of photovoltaics. Lithuania has a 50 MW capacity for photovoltaic installations. The solar energy sector is poised for robust growth, supported by strong policy frameworks, technological advancements, and increasing demand for clean energy. This growth aligns with the broader European and global trends in renewable energy expansion, positioning Lithuania as a significant player in the transition to sustainable energy sources. The country could see increased capacity from photovoltaic installations to about 100 MW in the coming years.

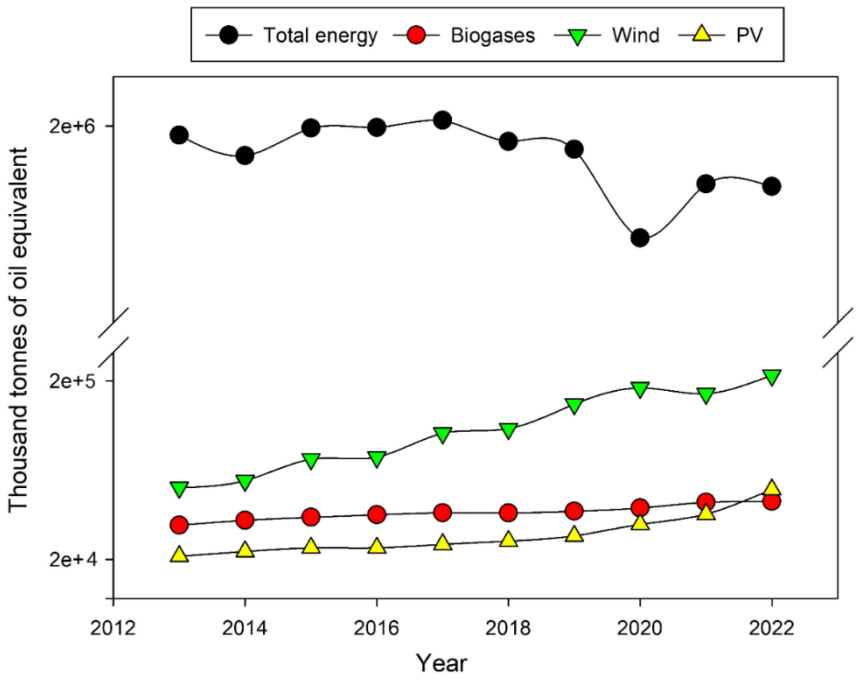
Information on renewable energy from solar in Europe, focusing on Germany, Lithuania, and Poland [41,46]. Table 4

Region	**New installed solar PV [MW]**	**Large-scale wind plant**	**Solar photovoltaic capacity [MW]**	**Power produced from solar photovoltaic [GWh]**	**Electricity generation from solar photovoltaic [TWh]**	**Cumulative solar photovoltaic capacity [MW]**	**Total electricity capacity from solar photovoltaics [GWh]**	**Potential**
Europe	239,000	Micropower up to 50 kW Small - power up to 40 - 500 kW Large - power above 500 kW	288,122	154,722	164	256,911.8	215,906.28	By 2050, it is estimated that the increase in energy obtained from PV will reach 428,535 GWh.
Germany	14,100	Micro - 0-0.6 kW, Small - 0-10 kW, Medium - 10-40 kW, Large - 40-100 kW, very Large > 100 kW,	81,700	61,216	61.2	82,191	NB: need clarification	The country plans to produce 215 GW of solar power by 2030.
Lithuania	1,224	Micropower up to 50 kW Small - power up to 40 - 500 kW Large - power above 500 kW	1200	8,293	0.01	1,165	1	The country could see increased capacity from photovoltaic installations to about 100 MW in the coming years.
Poland	added approximately 4.6 GW of new solar capacity in 2023	Micro: up to 50 kW Small: 51-999 kW Medium: 1-10 MW Large: over 10 MW	4,886.7	11,395.6	13,22	17,057.1	17	Poland is forecast to record high PV growth in the next decade and reach a power level of 30 GW by 2030.

IMPORTANCE OF GREEN ENERGY IN EUROPE

Owing to comprehensive and multidirectional efforts, Europe is visibly increasing the energy development generated from renewable energy sources annually. Using energy obtained from RES has many potential benefits, including reduced dependence on fossil fuel markets (especially oil and gas), reduced greenhouse gas emissions, and diversification of energy supply. The continued development of technologies and the combination of distributed RES sources in an efficient energy system can increase the chances of achieving the goals of the European Green Deal. This ambitious package of measures is a beacon of hope, enabling EU residents and entrepreneurs to reap the benefits of a sustainable green transition. By meeting all targets by 2050, Europe could become the world's first climate-neutral continent.

According to a report by the International Energy Agency (IEA), the global increase in RES capacity in 2023 was 507 GW, a substantial 50 % higher than in 2022. The IEA's analysis suggests that globally, RES capacity will continue to grow over the next five years, with the majority in the PV, wind, and biogas segments. Projections indicate that by 2030, the installed capacity of RES will reach 11,000 GW [47]. This means that RES energy will play a significant role, accounting for more than 42% of global electricity production. Figure 3 demonstrates the total energy production from available sources and RES, including biogas, PV, and wind power. Over the past decade, there has been a noticeable increase in the share of energy obtained from RES relative to all total energy obtained throughout Europe, underscoring the growing importance of RES in global electricity production.



Energy flow in Europe [48]. Figure 3

The "European Biogas Association," biogas and biomethane currently supply approx. The 421 billion m^3 represents 4.6% of the EU demand for gas used in power and heating. Thanks to the constant revisions of the European Green Deal's demands for an energy transition and closed-loop economy, we have seen a steady increase in the use of gaseous biofuels for several years. In 2020, the EU produced 18 bcm of biogas, including three bcm of biomethane. REPowerEU assumes that biomethane production in Europe will reach 35 bcm per year by 2030. It is believed that increased biogas and biomethane production will reduce EU greenhouse gas emissions by up to 15% by 2050. This is particularly important in countries with extensive agricultural sectors. In addition, it is assumed that the obtained biomethane can be injected into the transmission network or converted into bio-CNG or bio-LNG, among other uses for transportation. Implementing biomethane for transportation is a more straightforward solution than grid injection. This is due to the investment costs. This application increases the chances of EU countries to meet the requirements of the RED II directive on second-generation biofuels and biocomponents. Biogas production has a positive impact on agriculture and local communities. The role of substrates in biogas production can be played by municipal waste and waste from the agri-food industry. This approach will facilitate waste disposal and reduce costs. In addition, a by-product of this process is the so-called "post-ferment," which can act as a fertilizer with better parameters than, for example, slurry or manure. The creation of new biogas and biomethane plants in smaller households has a positive impact on the development of rural regions, providing new jobs and access to cheap sources of heat and electricity. An obstacle to the rapid growth of the EU industry is the lack of regulations in many countries. This is especially true for regulating biomethane quality, the legal framework for the financial support of biogas plants, investment in gas grid connections, and land-use guidelines. The lengthy procedures involved in obtaining approval for the construction of plants further hinder the implementation of investment. Germany has the most significant number of biogas and biomethane plants in rural areas. The number of biogas plants in Germany is 9,909, with electricity generation of 33.54 billion kWh. It should be emphasized that biogas and biomethane production in 2023 reached an estimated 91.27 billion KWh [49]. According to data, at the end of 2021, there were 128 biogas installations in Poland, producing 513 million m^3 of agricultural biogas. In 2022, there were almost three times as many; currently, there are 383 biogas plants. They produced 374 million m^3 of biogas and 795.613 GWh of electricity. Agricultural waste accounts for about 88% of all raw materials used for biogas production [50]. These forms of energy are sustainable ways for Lithuania to contribute to the SBS region environment. The study area of western Lithuania' s counties of Klaipėda, Tauragė, and Telšiai has approximately 35,800 farms of an average size of 22 hectares. These study regions have great potential for using organic waste materials in our country by utilizing them, reducing greenhouse gas

emissions, producing valuable renewable energy, and contributing to lower pollution levels for the SBS region. By using renewable sources like wind power plants and photovoltaic installations, these farms can create abundant renewable energy sources without direct emissions, further improving the SBS region. Using renewable energy sources can also position Lithuania as an electricity-exporting country, enhancing its economic prospects. Furthermore, one of Lithuania' s energy-supplying companies already imports biomethane for public use. Soon, the power gained from renewable sources will be used for hydrogen production [51–53].

Over the past two years, many EU countries have seen weakening wind farms and turbine revenues. The slowdown in investment is mainly due to inflation, low investment returns, policies, and permitting shortcomings. Recognizing the situation's urgency, the European Commission proposed a Wind Energy Action Plan outlining 15 actions to strengthen the European wind energy industry. The action plan outlines measures to help finance investments in new factories, infrastructure, and the wind-energy workforce. As part of the revised national energy and climate plans for 2030, EU member states will have to develop 10-year plans for wind energy, including an outlook for the 2040 year. A report conducted by WindEurope forecasts that wind energy production by 2030 in Europe will save 190 billion m^3 per year of fossil fuel imports and reduce the carbon footprint by 262 million CO_2 per year. In addition, wind energy will directly impact Europe's GDP of 49 billion Euros in 2030 and increase employment in the wind energy field to 210,000 people [54]. The EU's Wind Energy Package and the European Wind Charter are crucial in shaping the future of European wind energy development. These measures aim to increase the annual construction of new wind farms, already showing promising results. In the previous year, wind accounted for 19% of all the electricity produced in Europe, which is expected to rise with the implementation of these initiatives. Wind energy development takes place in two primary directions: onshore and offshore. Wind farms with smaller capacities are usually located on land and often have single turbines that generate enough electricity for one household. Offshore wind energy is an innovative solution for building wind farms in open waters beyond the coastline. According to data published by Wind Europe in 2018, the onshore turbines with the highest capacities are installed in Norway, with an average of 3.6 MW, while the lowest capacities, at 2 MW, were installed in Greece and Lithuania. The average capacity for all of Europe is 2.7 MW [55]. The average for all of Europe is 2.7 MW. Germany leads in wind power capacity in Europe, with approximately 50 GW capacity and 5 GW capacities coming from offshore and onshore wind energy plants, respectively. The electricity generation from offshore wind farms is 88 TWh, and 18

Germany has the most significant number of biogas and biomethane plants in rural areas

TWh from onshore wind farms, translating to 13% of electricity generation from wind power into the grid [56]. Currently, the total amount of energy produced from wind farms in Poland is 9.4 GW, and in Lithuania, 0.94 GW.

A last report by Solar Power Europe showed that solar power in Europe has seen phenomenal growth, owing to an increase in the number of photovoltaic installations in EU member states. In 2022, the power obtained from solar farms was recorded at 41.1 GW. This implies a 50% increase in the energy from photovoltaic panels was achieved. Currently, the energy obtained from photovoltaic panels accounts for approximately 5% of the electricity consumed by the EU. The obtained power quantities are sufficient to power 12.4 million European homes. Experts assume that the current rate of development of the photovoltaic market in the EU is likely to more than double in the next four years, thus reaching 484 GW of capacity. Despite its many successes and the prospect of rapid growth, solar energy faces several challenges that could hinder its current development. To ensure continued growth and cost-effectiveness, special attention must be focused on the efficiency of grid interconnections and the processes involved in comprehensive policy reform that consider lowering the cost of capital for green investments. The European Commission particularly emphasizes developing rooftop solar PV [57].

In 2023, 18 EU member states experienced a record amount of solar power generation. The Netherlands recorded the largest share in the national energy mix (22.7%), where solar energy was the second largest source of electricity. Such a high share was achieved owing to consistent government policies and a successive increase in photovoltaic installations. A sizable share of solar energy was also recorded in countries such as Germany (19.3%) and Spain (16.7%). In 2023, Germany recorded the highest share of electricity generation of about 14 GW from solar, which surpassed the target set by the German government' s statutory climate protection. This surge was achieved due to the increase in the number of solar PV installations in the country [58]. However, growth dynamics and the undisputed record belongs to Poland, which increased its share of solar energy in the national energy mix by as much as 26 times, with an increase of 8.1%. However, in Lithuania, solar energy contributes only to 1.6 % of national energy.

Policy and Regulations

An overview of current laws and regulations and the impact of European Union directives on bioenergy development in Europe (Poland, Lithuania, and Germany).

The first EU renewable development target was established during the Kyoto Protocol negotiations in 1997 [59], setting non-binding goals, financial support, and reporting tools. This initial target aimed for a 12% share of RES in gross energy consumption. In 2007, the EU countries took a significant step forward in their commitment to renewable energy by implementing the climate and

energy package. With a mandatory 2020 target, this package marked the introduction of the Directive on the Promotion of the Production and Use of Energy from Renewable Sources (RED). The RED set a goal of 20% RES share in gross final energy consumption by 2020, a goal that was surpassed at 22% [60,61]. In 2018, another mandatory target was set for EU member states to achieve 32% of the energy from RES in final consumption by 2030. The target sets were enshrined in the revised RED II Directive. However, given the upcoming challenges, it became apparent quickly that the target set was insufficient. Therefore, long-term targets were adopted in 2019, which assumes that Europe will achieve climate neutrality by 2050 as part of the so-called Green Deal. The proposed target gained legal force in 2021 [62]. The European Commission has proposed that RES account for 40% of the energy used by 2030. The Green Deal, or Fit for 55 packages, addressed the goal of reducing carbon footprint emissions by 55% relative to 1990. However, the EU experienced an energy crisis in 2019, caused first by the COVID-19 pandemic and then by the Russian-Ukrainian conflict. Among other things, the crisis caused the energy prices to rise. The dynamics of the price increase forced governments to intervene and seek savings in energy consumption and investments to support energy extraction from RES. The European Commission's response became the REPowerEU package, the main goal of which was to increase the use of RES to 45% by 2030 [63].

The EU adopted a binding target of 42.5% RES for 2030 as part of the third amendment to the RED III Directive. An aspirational target of 45% was adopted as part of a political compromise between the EU Council and the European Parliament. It is intended to mobilize member states to develop renewables even faster. Approval procedures for wind and solar energy are to be accelerated and simplified, while more stringent biomass use requirements are expected for biogas/biomethane. A vital role in this issue is to prevent the loss of biodiversity. The RED II and RED III directives indicate the necessity of using biomass as an RES, with the restrictions introduced in the latter applying mainly to forest biomass. In contrast, Agro biomass only suggests minimizing the use of food and feed crops for energy purposes, regardless of whether they are produced in the EU or imported. The proposed legislation requires EU countries to develop national support schemes based on the principle of cascading biomass use, according to which woody biomass is used according to its most significant economic and environmental value. It should be emphasized that, contrary to the claims propagated by opponents of energy biomass, there are no obstacles to the widespread use of Agro biomass as a RES for electricity and heating.

From a technological point of view, biomass is crucial because it can replace coal, even in existing boiler infrastructures. However, the specific conditions for the cultivation and use of biomass set by the directives should be implemented by the authorities of each country, considering its specificities. While the Directive emphasizes the role of biogas in the shift away from fossil fuels, mainly in the

transportation sector, the changes introduced may hinder their development. According to the amendment, biogas plants with a rated thermal capacity of more than 2 MW put into operation after 2011 will have to demonstrate an 80% reduction in greenhouse gas emissions. Adhering to the new law may be challenging for many EU countries, given that most biogas plants were built after 2012. That's why upgrading plants is often impossible or unprofitable. To meet the 80% requirement, some biogas plants would have to switch to substrates with higher GHG reductions in the short term, which is often not feasible or difficult for technical reasons, highlighting the complexity of this issue [64]. The REPowerEU plan has launched a strategy to double the capacity of solar PV systems to 320 GW by 2025 and install 600 GW of systems by 2030. The plan includes gradually introducing a legal obligation to install solar panels on new public, commercial, and residential buildings and a strategy to limit the use of heat pumps in local and municipal heating systems. The plan commits EU countries to identify and adopt plans for specific target areas for energy from renewable sources, with shorter and simplified permitting procedures. The revised Renewable Energy Directive sets out procedures for the rapid authorization of the installation of solar energy equipment [64]. On 19 November 2020, the Commission published the EU Strategy for Marine Renewable Energy. This strategy aims to increase electricity production from offshore renewable sources in the EU from 12 GW in 2020 to over 60 GW by 2030 and 300 GW by 2050. The TEN-E regulation, which entered into force in June 2022, introduced agreements on deploying marine renewable energy sources. In January 2023, EU countries agreed to higher non-binding targets for energy production from marine renewable sources of 111 GW and 317 GW by 2030 and 2050, respectively [65].

Long-term targets were adopted in 2019, which assumes that Europe will achieve climate neutrality by 2050 as part of the so-called Green Deal

Investment and Financing

Investment analysis, sources of funding, public support, and private investment in Europe and individual countries

As part of its efforts to achieve carbon neutrality by 2050, the EU has introduced further requirements to reduce emissions in construction and transport. The new rules are designed to encourage Europeans and businesses to invest in alternative energy sources, ensuring a future reduction in greenhouse gas emissions. To ensure that the energy transition is fair and inclusive, the European Commission has proposed the creation of a Social Climate Fund. The fund aims to provide a just climate transition. The fund seeks to reduce the economy's emission intensity, i.e., it assumes a just transformation towards an environmentally friendly and circular economy. The second goal of the fund is to ensure the construction of an effective and resilient transport system with the lowest possible negative impact on the natural environment and to improve transport safety. In addition, the fund aims to ensure equal access to healthcare, improve the healthcare system's resilience, and strengthen culture's role in social and economic development. The subsidies are divided into five categories. A significant portion, amounting to EUR 2.4 billion, will be allocated to "general decarbonization" projects that are large-scale (with investment expenditure exceeding €100 million), medium-scale (€20-100 million), or small-scale (€2.5-20 million).

Policy and Regulations for European Union countries. Table 5

Law/Regulation	Europe	Germany	Lithuania	Poland	Ref.
	BIOMETHANE				
REPowerEU Plan	It aims to achieve 35 bcm per year of biomethane by 2030.	Renewable Energy Law (EEG): This act supports the usage of biomethane for electricity generation. It aims to provide several incentives, including technology and gas upgrading bonuses.	The REPowerEU measures include one reform and three investments. The reform will facilitate the issuance of permits for renewable energy development. At the same time, the investments will accelerate the renovation of private buildings by financially supporting households, including through fully covered technical assistance expenses. New investments will also cover loans provided to businesses and public entities to increase solar or wind electricity generation capacity. Support for purchasing clean-energy boats will allow climate-friendly cargo transport between the Kaunas riverport and the Klaipėda seaport.	- Poland's Energy Policy until 2040 (PEP2040) - PEP2040 repeatedly refers to the use of biogas and biomethane as an alternative to natural gas (diversification of natural gas supplies and gasification of the so-called white spots) - Act on RES (Renewable Energy Sources) - the RES Act amends the system regulation to enable the injection of biomethane into the gas network; in addition, new regulations provide support for biomethane production	[66,67]
Staff Working Document	It aims to expand biogas production to a sustainable volume that can be upgraded into biomethane and promote biomethane production from waste and residues.	Renewable Energy Heat Act: This act backs the usage of biomethane in the heat generation market.	Lithuania has adopted policies that encourage the development of renewable energy sources, including biogas. This aligns with the broader EU directives promoting renewable energy and reducing greenhouse gas emissions. The government offers financial incentives such as feed-in tariffs and subsidies to support the construction and operation of biogas plants. These measures are designed to make biogas production economically viable and attractive to investors.	- Act on renewable energy - *Act of 20/02/2015 (Journal of Laws 2015, item 478, as amended) - defines the rules for supporting the production of energy from renewable energy sources, including biomethane and biogas *auction system - a system enabling producers to obtain financial support for the development of installations Energy Law—The Act of April 10, 1997 (Journal of Laws 1997, No. 54, item 348, as amended) regulates the principles of operation of the energy market, including issues related to the production, transmission, and distribution of renewable energy. -PEP2040 – contains a strategy for the development of the energy sector with an emphasis on renewable energy sources (including biomethane) - National Energy and Climate Plan for 2021-2030 (NECP) – specifies goals and actions aimed at developing renewable energy sources (including biomethane and biogas) - Rural Development Program (RDP) - supports investments in the development of biogas infrastructure -Modernization Fund – supports initiatives related to the modernization of biogas infrastructure	[67,68]

Waste Framework Directive (2008/98/EC)	The directive aims to require EU countries to collect organic waste separately. This would allow for the scaling up of sustainable biomethane production and create income opportunities for farmers and foresters.	Federal Pollution Control Act: This act ensures the application of biomethane in the transportation sector.	Lithuania promotes waste prevention through public awareness campaigns and incentives for businesses to adopt sustainable practices. Producers are responsible for the entire lifecycle of their products, including take-back schemes for specific waste streams such as packaging, electronics, and batteries. Lithuania has implemented separate collection systems for different types of waste, including household waste, bio waste, and hazardous waste. This facilitates higher recycling rates and better-quality recyclables. **National Waste Management Plan:** Lithuania develops and updates its National Waste Management Plan, which outlines the strategy and actions for achieving waste management goals, including prevention, recycling, and disposal.	- Act on packaging and packaging waste management of 13/06/2013 (Journal of Laws 2013, item 888) - promotes recycling and production of biogas from waste - Waste Act of December 14, 2012 – regulates the principles of waste management, including selective waste collection - Act on maintaining cleanliness and order in municipalities of September 13, 1996 – imposes on municipalities the obligation to selectively collect waste and provide residents with access to it - Regulation of the Minister of Climate and Environment on the detailed method of selective collection of selected waste fractions of December 29, 2020 – defines the rules for the collection of bio-waste and their subsequent use in the production of biomethane - National Waste Management Plan 2022 (NWMP 2022) - promotes selective collection of bio-waste and development of biogas infrastructure (including installations)	[67,69]
Biomethane Industrial Partnership (BIP)	It aims to support the achievement of the EU' s 2030 target of 35 bcm annual production and use of sustainable biomethane and to create the conditions for a further ramp-up of its potential by 2050.	Regulatory framework on imported biomethane: This regulatory framework ensures that imported bioenergy into the country is used solely for heating purposes.	**National Renewable Energy Action Plan (NREAP):** Lithuania has integrated biomethane development into its NREAP, which outlines the country' s strategies and targets for renewable energy adoption. This plan supports the objectives of the BIP by prioritizing biomethane as a key component of the renewable energy mix. Lithuania is investing in biogas upgrading technologies to convert biogas into biomethane. Several projects have been initiated to establish biogas upgrading facilities, enhancing the capacity to produce biomethane that meets natural gas quality standards.	- Polish Energy Policy until 2040 (PEP2040) - sets the directions for the development and production of biomethane, assumes the development of infrastructure for production and its integration with the national energy system -Renewable Energy Act of February 20, 2015 – defines support mechanisms for biomethane production, provides for certificate systems and support for biomethane producers -energy law section From April 10, 1997 – regulates issues related to the transmission and distribution of biomethane, supports the development of infrastructure and its integration with the national gas system - National Energy and Climate Plan for 2021-2030 (NECP) – financial support for investments, promotion of research and innovative solutions	[67]

WIND POWER					
European wind power action plan (COM/2023/669)	The goal is to obtain a capacity of 37 GW/year to meet the EU goals for 2030.	Renewable Energy Sources Act (EEG): This act will ensure that the 2030 target for wind power is achieved.	Lithuania has set ambitious renewable energy targets in line with EU directives. The country aims to increase the share of wind energy in its energy mix as part of its commitment to the European Green Deal and the Renewable Energy Directive (RED II). **National Energy and Climate Plan (NECP):** The NECP outlines Lithuania' s strategies and measures to achieve its renewable energy targets. This plan includes specific actions to promote wind power development, streamline permitting processes, and integrate wind energy into the national grid.	- Poland's Energy Policy until 2040 (PEP2040) - assumes the development of both onshore and offshore wind farms, defines the goals and directions of wind energy development - Act on Renewable Energy Sources (RES) – dated February 20, 2020 – supports the development of new wind installations and the modernization of existing ones - Act on promoting electricity generation in offshore wind farms, Act of December 17, 2020 – regulates issues related to the construction and operation of offshore wind farms, supports wind energy - Energy Law Act of April 10, 1997 – regulates the operation, transmission, and distribution of energy from wind farms - National Energy and Climate Plan for 2021-2030 (NECP) - the plan assumes a significant increase in power both on land and at sea	[70]
Communication on delivering on the EU offshore renewable energy ambitions (COM/2023/668)	It aims for EU Member States to achieve 111 GW of marine renewable energy by 2030, almost twice the ambition set by the European Commission in the EU Strategy on Marine Renewable Energy (COM(2020)741) in November 2020.	Offshore Wind Energy Act (WindSeeG): The German Offshore Wind Energy Act projects that by 2030, the installed wind offshore power to the grid should be increased to 30 GW and 70 GW by 2045.	**National Energy and Climate Plan (NECP):** Lithuania's NECP includes specific targets and measures for offshore renewable energy. This plan outlines the country's commitment to developing offshore wind and other marine renewable energy sources as part of its broader renewable energy strategy. **Maritime Spatial Planning (MSP):** Lithuania has developed a maritime spatial plan that designates specific zones for offshore renewable energy projects. This plan helps optimize marine space use and minimize conflicts with other maritime activities.	- Act on promoting electricity generation in offshore wind farms of December 17, 2020 - introduces a support system for offshore wind energy, which aims to accelerate the development of this technology - Polish Energy Policy until 2040 (PEP2040) - assumes the construction of offshore wind farms with a total installed capacity of approximately 11 GW by 2040 (a significant part of the capacity is planned for 2030) - National Energy and Climate Plan for 2021-2030 (NECP) - the plan contains specific commitments and actions to contribute to the achievement of EU goals - Energy Law Section Of April 10, 1997 – supports the development of transmission infrastructure for the integration of wind farms with the energy system - Strategy for the development of offshore wind energy in the Baltic Sea - provides support for investments and administrative processes and, consequently, a significantly increased increase in installed capacity in the Baltic Sea	[71,72]

An EU Strategy to harness the potential of offshore renewable energy for a climate neutral future	It aims to call on the EU and its member states to increase energy production from marine renewable sources and extend its scope to all European sea basins. The European Commission assumed that offshore wind farms' total production capacity may reach approximately 300 GW by 2050. Additionally, the strategy considers that offshore wind farms' production capacity can be supplemented with approximately 40 GW of ocean energy (tidal, wave) and energy generated by other emerging marine technologies (e.g., floating wind farms and solar energy, algae for biofuels).	Onshore Wind Energy Act: This act sets binding area targets for developing the country' s wind power plants. For instance, a total of 2% of the country' s land area has to be demarcated for the building of wind power plants in 2032.	**National Energy and Climate Plan (NECP):** Lithuania's NECP is aligned with the EU's strategy. It sets national targets for offshore renewable energy and outlines the measures needed to achieve them. The plan integrates offshore wind energy as a critical component of the country's renewable energy mix. **Maritime Spatial Planning (MSP):** Lithuania has developed a maritime spatial plan that designates suitable areas for offshore renewable energy projects, ensuring efficient use of marine space and minimizing conflicts with other maritime activities.	-Polish Energy Policy until 2040 (PEP2040) - the document assumes support for research and development of new technologies related to the production of energy from marine renewable sources - Act on Renewable Energy Sources (RES) of February 20, 2020 – provides for support systems and green certificate systems to be used in new technologies - Energy Law Section Of April 10, 1997 – supports the development of transmission infrastructure for the integration of energy from marine renewable sources with the energy system -Infrastructure and Environment Operational Program (IEOP) - the program finances research projects and the development of innovative methods of obtaining energy from marine renewable sources The National Fund for Environmental Protection and Water Management (NFEPWM) finances pilot and demonstration projects that influence energy development from tides, waves, algae, etc. -Strategy for Responsible Development (SOR) – supports innovation and the development of new technologies, including obtaining energy from marine renewable sources	[73,74]
Blue Energy Action is needed to deliver on the potential of ocean energy in European seas and oceans by 2020 and beyond the COM/2014/08 final.	The strategy provides the opportunity to generate economic growth and create jobs, increase the security of energy supplies, and improve competitiveness through technological innovation. Additionally, its activities refer to the communication on offshore wind energy and the Europe 2020 strategy. The strategy aims to help unlock wind energy's potential.		**National Energy and Climate Plan (NECP):** Lithuania' s NECP incorporates the goals of the Blue Energy Action, setting targets for the development of ocean energy alongside other renewable energy sources. The plan aligns with EU objectives to diversify renewable energy sources and reduce greenhouse gas emissions. **Maritime Spatial Planning (MSP):** Lithuania has developed maritime spatial planning that includes designated zones for developing ocean energy projects. This planning helps to ensure the optimal use of marine space while minimizing conflicts with other activities such as shipping and fishing.	- Polish Energy Policy until 2040 (PEP2040) - Act on Renewable Energy Sources (RES) - Act on promoting electricity generation in offshore wind farms - Energy law - National Energy and Climate Plan for 2021-2030 (NECP) – (as above) -Operational Program Infrastructure and Environment (OPIE) - National Fund for Environmental Protection and Water Management (NFEPWM) - Strategy for Responsible Development (SOR) Each of these plans/acts/funds supports development, infrastructure, research projects, innovations, financial support, etc., which affects economic development and increases the number of jobs.	[75]

SOLAR POWER					
EU Solar Energy Strategy COM/2022/221 final	The strategy aims to install over 320 GW of solar photovoltaic capacity by 2025 and almost 600 GW by 2030.	Renewable Energy Act (EEG): This act aims to achieve 215 GW of solar power by 2030.	**National Energy and Climate Plan (NECP):** Lithuania's NECP sets specific targets for increasing solar energy capacity as part of its overall renewable energy mix. The plan outlines various measures and policies to support the deployment of solar technologies. Lithuania collaborates with neighboring countries and regional organizations to share best practices, harmonize regulations, and develop joint projects to promote solar energy deployment.	- Polish Energy Policy until 2040 (PEP2040) – supports the development of photovoltaic technologies, but their goals are more realistic and adapted to national possibilities - Act on Renewable Energy Sources (RES) - supports photovoltaic investments, which contributes to increasing the installed capacity - "My Electricity" program - supports the installation of photovoltaics for households - National Energy and Climate Plan for 2021-2030 (NECP) - provides financial support for the development of photovoltaics - Energy law – supports the development of transmission infrastructure - Solar Energy Plan - assumes an increase in installed capacity - Act on electromobility and alternative fuels - supports the integration of photovoltaics with the transport system - Strategy for Responsible Development (SOR) – promotes investments in photovoltaics - Local development plans - regulate the location of photovoltaic installations - Polish Solar Energy Association (PSES) - promotes the development of solar energy in Poland	[76]
Renewable Energy Directive (EU/2023/2413)	The EU solar energy strategy launched the European Solar Rooftops Initiative, the EU large-scale skills partnership, and the EU Solar PV Industry Alliance.	Zero VAT Rate: With this initiative by the government, private sectors involved in solar services will no longer pay for VAT on purchases and installations of PV systems.	Lithuania has updated its national targets for renewable energy to align with the new directive, aiming for a significant increase in the share of renewables in its energy consumption by 2030. **National Energy and Climate Plan (NECP):** Lithuania' s NECP reflects the new targets and includes specific measures and policies to achieve them. The plan outlines sectoral targets for electricity, heating and cooling, and transport. Lithuania has amended its national legislation to incorporate the requirements of the Renewable Energy Directive. This includes laws supporting renewable energy deployment, simplifying permitting procedures, and ensuring grid access for renewable energy producers.	- Act on Renewable Energy Sources (RES) - National Energy and Climate Plan for 2021-2030 (NECP) - Energy Efficiency Act - supports renewable energy goals - Energy law	[77]

European Solar Charter	The Charter marks the latest step in the Commission' s European solar panel manufacturing support.	SolarPLUS: This government initiative aims to increase the expansion of photovoltaics in Berlin.	The Lithuanian government is encouraging innovative forms of solar energy deployment, including agri-PV (solar panels combined with agriculture), floating solar installations, and building-integrated photovoltaics (BIPV). These innovative deployments are supported by the removal of regulatory and permitting barriers and the adaptation of public support schemes	Poland has no special laws or acts dedicated exclusively to implementing the European Solar Charter. Instead, Polish regulations include a broader legal framework supporting the development of solar energy (see above)	[78]
European Solar PV Industry Alliance (ESIA)	The strategy aims to achieve 30 GW of PV production capacity along the value chain by 2030.	Balcony power plants: This ensures that solar PV installations on balconies or in gardens do not exceed 800 W.	Lithuania is focusing on establishing new manufacturing facilities and expanding existing ones to increase its PV production capacity. This involves creating a favorable business environment through regulatory support and incentives for local and foreign investments in the solar sector	Poland does not directly implement the provisions of ESIA; however, the general assumptions regarding photovoltaics are in line with its goals and objectives (see above).	[79]
Net-Zero Industry Act (NZIA)	The strategy aims to ensure the Union' s overall strategic net-zero technologies manufacturing capacity, including solar PV, approaches or reaches at least 40% of the annual deployment needs by 2030.	Solarstrombonus: This is a government subsidy for solar power producers to generate electricity from solar energy.	Lithuania is focused on expanding its solar PV manufacturing capacity to contribute to the EU's net-zero goals. This includes attracting investments for new manufacturing plants and scaling up existing facilities to increase the production of solar panels and related components	No act or law in Poland directly implements the idea of NZIA; however, the main objectives of this act are implemented by several legal acts and regulations that support the industry's transformation towards sustainable development and a net zero industry (see above).	[80]

Around €1.4 billion will be allocated to clean technology production projects focusing on producing components for renewable energy, energy storage, heat pumps, and hydrogen production, with a minimum investment of €2.5 million. Another EUR 200 million will be allocated to pilot projects with an investment outlay of over EUR 2.5 million, focusing on "deep decarbonization". The innovation fund can cover up to 60% of project costs. A separate program worth EUR 800 million, in the form of an auction, will aim to increase renewable hydrogen production. Table 6 provides an overview of financing options under the 2021-2027 Multiannual Financial Framework and NextGenerationEU, taking into account only programs for energy production from renewable energy sources (RES), including wind energy, photovoltaics, biomass energy production, and biomethane production along with energy storage and grid connection infrastructure.

The European Commission increasingly focuses on developing rural areas with the greatest potential for renewable energy sources. Estimating the exact potential of villages is challenging due to the constantly changing activity and diverse resources available. Financial support for rural areas can be provided through grants or loans, and it's not limited to just farmers. Energy cooperatives can also apply for support. For photovoltaic installations or wind turbines, applying for a loan covering up to 100% of eligible costs is possible. A subsidy of up to 65% of eligible costs is available for biogas plants.

Lithuania receives substantial funding from European institutions to boost its renewable energy infrastructure. For instance, the European Investment Bank (EIB) has provided a €105 million loan to Ignitis Group to expand the Kruonis Pumped Storage Hydroelectric Power Plant. This project aims to enhance grid flexibility and support Lithuania's goal of meeting 100% of its electricity demand from renewable sources by 2030 [81]. Private companies are also investing heavily in renewable energy. AB Achema, the largest fertilizer producer in the Baltics, is purchasing all the electricity generated by the new Pagėgiai wind farm to produce green hydrogen and green ammonia, reducing its CO_2 emissions significantly [82]. Lithuania's government is committed to accelerating the transition to renewable energy. The Ministry of Energy has outlined strategies to promote clean energy technologies, including hydrogen, offshore wind, and battery storage systems. Moreover, Lithuania's net metering system encourages distributed energy generation, particularly solar power, by allowing consumers to offset their electricity bills with the energy they produce. There is a strong focus on improving energy efficiency across various sectors. The IEA has recommended that Lithuania prioritize energy efficiency by implementing stringent performance standards and reforming energy taxation to curb rising energy consumption [83]. The Renewable Energy Sources Act (2017) clearly states how funds are released to expand renewable energy projects in Germany. This Act is the sole responsibility of Bundesnetzagentur to determine the limit of funds that go to operators. The rates determined by auction are allowed to be bid by operators in the solar, biogas, and wind

energy sectors. It should be emphasized that the lowest bidder wins [84]. Germany also receives funding from the European Union to expand the RE sector. For example, investments from the European Investment Bank (EIB) in Germany' s RE sector increased from 6.6 billion Euros in 2022 to 8.6 billion Euros in 2023 [85]. In other jurisdictions, the European Union approved a financing scheme worth 3 bn Euros submitted by Germany to support private partners investing in strategic goods needed for transition into a net-zero economy [86].

In Poland, investments in biomass primarily include the modernization of existing installations and the construction of new biomass processing plants. In Poland, biomass is mainly used in heating and producing electricity1. When it comes to the use of solar energy in Poland, its dynamic development is observed. The photovoltaic sector is developing regarding installations on building roofs and large solar farms. Investments include both small prosumer installations and large commercial projects. Regarding investments in wind energy, its development is focused on constructing new wind farms, both onshore and offshore. Poland plans to develop significant offshore wind energy associated with large investment outlays. Currently, the main sources of financing for using RES are bank loans, which enable various forms of financing, including loans for implementing projects related to renewable energy sources. Sustainable loans and green financing are becoming increasingly popular. Other forms of financing include EU funds. Poland is using the Cohesion Fund and the National Recovery Plan (KPO), which support investments in green energy. Other sources of financing include international financial institutions such as the European Bank for Reconstruction and Development (EBRD), the International Finance Corporation (IFC), and the European Investment Bank (EIB), which offer financial support for projects related to renewable energy sources. In 2004-2027, EU funding for projects related to generating electricity from renewable energy sources may amount to PLN 20.1 billion. The largest share is held by planned projects related to the construction of offshore wind farms - PLN 14.5 billion. Contracted funding for PV projects amounts to PLN 3.18 billion, onshore wind farms - PLN 1.9 billion, and biogas plants - PLN 0.54 billion [87].

Investment and financing for European Union countries. Table 6

Fund	Europe	Germany	Lithuania	Poland	Ref.
Horizon Europe	It aims to promote excellence and provide valuable support to the best scientists and innovators, thereby driving the systemic changes needed to ensure a green, healthy, and resilient Europe.	KFW (Reconstruction Credit Institute) aims to finance renewable energy development, such as solar and wind.	Horizon Europe in Lithuania is structured around three pillars with different clusters and a series of cross-disciplinary initiatives. Pillar 1, "Excellence Science," consists of the European Research Council (ERC), Marie Skłodowska-Curie Actions (MCSA), and Research Infrastructures. Pillar 2, "Global Challenges and European Industrial Competitiveness," consists of six thematic clusters supporting transnational consortia through strategic work programs and calls. Pillar 3 comprises a new independent organization, the European Innovation Council, European Innovation Ecosystems, and the European Institute of Innovation and Technology. It will also cover the program's Widening Participation and Strengthening the European Research Area part and relevant activities in other pillars.	AgEnergy Platform - facilitating the dissemination of valuable information that will enable broader adoption of fossil fuel-free strategies and technologies (FEFTS) IDEAL4GREEN Building decentralized, DistributEd, And Local micro-GRids for decarbonization Electrification challenge The IDEAL4GREEN project addresses the urgent challenges of climate change and the global shift towards sustainable energy systems. It focuses on developing and integrating microgrids, which are crucial in managing the variability of renewable resources and achieving Training Wind Energy Experts on Digitalisation Training Wind Energy Experts on Digitalisation (TWEED) Doctoral Network (DN) aims to train the next generation of excellent researchers equipped with a full set of technical and complementary skills to develop high-impact careers in wind energy digitalization.	[88–90]
InvestEU Fund	It aims to promote green and digital transitions, enhance resilience, and strengthen strategic value chains.	Renewable Energy Act: In Germany, the Renewable Energy Sources Act (2017) clearly outlines how funds are released to expand renewable energy projects. Even in this Act, Bundesnetzagentur is solely responsible for determining the limit of funds that go to operators. Operators in the solar, biogas, and wind energy sectors can bid on the rates determined by auction. It should be emphasized that the lowest bidder wins.	InvestEU has been launched in Lithuania. It mobilizes investment across key sectors through various financial instruments and advisory services. The program, managed by the European Investment Bank (EIB) Group and other financial partners, aims to align with EU priorities such as the European Green Deal and digital transition.	EU Sustainable Infrastructure Lending Envelope This Framework Operation will support corporate investments across the EU Member States to address the transition towards a more sustainable economy. The sub-projects are related to the development of the energy sector, according to Energy Union priorities, the development of sustainable and safe transport infrastructures and mobility solutions, and the environment and resources.	[84,91,92]

				Green-Capped Guarantee Framework The Framework Operation will comprise capped unfunded portfolio guarantees to private commercial Financial Intermediaries in 12 Member States. It will target sustainable investments across all sectors under the EU Compartment of InvestEU, contributing to energy savings and CO2 emission reductions. White Summit Capital Infrastructure Decarbonisation Fund II (Multi-Country) The Fund's investment strategy comprises mostly greenfield investment across different sectors with the aim to contribute to the decarbonisation of assets. In particular, the Fund will seek investments in the areas of renewables integration	
Connecting Europe Facility (CEF)	It aims to promote the EU's policy on linking the energy infrastructure of EU countries (TEN-E policy) and on establishing standard rules and targets for the development of renewable energy across all sectors of the economy (Renewable Energy Directive)	Federal Office of Economic Affairs and Export Control (BAFA): BAFA's focus has been promoting the integration of renewable energies in the building sector.	Lithuania's Connecting Europe Facility (CEF) supports investment in critical transport, digital, and energy infrastructure projects. It was divided into three categories: CEF Energy, CEF Transport, CEF Telecom	LEM project - pilot implementation of electromobility along the roads of the TEN-T core network (CEF project no. 2016-PL-TM-0281-S) Research optimizing the operation and location of alternative fuel stations of the TEN-T core network (CEF project no. 2014-PL-TMC-0220-S)	[93–95]
European Regional Development Fund (ERDF)	It aims to promote correcting imbalances between regions, enabling investments in a more intelligent, greener, more connected, and more social Europe.	The federal states of Germany are responsible for implementing this fund which seeks to promote economic, terrestrial, and social cohesion among the EU countries. Germany receives 11 billion euros from ERDF in the current programming period	The European Regional Development Fund (ERDF) in Lithuania for the 2021-2027 period aims to invest significantly in various sectors to enhance the country's economic and social well-being. Initiatives implemented focus on promoting competitiveness, transitioning to a green economy, improving digital connectivity, enhancing social inclusion, and supporting sustainable mobility. Key priorities include innovations, green transitions, and strengthening human capital, with substantial	Currently, 2267 projects are being implemented in programming 21-27, including: Purchase of zero-emission rolling stock –ŚLĄSKIE VOIVODESHIP, RES loans in Western Pomerania, Loans to support RES in the Podkarpackie Voivodeship, Financial instruments in the environmental area - Bank Gospodarstwa Krajowego - loans will finance investments supporting energy efficiency and reduction of greenhouse gas emissions as well as renewable energy, Development of renewable energy (RES) - Financial Instruments - Bank Gospodarstwa Krajowego, financial instruments for the development of Warmia and Mazury - Renewable energy sources,	[96,97]

			funds directed toward regional development and local initiatives across Lithuania. The program emphasizes partnership with social and economic stakeholders to ensure strategic investment and effective implementation aligned with EU cohesion policy objectives.		
Cohesion Fund (CF)	It aims to promote the Cohesion Fund and support investments in environmental and trans-European networks in transport infrastructure (TEN-T).	Germany received 20 billion euros in 2022 from the Cohesion fund for the period 2021 – 2027 to support in promoting economic, social, and terrestrial cohesion in line with key EU policies such as green and digital transition.	The Cohesion Fund and other EU funds support economic, social, and territorial cohesion initiatives. Key priorities include advancing the green and digital transitions, improving energy efficiency, increasing renewable energy usage, and enhancing innovation through digital technologies. Significant allocations are directed towards social cohesion measures, such as improving access to education and social services, and supporting sustainable urban and rural development. The Partnership Agreement underscores Lithuania's commitment to leveraging EU funds to address regional disparities, foster inclusive growth, and strengthen resilience in the face of economic and environmental challenges.	Currently, 30 projects are being implemented in programming 21-27, including the priority program "Clean Air", which involves replacing ineffective heat sources with solid fuels and improving the energy efficiency of single-family residential buildings.	[97,98]
Recovery Assistance for Cohesion and the Territories of Europe (REACT-EU)	This funding is entirely new: it is a top-up to 2014-2020 programs and an addition to the cohesion allocations for 2021-2027. The funding fosters crisis repair capacities in the context of the coronavirus crisis and investments in operations that contribute to preparing a green, digital, and resilient recovery of the economy.	Germany was supported with over 2.3 billion euros in current prices from the REACT-EU fund. This was given with the aim to provide supporting measures under the European Regional Development Fund (ERDF) and the European Social Fund (ESF). The REACT-EU funded several projects in 15 Federal states of Germany and was implemented by both the Federal Ministry of Labour and Social Affairs together with the	Renewable Energy and Energy Efficiency: Significant funding has been allocated to projects to increase the use of renewable energy sources and improve energy efficiency in buildings. This includes support for installing solar panels, modernization of heating systems, and retrofitting buildings to reduce energy consumption. Digital Infrastructure: Funding is provided for expanding high-speed	Support for investments in renewable energy sources will consist of co-financing the My Electricity Priority Program, implemented in the grant project formula. The beneficiary of the project - the National Fund for Environmental Protection and Water Management - will provide grants - to natural persons - for a photovoltaic installation producing electricity for the needs of single-family houses. The entity responsible for the project's recruitment, evaluation, and settlement will be the	[99,100]

		Federal Ministry of Economic Affairs and Climate Protection.	internet access, especially in rural and underserved areas. This aims to bridge the digital divide and ensure equitable access to digital services and opportunities. Energy Efficiency in Schools and Hospitals: Projects aimed at improving energy efficiency in public buildings, including schools and hospitals, to reduce operational costs and carbon footprints while enhancing comfort and functionality.	Ministry of Climate and Environment (Department of European Funds). Additional support under priority axis XI of REACT-EU will be co-financing the project to build the Gustorzyn-Wronów transmission gas pipeline as an element of infrastructure enabling Poland's energy transformation. The project aims to increase the availability and use of natural gas as a low-emission fuel. In the medium and long term, the Gustorzyn-Wronów gas pipeline will help integrate renewable and decarbonized gases into the transmission and distribution system.	
Recovery and Resilience Facility	It aims to promote and contribute to the four dimensions outlined in the 2021 Annual Sustainable Growth Strategy, which launched this year's European Semester cycle: environmental sustainability, productivity, fairness, and macroeconomic stability.	The German recovery and resilience plan allocates more than 90% of the country' s spending towards climate action and digital transformation.	Solar and Wind Energy Projects: Investments are being made in expanding solar and wind energy capacities to reduce dependence on fossil fuels and lower carbon emissions. This includes the construction of new solar farms and wind turbines across the country Energy Efficiency Improvements: Funding is allocated for improving the energy efficiency of residential and public buildings through renovations that include insulation, modern heating systems, and smart energy management systems	Currently, 406 projects are being implemented in programming 21-27, including: Construction of offshore wind farms, Investments in energy-efficient housing for low- and medium-income households, Replacement of heat sources and improvement of energy efficiency in residential buildings (in the part regarding multi-family buildings), Central Laboratory for Phenotyping and Genotyping of Agricultural Plants - modernization or creation of specialized laboratories dedicated, among others, analysis of quality characteristics of plant products intended for food and non-food purposes.	[97,101]
Technical Support Instrument (TSI)	The TSI provides technical support to Member States in various policy areas, including green transition climate action, circular economy, and energy transition.	Germany has implemented 19 projects which was financed by the Technical Support Instrument.	Development of Climate Strategies: Lithuania is working on comprehensive climate adaptation and mitigation strategies with TSI support. This includes integrating climate considerations into national and local planning and enhancing resilience to climate impacts Carbon Reduction Projects: Investments in projects to reduce carbon emissions across different	Technical Aid in reform implementation: Boosting competitiveness of the railway sector to increase the competitiveness of green mobility and reach solid socio-economic convergence 2022 Recharge and Refuel - Clean, smart and fair urban mobility 2024 Strengthening Poland's capacity to model the macroeconomic effects of 'green'	[102,103]

			sectors, including transportation, industry, and agriculture. These projects are designed to help Lithuania meet its climate targets under the EU's Green Deal	policies and investments through the GreenREFORM model	
Common agricultural policy funds refer to the: • European Agricultural Guarantee Fund (EAGF) • European Agricultural Fund for Rural Development (EAFRD)	It aims to promote cross-cutting to foster knowledge, innovation, and agricultural digitalization. It includes basic income support for sustainability, complementary redistributive income support for sustainability, complementary income support for young farmers, and schemes for the climate, the environment, and animal welfare.	The EAFRD is implemented through 13 country programs in Germany, with each of them having a different focus. EAFRD regulation requires that a National Network for Rural Areas be set up in every country of the European Union. DVS is the hub for all partners in Germany. The available EAFRD funds for Germany in 2022 was 1.9 billion euros.	Direct Payments to Farmers: EAGF funds provide direct payments to Lithuanian farmers to ensure a stable income. These payments support farmers' income stability, allowing them to invest in sustainable farming practices and technologies. Greening Practices: Farmers receive additional payments for implementing environmentally friendly practices such as crop diversification, maintaining permanent grasslands, and creating ecological focus areas. These practices contribute to biodiversity and environmental sustainability Youth Agriculture Initiatives: EAFRD funds provide additional payments to young farmers starting their agricultural ventures. This support includes financial grants, training, and advisory services to help young farmers establish and manage their farms effectively. Access to Resources and Land: Young farmers benefit from programs facilitating access to land, credit, and other resources necessary for sustainable farming. These programs aim to attract and retain young people in the agricultural sector	European Agricultural Guarantee Fund (EAGF) - Improving energy efficiency	[104,105]

Programme for the Environment and Climate Action (LIFE)	It aims to promote and facilitate the shift towards a sustainable, circular, energy-efficient, renewable energy-based, climate-neutral, and resilient economy to protect, restore, and improve the quality of the environment.	The LIFE programme in Germany together has funded 422 projects at a cost of 1193 million euros. Out of this amount, the EU has contributed 524 million euros.	The LIFE Climate change mitigation and adaptation strand, a significant initiative, will support actions that help implement the 2030 energy and climate policy framework and meet the European Union's commitments under the Paris Agreement on Climate Change. Renewable Energy Projects: LIFE funding supports developing and deploying renewable energy sources such as solar, wind, and biomass. These projects aim to increase the share of renewable energy in Lithuania's energy mix and reduce greenhouse gas emissions	69 projects were implemented in Poland in the years 1992-2017; among those awarded in BEST LIFE PROJECTS were in the BEST LIFE ENVIRONMENT PROJECTS category: New soil improvement measures to reduce pollution and revitalize the ecosystem soil, ECOtones for reducing area pollution, others Thermal utilization of sewage sludge by pyrolysis, Production of electricity and heat in cogeneration based on gasification of fuel from waste municipal and sewage sludge - design, construction and demonstration of the first complete one thermal waste processing installations, Management of excrement from animal production and methods of its processing - promotion of the use of technologies for processing excrement from animal production, Electricity from micronized biomass - generating energy from straw from agricultural plants, renewable energy sources on farms and smart grids - development of practical tools for the design and selection of small-scale renewable energy sources (RES), Living laboratory for improving the efficiency of the end-use of electricity, Use of hemp for land declamation degraded. Currently, the following are being implemented: " Life Małopolska" (2021-2031) includes, among others: implementation of the Regional Action Plan for Climate and Energy, low-emission transformation of the heating equipment market, creation of IT tools determining	[106–108]

Development and Outlook

Bioenergy Sector Development Forecasts and Growth Potential

As an energy source, the bioenergy sector has been steadily gaining popularity in recent years, and the future looks promising. This growth is primarily due to changes in EU directives and the financial support offered by the European Commission across all sectors of the economy. The proposed new climate policies are expected to further boost bioenergy use. As a result, organizations such as Transport & Environment and Birdlife Europe have analyzed the pathways to decarbonize the economy, particularly by the year 2050. With the unwavering support of EU policies, technological progress, and a commitment to sustainable development, Germany, Lithuania, and Poland are well-positioned for renewable energy development in the bioenergy sector. The global biogas sector is projected to grow by 32% between 2023 and 2028, with Europe leading in this expansion. Lithuania is expected to benefit from these trends as part of the European biogas network. EU policies promoting renewable energy and decarbonization will support Lithuania's biogas sector, potentially increasing biogas capacity by 20-40 MW over the coming years. In Germany, biogas and biomethane production are estimated to increase elevenfold, contributing significantly to the attainment of this target. The biogas market in Germany is expected to grow to 10 billion Euros by 2030, indicating a bright future for the bioenergy sector.

Nowadays, wind turbine technology ensures high efficiency for energy systems in Europe. However, the next goal is to install another terawatt over the succeeding seven years, reaching a total capacity of 2 TW by 2030 and attaining 8 TW by 2050. Achieving these goals will require cooperation within the industry, exchange of technological and scientific resources, and training for a professional workforce to drive energy transformation. Forecasts indicate that Lithuania aims to generate more than 90% of its electricity from renewable energy sources by 2030, with a significant portion coming from wind energy. The country is developing around 40 wind power and hybrid projects and plans to increase its wind power capacity to about 5 GW in the coming years, with 1.4 GW from offshore wind and 3.6 GW from onshore wind. Germany has an installed capacity of 61GW of onshore wind power from approximately 28,700 turbines. The country' s projection is to reach a total installed capacity of 115 GW by 2030. To achieve this, Germany strives to build about five new turbines daily [86, 87]. The German Offshore Wind Energy Act projects that by 2030, the installed wind offshore power to the grid should be increased to 30GW. To achieve this, a plan exists to allocate areas for future expansion [88]. In Poland, according to the National Energy and Climate Plan (PKEIK), the installed capacity of onshore wind farms is to reach about 15.8 GW by 2030 [99]. In offshore wind energy, dynamic development is planned to achieve 5.9 GW of installed capacity by 2030. For this purpose, the "Sectoral Agreement for developing

offshore wind energy" was signed to coordinate activities between various stakeholders. Additionally, the document Energy Policy of Poland until 2040 (PEP2040) sets out strategic directions for developing the energy sector for Poland, including wind energy. PEP2040 assumes that over half of the installed capacity 2040 will be zero-emission sources, including a significant share of wind energy [109,110].

The demand for solar energy in Europe is expected to increase significantly. It is projected that the 2 TW threshold will be reached by the end of 2025, with 2.3 TW of solar power to be installed globally by the end of 2026. European Union countries are progressively implementing new strategies to generate as much clean electricity as possible through photovoltaics. Recently, there has been much discussion about agro-voltaics, which involves using land for agricultural purposes and generating energy from the sun. In addition, there are plans to install PV modules on acoustic screens along the roads, with solar highways expected to create up to 55 GW of power. Other innovative approaches include placing photovoltaic panels on railway sleepers and natural or artificial water reservoirs and creating floating solar parks. Lithuania's solar energy sector is poised for robust growth, supported by strong policy frameworks, technological advancements, and increasing demand for clean energy. This growth aligns with the broader European and global trends in renewable energy expansion, positioning Lithuania as a significant player in the transition to sustainable energy sources. The country could see increased capacity from photovoltaic installations to about 100 MW in the coming years. The growth of Germany's solar sector can be attributed to the involvement of the private sector and the increase in the capacity of commercial roof-top and ground-mounted installations. To establish 215 GW of installed solar capacity by 2030, the country needs an estimated 19 GW of new solar capacity annually. According to the National Energy and Climate Plan (KPEiK) for 2021-2030, Poland plans to increase the installed capacity of photovoltaics significantly and will reach a capacity of around 15 GW by 2030. To achieve the goals, the government is introducing various support mechanisms, such as auction systems, subsidies, and tax breaks, to encourage investments in solar energy [111,112].

The bioenergy sector in Germany, Lithuania, and Poland is experiencing significant growth potential and optimistic forecasts due to national strategies and investments in renewable energy. Each country's government has ambitious plans to increase bioenergy production as part of broader renewable energy targets—Table 7 lists notable trends and forecasts.

Trends and forecasts renewable energy development in Germany, Lithuania, and Poland. Table 7

Factors	Germany	Lithuania	Poland	Ref.
	Description			
Policy Support and National Strategies	Germany' s Renewable Energy Act, amended on December 14, 2020, and enforced on January 1, 2021, stressed the commitment to continue expanding the Renewable Energy sector to achieve the set target of incorporating 65% of electricity generation into the energy mix by 2030.	Lithuania's National Energy Independence Strategy aims to increase the share of renewable energy in the total energy mix. By 2030, the strategy targets substantial contributions from bioenergy, particularly in the heating and transport sectors.	**Subsidy programs** such as "Moj Prąd" and "Clean Air" offer direct financial support for renewable energy installations, including photovoltaics. The feed-in tariff system and renewable energy auctions ensure a stable income for renewable energy producers. Poland's Energy Policy until 2040 (PEP2040) assumes an increase in the share of renewable energy sources in the energy mix, emphasizing the development of wind and solar energy.	[113,114]
Bioenergy in Heating and Electricity	In Germany, biomass from energy crops, wood, agricultural wastes, etc., are used for heating, electricity production, and fuel generation. The heating sector assumes a more significant percentage of bioenergy's contribution to providing a clean energy supply.	Biomass is crucial in Lithuania's renewable energy landscape, primarily from wood and agricultural residues. Biomass is used extensively for district heating and is increasingly being integrated into the electricity grid.	Biomass is considered one of the main sources of renewable energy in Poland. The Polish Energy Policy until 2040 (PEP2040) emphasizes its key role in reducing the energy sector's emission intensity. Using biogas allows for efficient waste management and is promoted as a stable renewable energy source. Heat pumps, solar energy, and magazines are increasingly important in heating. These technologies are considered key to the future of heating in Poland.	[115,116]
Innovative Technologies and Infrastructure Development	Innovative technologies such as cellulosic ethanol, gasification, upgrading biogas to biomethane, and gas processing technologies, among others, are being developed in the country to facilitate the injection of biogas into the natural gas grid or its use as transportation fuel. It should be mentioned that Germany is expanding its green gas infrastructure, which includes pipelines and filling stations to support biomethane production and use.	The Lithuanian government promotes advanced bioenergy technologies such as biogas and biomethane production. Efforts are focused on improving infrastructure, including biogas plants and biomethane refilling stations, to enhance the use of bioenergy in transportation	Work is being carried out to support renewable energy sources with the latest technological solutions. State-of-the-art energy storage technologies are being developed in both classic and hybrid solutions. Hybrid warehouses allow you to achieve the desired efficiency by combining appropriate functions of various technologies. Hybrid energy storage systems (HESS) are characterized by combining two or more electrical energy storage technologies selected to provide the performance of the entire energy storage system in terms of service life, cost, energy value, power density, and dynamic response.	[117,118]

Environmental and Economic Benefits	In Germany, sustainable approaches to generating bioenergy while protecting the environment are strongly discussed. Consequently, new policies to reduce the use of biomass for power production are underway. Germany' s bioenergy sector employs close to 150,000 people, hence contributing to rural development.	Bioenergy development in Lithuania is aligned with EU sustainability criteria, ensuring that biomass use does not negatively impact biodiversity and land use. This sustainable approach supports environmental goals and stimulates economic growth by creating jobs and promoting rural development	The development of renewable energy sources in Poland brings significant environmental benefits, such as reducing greenhouse gas emissions and pollutants, protecting soil and water, and effectively managing waste. Economically, bioenergy production creates new jobs, supports local environments, increases energy independence, enables efficient resource use, and stabilizes energy prices.	[119,120]
Market Dynamics	The German renewable energy market is expected to grow, projected to 276.50 billion kWh in 2024. Sources suggest an annual growth of 4.03% is anticipated between 2024 and 2029.	The bioenergy market in Lithuania is semi-fragmented, with several key players, including local and international companies. This competitive environment fosters innovation and investment, driving the sector's growth	In the National Energy and Climate Plan for 2021-2030 (NECP), Poland declared an increase in the share of renewable energy sources in final gross energy consumption (including electricity, heating and cooling, and transport) to 21-23%. According to the assessment of the authors of the plan, the share of renewable energy in heating and cooling in the perspective of 2030 will increase by an average of 1.1% per year (to the level of 28.4%), while in the electricity sector it is to reach the level of 32% (an increase of approx. 6% per year). The planned share of renewable energy in transport is 14%. The means of achieving these goals in the NECP include further support for renewable energy sources (RES) by increasing the use of advanced biofuels, developing offshore wind energy, and supporting the development of RES micro-installations. Together, these actions are expected to reduce CO^2 emissions by 30%. Compared to the 1990 level.	[121,122]

Summary & Recommendations

The whole world has been relying on uses on non-renewable energy sources like coal, oil, and natural gas. However, their use is expensive and harmful to the environment and human health. In 2021, Europe alone emitted 36.3 billion tons of carbon dioxide. The European Commission aims to reduce these emissions by increasing electricity production from renewable sources. A report by Ember showed that in 2021, renewable sources generated 37% of the EU's electricity, providing member countries with 547 TWh. Fossil fuels also produced 37% of the electricity, while nuclear power accounted for 26%. The advantages of renewable energy make the shift towards these sources crucial for the economy, society, and the environment. Renewable energy sources also foster better cooperation between people and the natural environment. They are fundamental elements with long-lasting benefits. When skillfully designed, they act as a kind of perpetual motion machine, constantly providing us with electricity without risking the exhaustion of the energy source.

Currently, numerous visible initiatives show that people worldwide, not just in Europe, are enthusiastically taking grassroots actions toward energy self-sufficiency and independence from oil. The Sustainable Development Goals are a call to action not only for governments, local governments, businesses, and international institutions but also an initiative for all of us, i.e., for the citizens of a given country. To accomplish specific tasks and achieve all the goals set out in the 2030 Agenda, all sectors must cooperate closely and seek common solutions to global challenges.

Stakeholders' Needs and Challenges: Survey Results

This survey was conducted to better understand the needs, motivations and barriers that farmers in the South Baltic region face when considering or adopting renewable energy solutions. We interviewed 270 farmers: 170 from Poland, 51 from Lithuania, and 50 from Germany. The questionnaire was completed through online forms, paper-based responses, or direct phone interviews. We gathered insights into what influences their decisions, the main challenges they encounter, and where they get their information.

In this section, we will provide an in-depth analysis of the survey results gathered from farmers and stakeholders across the South Baltic region, specifically focusing on Poland, Lithuania, and Germany. The data includes both close-ended questions from farmers, which cover key aspects such as renewable energy adoption, challenges, and opportunities, as well as open-ended responses from various stakeholders, including energy providers, policymakers, energy suppliers, NGOs and financial institutions. These insights offer a comprehensive view of the current state of renewable energy in the agricultural sector, highlighting the obstacles farmers face, the support they need, and the potential for expanding sustainable practices within the region. In the following sections, we will delve into these findings, comparing perspectives from each country to provide a holistic understanding of renewable energy use in farming.

Map data ©2025 GeoBasis-DE/BKG (©2009), Google, Inst. Geogr. Nacional [123]

Poland's results

Farmers demographics in Poland South Baltic region

This part aims to provide an in-depth analysis of the questionnaire results gathered from farmers in Poland's South Baltic region, focusing on demographic characteristics and their implications for agricultural practices. As part of the BIOSOLFarm project—titled "South Baltic Farms: An Essential Part of Renewable Energy Systems"—this analysis serves to support the overarching goals of enhancing energy production, storage, and self-sufficiency within the agricultural sector.

The demographic data of farmers in Poland's South Baltic region reveals several key trends across various categories. The gender distribution shows a significant majority of men at 69%, indicating a strong male presence in farming roles. Women represent 30%, showcasing noteworthy participation,

though they remain underrepresented compared to men. A small portion of respondents, at 1%, chose not to disclose their gender.

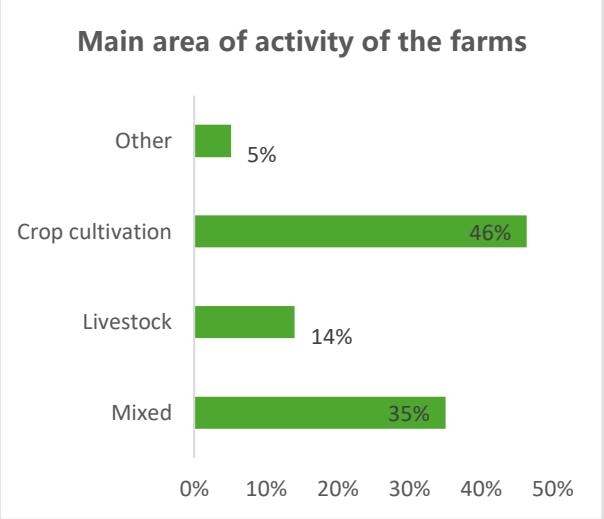
In terms of age distribution, the most prevalent age group among farmers is 45-54 years, accounting for 31%. This suggests that a significant portion of the farming population is approaching retirement age. The 35-44 years age group follows closely at 21%, indicating a solid foundation of experienced farmers. However, younger demographics, particularly those aged 18-24 years, represent only 3%, which highlights challenges in attracting younger individuals to the farming sector.

When examining land size distribution, the largest proportion of farmers, approximately 32%, manage farms ranging from 10 to 25 hectares. This may indicate a common farm size that is both manageable and productive. Additionally, 26% of farmers operate on less than 10 hectares, while 21% manage farms between 26 and 50 hectares. Larger farms, those 51 hectares and above, are less common, with only 12% of respondents indicating such operations. This suggests a trend towards smaller or medium-sized farming enterprises in the region.

Regarding the years of operation, a significant number of farms have been running for 21 to 30 years, comprising 30% of the total. This indicates a stable and experienced farming community. Furthermore, 26% of farms have been in operation for 11 to 20 years, while 18% are relatively new, having been established for less than 5 years. The data highlights a mix of seasoned farmers and newer entrants in the sector.

In terms of the main area of activity, crop cultivation stands out as the most common, representing 46% of farmers. This highlights a focus on agricultural produce within the region. Mixed farming constitutes 35%, indicating some degree of diversification among operations. Livestock farming is less prevalent, at 14%, with only 5% of respondents engaging in other activities, which may include niche markets or alternative agricultural practices.

Figure 4



In conclusion, the demographic profile of farmers in Poland's South Baltic region presents a mature and predominantly male workforce, with a strong emphasis on crop cultivation. The age distribution indicates a potential future challenge, as many farmers are approaching retirement age while fewer young individuals are entering the field. The prevalence of smaller to medium-sized farms and a diverse range of activities indicate a varied agricultural landscape. This landscape may benefit from targeted initiatives to attract younger generations and support sustainable

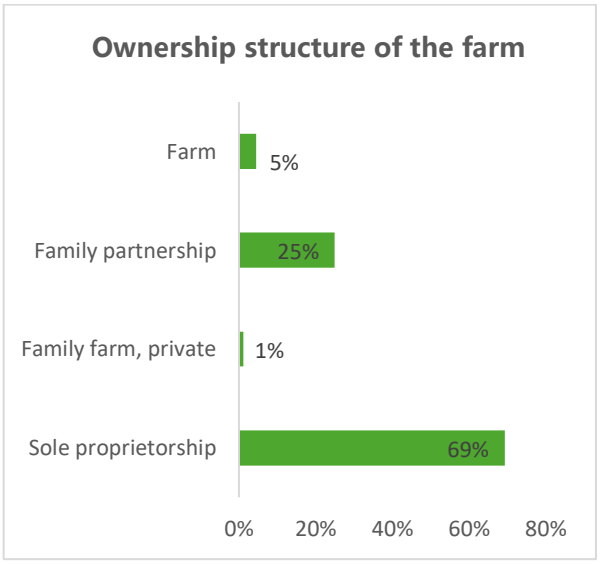
farming practices in the region.

Farms structure, ownership and workforce used

The demographic analysis of farmers in Poland's South Baltic region continues with an examination of the ownership structure, workforce dynamics, and land ownership characteristics.

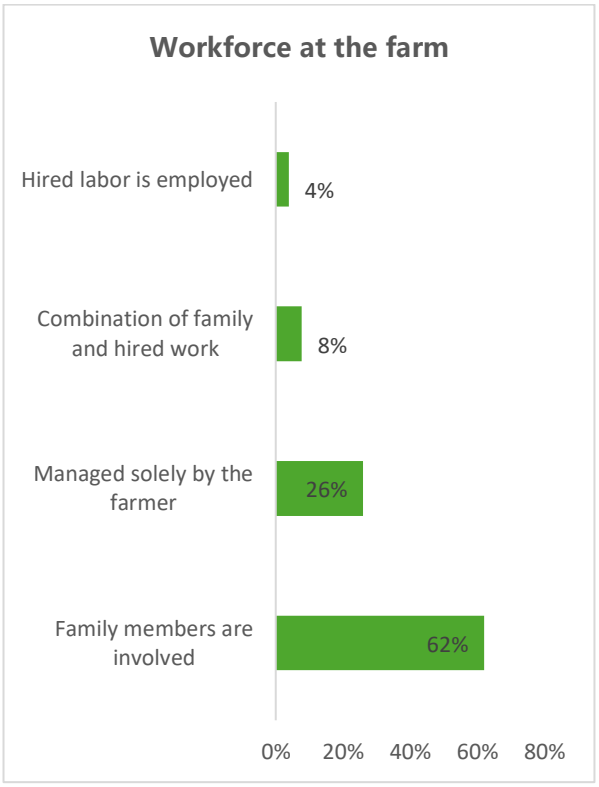
Most farms are organized as sole proprietorships, constituting 69% of the total responses. This structure indicates a significant prevalence of individual management in farming operations, which may influence decision-making processes, resource allocation, and the adoption of new technologies. Family partnerships follow, making up 25% of the farms, while family farms and general farms account for a smaller portion at 1% and 5%, respectively. This ownership distribution highlights a trend toward individual management rather than cooperative or collective farming structures, which may affect collaboration and resource sharing among farmers.

Figure 5



In terms of workforce composition, 62% of farms involve family members in their operations. This reliance on family labor reflects traditional farming practices and underscores the importance of familial ties in agricultural work. Meanwhile, 26% of farms are managed solely by the farmer, suggesting a degree of independence in operational management. Only a small fraction of farms, 8%, utilize a combination of family and hired labor, and 4% employ hired labor exclusively. This workforce distribution may limit the scalability of operations and the capacity to adopt more complex agricultural practices, as reliance on family labor can restrict the availability of diverse skills.

Figure 6



Regarding land ownership, a substantial 69% of farmers report owning their land as private property, while 31% have a combination of ownership and leasehold arrangements. This

indicates a strong trend toward land ownership, which can provide farmers with greater autonomy and security in their agricultural endeavors. However, the presence of leasehold arrangements may reflect the challenges some farmers face in acquiring land, highlighting potential barriers to entry for new or expanding agricultural operations.

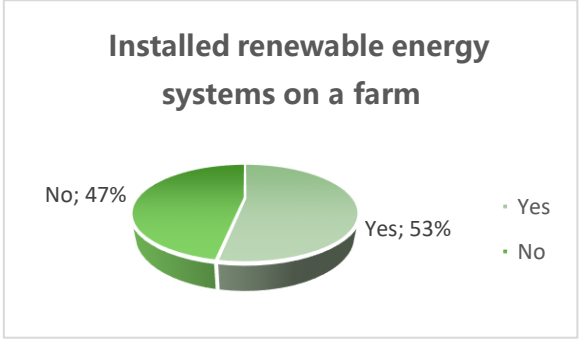
Overall, these demographic insights shed light on the characteristics of farmers in the South Baltic region and their implications for agricultural practices, collaboration, and the transition to renewable energy systems. Understanding these factors will be critical for developing tailored strategies to support farmers in optimizing their operations and contributing to a more sustainable future.

Overview of Sustainable Energy Installations in Poland South Baltic Region Farms

The following report presents the findings regarding the adoption of renewable energy systems among Polish farmers, highlighting the types of installations, challenges faced, and barriers to adoption.

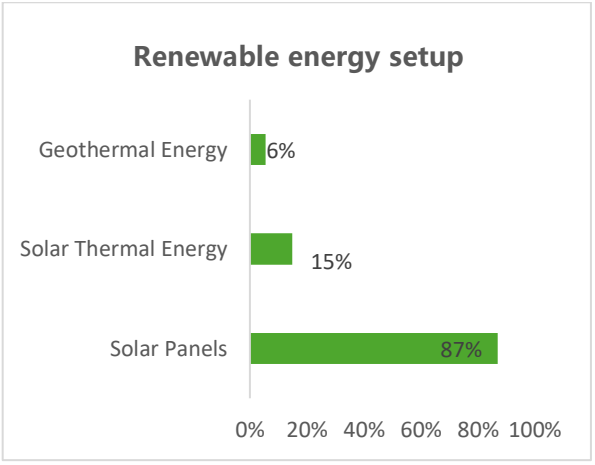
A significant portion of respondents, 53%, indicated that they have installed renewable energy systems on their farms, while 47% reported that they have not.

Figure 7



Among those who have installed renewable energy systems, solar panels are the most used technology, with 87% of respondents specifying this type of installation. Other systems reported that they include solar thermal energy at 15% and geothermal energy at 6%. The high percentage of solar panel installations reflects their increasing popularity and accessibility among farmers.

Figure 8



When examining the challenges encountered during the implementation of these systems, 60% of respondents highlighted high initial costs as a significant barrier. Regulatory or permitting challenges and technical issues were also noted, each reported by 19% of the respondents. Difficulty in finding qualified installers was mentioned by 10%, while a small percentage, 6%, stated that they faced no difficulties during installation. The percentages do not add up to 100 because respondents could select multiple challenges, leading to a cumulative total greater than 100%.

Regarding ongoing challenges in maintaining or operating renewable energy systems, a majority of 88% reported having no issues, while 12% indicated they encountered

ongoing challenges. This indicates a positive trend in the long-term viability of the systems among most farmers.

Among those who have not adopted renewable energy systems, 71% cited high initial costs as the primary barrier to adoption. Other significant challenges include limited information or lack of awareness at 40%, and system reliability concerns at 22%. Insufficient government incentives and lack of technical knowledge were noted by 18% and 15% of respondents, respectively. The remaining barriers, such as legal aspects and aesthetic concerns, were reported by smaller percentages. The cumulative percentages exceed 100% due to respondents being able to identify multiple barriers to adoption.

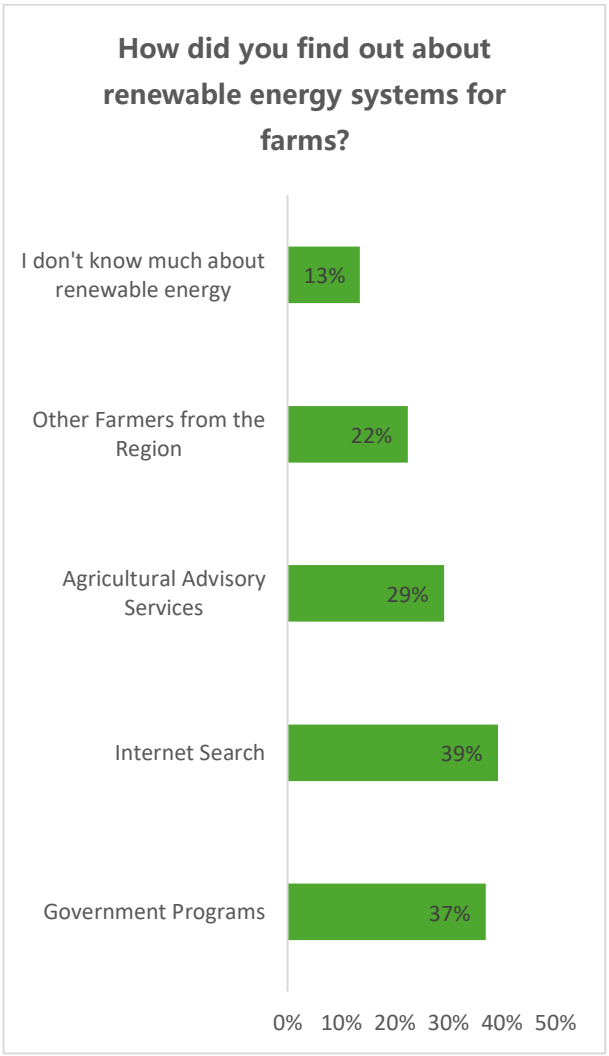
In terms of support needed for adopting renewable energy systems, 76% of respondents identified financial incentives or grants as crucial. Access to reliable information and resources was also important for 44% of farmers, while 35% called for government assistance with permits. Technical workshops and training were suggested by 21%, and 7% of respondents mentioned joint initiatives with other farmers as a means of support. The cumulative percentages exceed 100% due to respondents being able to identify multiple barriers to adoption.

Overview of farmers knowledge and perceptions of renewable energy

The analysis of the data regarding farmers' knowledge and perceptions of renewable energy systems reveals significant insights into how they access information, the challenges they face, and their willingness to engage in knowledge-sharing networks.

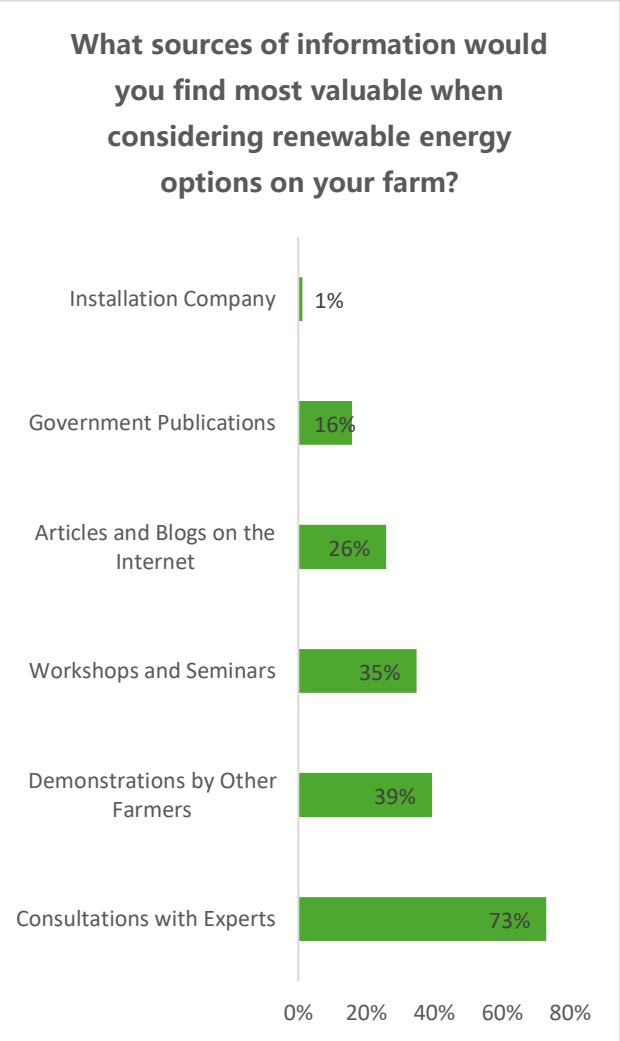
In exploring how farmers discovered renewable energy systems, the most common sources identified were government programs and internet searches, which accounted for 37% and 39%, respectively. This suggests a reliance on both official resources and personal research. However, agricultural advisory services and regional farmers contributed to a lesser extent, at 29% and 22%. Notably, a segment of farmers (13%) acknowledged their limited understanding of renewable energy at the farm level, indicating a potential gap in awareness that may hinder adoption.

Figure 9



When considering what sources of information would be most valuable in making decisions about renewable energy options, consultations with experts emerged as the most favored, with a significant 73%. This highlights the need for direct access to knowledgeable individuals who can provide tailored advice. Demonstrations by other farmers (39%) and workshops and seminars (35%) also featured prominently, suggesting that practical, peer-led learning experiences are valued. Meanwhile, government publications and articles online received comparatively less interest, at 16% and 26%, respectively, with installation companies rated as the least valuable source (1%).

Figure 10



Farmers indicated several specific challenges encountered while researching or implementing renewable energy systems. A substantial 51% reported difficulty in distinguishing reliable sources, which aligns with the earlier finding of limited understanding. Inadequate information regarding financial aspects (42%) was another prominent concern, further complicating decision-making. The lack of accessible and understandable information (26%) and limited knowledge of available technologies (21%) were also noted, with 17% of respondents citing insufficient information on maintenance requirements. General awareness issues, while less frequently mentioned (7%), still indicate that a portion of the farming community struggles with the overall concept of renewable energy systems.

Table 8

Specific challenges or gaps in information that farmers encountered when researching or implementing renewable energy	
Difficulty in distinguishing reliable sources	51%
Inadequate information regarding financial aspects	42%
Lack of accessible or understandable information	26%
Limited information on available technologies	21%
Insufficient information on maintenance requirements	17%
General awareness issues	17%

To enhance awareness and knowledge of renewable energy among farmers, several initiatives were suggested. Notably, the success stories of local farmers were valued by 34% of respondents, making it one of the most important resources. Collaboration

platforms for information exchange followed closely, at 32%. Regional workshops and training were also seen as significant resources, with 25% of respondents indicating their importance. Additionally, increased communication activities and broad government information campaigns garnered support from 22% of respondents, while educational campaigns in farming communities were favored by 20%.

Table 9

Initiatives or resources that could increase awareness and knowledge of farmers about renewable energy	
Collaboration platforms for information exchange	32%
Regional workshops and training	25%
Cases and success stories of local farmers	34%
Increased communication activities and broad government information campaigns	22%
Educational Campaigns in Farming Communities	20%

Regarding participation in networks or forums for exchanging knowledge about renewable energy, a notable 52% expressed interest. This suggests a willingness among farmers to engage with each other to enhance their understanding and application of renewable energy solutions. However, 22% stated they were not interested, and 26% remained undecided, indicating a potential barrier to forming cohesive networks.

It is essential to note that the percentages reported in some sections do not total 100%. This discrepancy arises because respondents could select multiple answers for certain questions, leading to the totals exceeding 100%. For example, when asked about how they found out about renewable energy systems, farmers could choose more than one source. This multi-selection aspect is also reflected in the various initiatives and resources suggested, highlighting the diverse perspectives and needs within the farming community.

Overall, the data suggests that while there is a strong interest in renewable energy systems among farmers, significant barriers to information access and understanding remain. Addressing these gaps through targeted educational initiatives, peer-to-peer learning opportunities, and expert consultations could foster a more informed and engaged farming community ready to embrace renewable energy solutions.

Awareness and Opinions Regarding Government Support for Renewable Energy in Farming

The data collected reflects farmers' awareness and opinions regarding government incentives and programs supporting the implementation of renewable energy systems on farms. The findings reveal a mixture of perspectives, particularly in terms of awareness of available incentives, their influence on adoption decisions, encountered challenges, and suggestions for improvement in government policies.

When asked about awareness of government incentives or programs supporting renewable energy implementation on farms, responses were evenly split. This balance suggests that the government may need to enhance communication efforts to ensure that more farmers are informed about available resources.

In terms of the influence these incentives have had on farmers' decisions to adopt renewable energy systems, a majority of 55% affirmed that such incentives positively influenced their decision-making, while 45% did not find them impactful. This shows a split correlation between awareness of incentives and the decision to adopt renewable technologies.

The challenges farmers have encountered or observed regarding government support for renewable energy implementation are varied. The most identified challenge was insufficient awareness of available incentive programs, cited by 53% of respondents. This was followed closely by a lack of transparency in incentive programs (47%) and limited financial support (43%). Other notable challenges included long and complex application processes (33%) and difficulty in accessing government support (28%). The percentages indicate that respondents could identify multiple challenges, which account for the total exceeding 100%. This overlap suggests that the challenges are interconnected, reflecting a broader issue of accessibility and awareness regarding government programs.

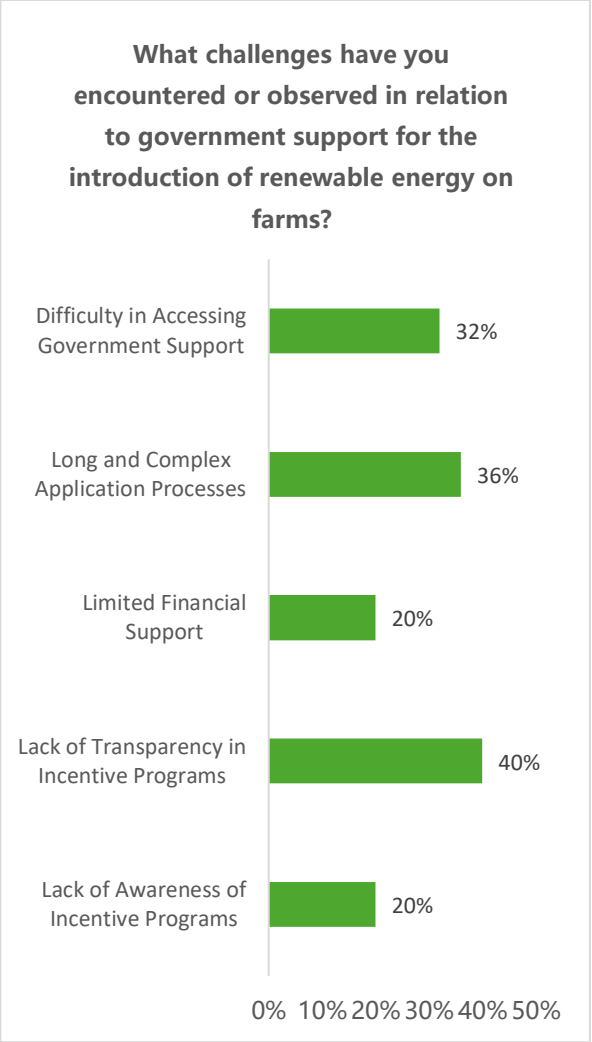


Figure 11

Farmers provided several suggestions for improving existing government policies or proposing new initiatives. The most frequent suggestion was increased financial incentives or subsidies, supported by 59% of respondents. Better communication and awareness campaigns followed, with 35%, while tailored support for small farmers received 46% support. Other suggestions included streamlining application processes (30%) and establishing cooperation programs with agricultural organizations (18%). Again, since respondents could select multiple suggestions, the total percentage exceeds 100%, indicating a range of desired improvements.

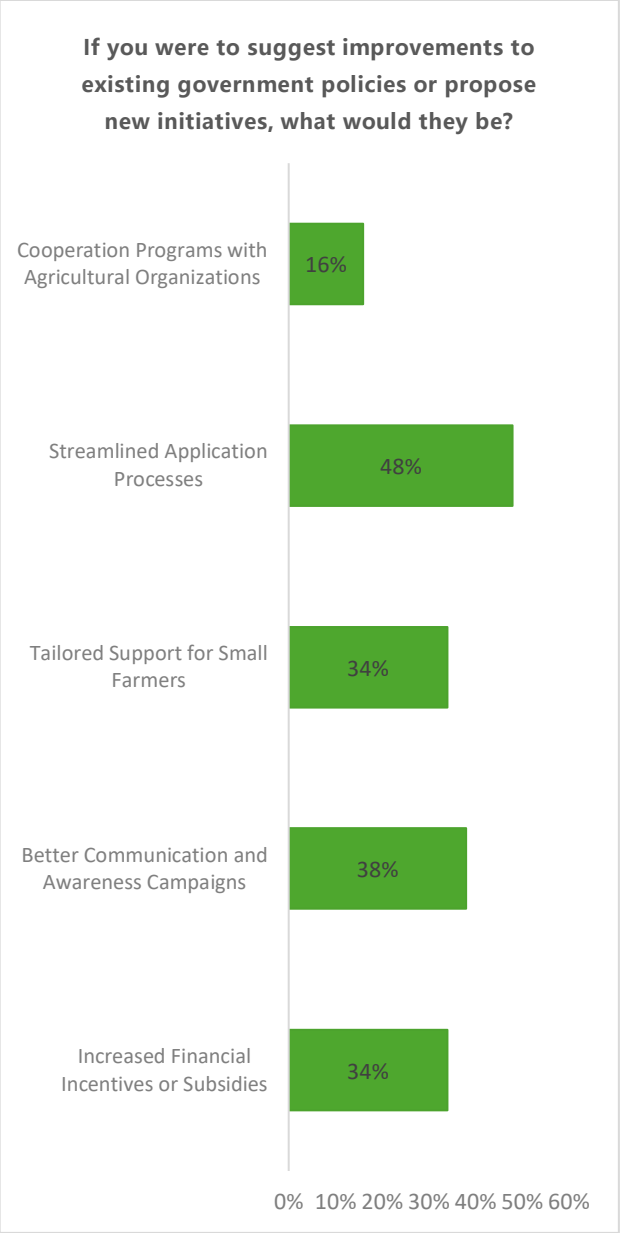


Figure 12

Regarding whether current government policies effectively meet the diverse needs of farmers in the Southern Baltic Sea region concerning renewable energy use, the majority (55%) indicated they do not believe policies are effective, while only 8% expressed confidence in their effectiveness. A significant portion, 37%, remained undecided. This data suggests a general dissatisfaction with existing policies and highlights an opportunity for government agencies to reassess and enhance their strategies to better serve farmers.

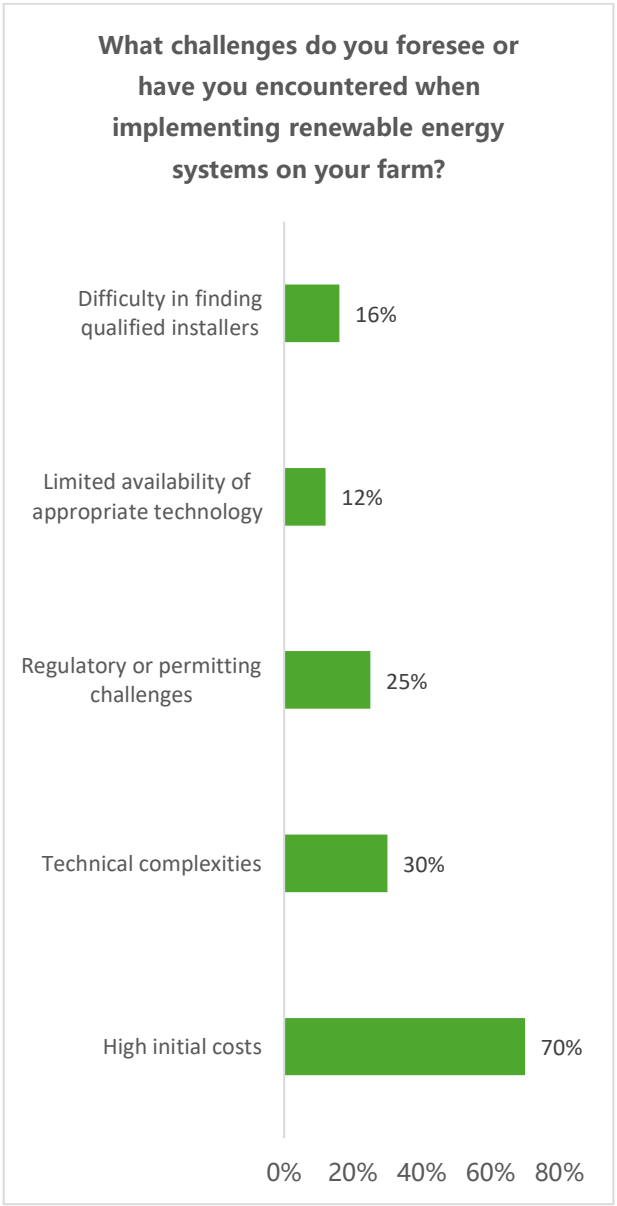
Finally, the question of whether farmers would benefit from additional government-funded resources or assistance concerning regulatory aspects of installing and maintaining renewable energy systems yielded a positive response. A substantial 69% of respondents affirmed that they would benefit from such resources, while only 9% disagreed. The undecided category represented 22%. This indicates a strong demand for further government support to assist farmers in navigating regulatory requirements related to renewable energy.

The findings highlight a critical need for improved communication regarding government incentives and support programs. While awareness exists, many farmers remain uninformed or encounter challenges that hinder their access to support. There is a strong call for increased financial incentives, better communication strategies, and tailored support to enhance the adoption of renewable energy systems in farming. The overall dissatisfaction with current policies indicates that stakeholders should prioritize addressing farmers' needs to foster a more sustainable agricultural sector in the Poland South Baltic Sea region.

Challenges in installing renewable energy in Poland South Baltic region

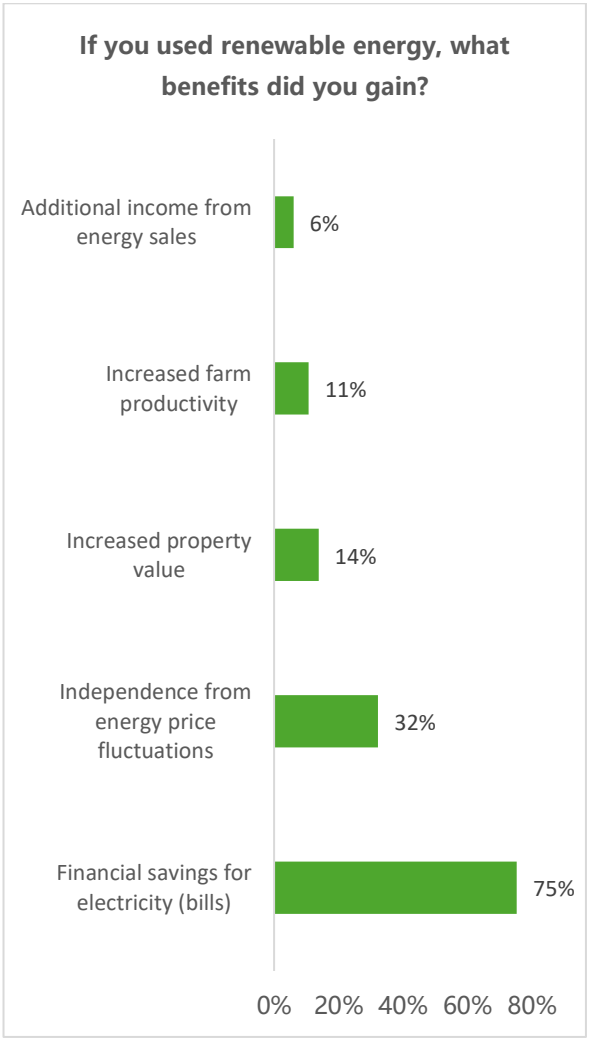
The survey conducted on the implementation of renewable energy systems on farms in the Poland South Baltic Sea region revealed several insights into the challenges, benefits, resources needed, and perceptions regarding current support structures.

In terms of challenges encountered or foreseen in implementing renewable energy systems, the most significant barrier identified by respondents was the high initial costs, which affected 70% of participants. Technical complexities followed, impacting 30% of the respondents, while regulatory or permitting challenges were cited by 25%. Limited availability of appropriate technology and difficulty in finding qualified installers were also noted, affecting 12% and 16% of respondents, respectively. The percentages do not sum to 100% as respondents could select multiple challenges. Figure 13



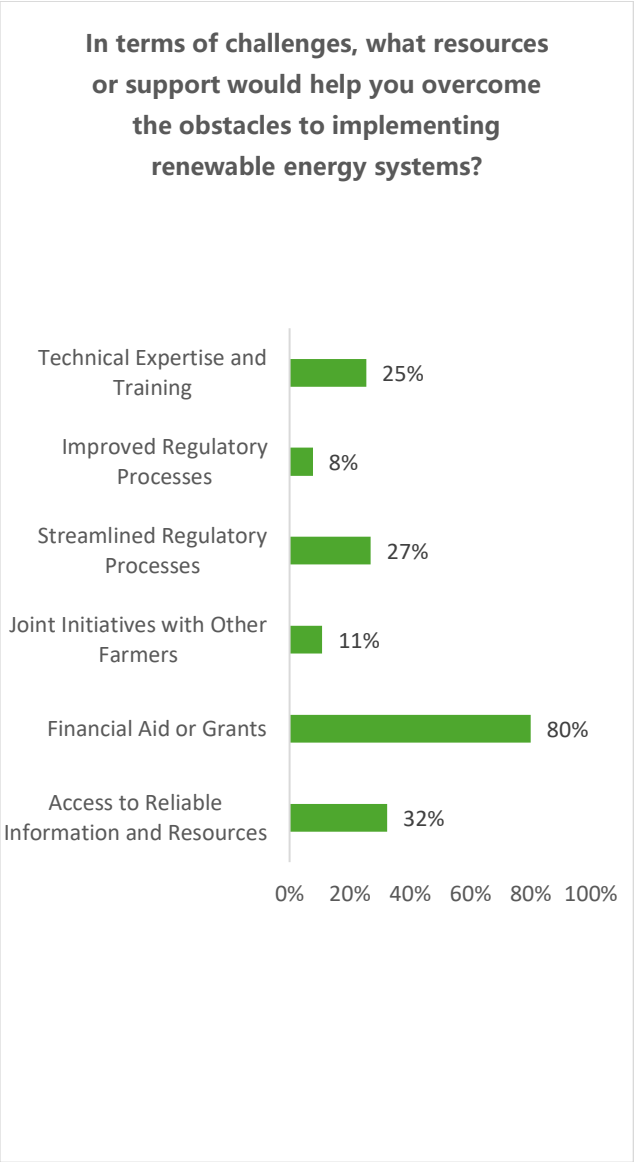
Regarding the benefits gained from the use of renewable energy, financial savings on electricity bills were highlighted by 75% of respondents, indicating a strong economic advantage. Additionally, 32% mentioned increased resilience and independence from energy price fluctuations, while 14% noted an increase in property value. Increased farm productivity and additional income from energy sales were acknowledged by 11% and 6% of respondents respectively. Like the challenges, these percentages do not total 100% because respondents could choose more than one benefit.

Figure 14



When asked about the resources or support that would help overcome obstacles to implementing renewable energy systems, 80% of respondents identified financial aid or grants as crucial. Access to reliable information and resources was deemed important by 32%, while streamlined regulatory processes were highlighted by 27%. Technical expertise and training were also noted by 25%, with joint initiatives among farmers garnering 11% of support. The percentages for this question also do not add to 100% as respondents could select multiple resources needed.

Figure 15



Lastly, perceptions regarding the effectiveness of current support structures revealed significant dissatisfaction. Only 6% of respondents felt that existing support structures effectively addressed the diverse challenges and needs of farmers concerning renewable energy. In contrast, 44% expressed that they did not find the support adequate, while a notable 50% remained undecided on the matter.

The survey on renewable energy adoption in the Poland South Baltic Sea region reveals that high initial costs and regulatory challenges are the main obstacles for farmers. Despite these challenges, many farmers reported financial savings and increased energy independence as key benefits of renewable energy use. To overcome barriers, respondents emphasized the need for financial aid, better information access, and streamlined regulatory processes. However, there is widespread dissatisfaction with the current support structures, as many farmers feel they do not adequately address their needs.

Assessing Renewable Energy Engagement and Support Among Farmers in the Poland South Baltic Sea Region

The survey results regarding various aspects of renewable energy systems (RES) indicate several key findings concerning government policies, investor engagement, collective actions, energy generation practices, and legal incentives for farmers in the Poland South Baltic Sea region.

When asked if there are feed-in tariffs for small and large-scale installations to attract investors for leasing roofs or land, 10% of respondents affirmed their existence, while 12% reported that there are none. A significant majority, 78%, indicated they had no idea about the availability of such tariffs. This suggests a considerable gap in awareness regarding financial mechanisms designed to incentivize renewable energy investments.

In terms of investor engagement, only 10% of farmers are currently in talks with investors interested in implementing or improving RES installations on their farms. Conversely, 90% of respondents reported that they are not engaged in such discussions, highlighting a lack of investor interest or engagement in this sector among farmers.

The survey also inquired about collective actions among farmers for adopting renewable energy. A mere 8% of respondents confirmed that collective initiatives exist, while a staggering 92% stated there are no such efforts. This indicates a substantial lack of collaboration or joint efforts among farmers in the region to embrace renewable energy solutions.

Regarding the use of decentralized generators, 32% of respondents reported that they occasionally use these power generators throughout the year, while 68% do not utilize such systems. This suggests a reliance on centralized power sources among the majority of farmers, which may hinder the adoption of more sustainable practices.

Interest in conducting feasibility studies to enhance renewable energy situations is low, with only 16% of respondents expressing a desire to pursue such studies, while 84% indicated they do not wish to carry them out. This may reflect a lack of resources or motivation to explore potential improvements in renewable energy usage.

Lastly, when questioned about the presence of legal regulations encouraging farmers to expand their businesses or providing incentives in the past, only 15% affirmed the existence of such regulations. In contrast, a substantial 85% stated there are no encouraging legal frameworks in place,

indicating a significant barrier to expanding renewable energy initiatives among farmers. Overall, these findings reveal a critical need for increased awareness, collaboration, and legal support to foster a more favorable environment for renewable energy adoption among farmers in the Poland South Baltic Sea region.

Stakeholder Perspectives on Renewable Energy Adoption in the Poland South Baltic Sea Region

In this section, we will explore the perspectives of other stakeholders regarding renewable energy adoption in the Poland South Baltic Sea region, informed by the responses to both questionnaire and open-ended questions. Stakeholders include policy makers, energy providers, financial institutions, NGOs, and representatives from research and academia. By analyzing their viewpoints, we can gain a comprehensive understanding of the broader landscape affecting farmers' efforts to implement renewable energy systems, identify potential gaps in support, and recognize collaborative opportunities that may enhance the overall effectiveness of renewable energy initiatives in the region. This stakeholder analysis will help elucidate the interplay between farmers' needs and the roles these entities play in fostering an environment conducive to sustainable energy practices.

Insights from Energy Suppliers on Renewable Energy Services for Farmers in the Poland South Baltic Region

The responses from energy suppliers in Poland's South Baltic region highlight various aspects of renewable energy services available to farmers and the evolving landscape of demand and innovation.

Energy suppliers currently offer connection options for renewable energy sources (RES), enabling farmers to integrate these systems into their operations. Over the past decade, demand has surged, with the power connected to medium and low voltage networks increasing eightfold. However, the saturation of the power grid with renewable energy presents challenges, particularly in determining connection points for new installations. The Distribution System Operator (DSO) adheres to legal obligations to treat all customers equally, meaning farmers do not receive special treatment compared to other social or business groups. Their cooperation with farmers primarily involves processing applications and conducting expert analysis to establish connection conditions.

Energy suppliers identified challenges such as the unpredictability of renewable energy production, which can lead to excess energy generation, causing fluctuations in voltage and energy quality. To address these issues, suppliers are implementing network management systems and digitization. Additionally, the DSO sees promise in developing technologies like biomethane and hydrogen, which could enhance predictability

and energy storage capabilities.

While some suppliers do not currently provide specific services or incentives for farmers, they recognize the importance of being informed about the latest developments in the industry through conferences and training sessions.

Promising trends include the advancement of energy storage systems, particularly in optimizing the use of excess electricity generated from unpredictable sources, as well as increasing interest in alternative fuels like biomass and geothermal energy.

Overall, the insights gathered from energy suppliers underscore the growing demand for renewable energy solutions, the need for effective management of energy production, and the potential for emerging technologies to support farmers in the South Baltic Sea region.

Insights from Financial Institutions' Responses on Supporting Renewable Energy for Farmers in the Poland South Baltic Region

Financial institutions in Poland's South Baltic region offer various financing options for farmers interested in adopting renewable energy solutions, including working capital and investment loans. These financing options are designed to be flexible, allowing for monthly, quarterly, and semi-annual installment repayments to accommodate farmers' diverse financial needs.

When assessing financial risk associated with renewable energy projects in agriculture, these institutions acknowledge the unique challenges that arise. Key challenges include the high initial costs and uncertainties related to project outcomes, which can deter potential investments. Furthermore, financial institutions are engaged in facilitating financing by collaborating with other stakeholders such as farmers, policymakers, and energy suppliers through meetings and training sessions at local agricultural offices (ODRs).

> DSO sees promise in developing technologies like biomethane and hydrogen, which could enhance predictability and energy storage capabilities

The alignment of agricultural renewable energy projects with the overall investment strategy of these financial institutions is evident, as there is a noticeable increase in interest in financing such projects. Financial institutions have observed a positive trend in the financial performance of renewable energy projects, highlighting their potential for sustainability and profitability.

Looking ahead, there are plans to introduce new financial instruments and strategies to further support farmers in utilizing renewable energy. The promotion of renewable energy sources is expected to continue, with an emphasis on greater dissemination of information and resources related to financing options. Factors that could influence financial institutions to increase support for renewable energy in agriculture include a growing interest among farmers and the

potential for improved financial performance of renewable energy projects.

Insights from Research and Academia Responses on Renewable Energy in Agriculture in the Poland South Baltic Region

Research initiatives in the South Baltic region, particularly the "AgroEnergija" project under the Horizon 2020 program, focus on integrating various renewable energy sources such as photovoltaic panels, biogas plants, and wind turbines into agricultural practices. The main goals of these initiatives include increasing energy efficiency, reducing CO2 emissions, and promoting sustainable agricultural methods. Collaborations with technical universities, research institutes, and agricultural enterprises are integral to these projects, which also involve pilot studies on selected farms to assess technology effectiveness in local contexts.

Researchers actively engage with farmers, policymakers, and other stakeholders through interviews and surveys to address challenges related to renewable energy adoption. This collaboration helps translate research findings into practical applications and recommendations for farmers. Detailed guides and manuals are produced to assist farmers in implementing renewable energy systems, with many of these resources available online for broader accessibility.

Promising new technologies identified in ongoing research include agro-photovoltaics, biochar, heat pumps powered by renewable energy, and innovative energy storage systems. However, challenges such as financial barriers, logistical issues, and regulatory hurdles persist, alongside regional factors like climatic conditions that affect the feasibility of renewable energy technologies.

Future research directions aim to enhance efficiency and sustainability in renewable energy applications for agriculture. Specific areas requiring further investigation include adapting technologies to various climatic conditions and fostering international cooperation to share best practices. The research is expected to have a significant impact on farmers, policymakers, and local communities by promoting sustainable development and improving energy independence. Continuous research and effective communication of results are deemed essential for fostering a collaborative approach to renewable energy adoption in agriculture.

Insights from NGO Responses on Promoting Renewable Energy Adoption Among Farmers in the Poland South Baltic Region

NGOs in the South Baltic region actively participate in various initiatives to promote renewable energy use among farmers, notably through the Rural Energy Community Advisory Hub (RECAH). These initiatives focus on raising awareness of energy cooperatives and agricultural biogas plants, addressing the unique needs of the farming community by providing tailored solutions that align with local government policies on renewable energy projects.

To support farmers interested in adopting renewable energy, NGOs organize discussions, seminars, and training sessions

that facilitate knowledge exchange and problem-solving. Direct contact with farmers allows for collaborative analysis of challenges, particularly in instances where local government policies are not conducive to farmer participation. Success stories include the establishment of Poland's first startup village and examples of farmers successfully utilizing heat from energy crops and installing photovoltaic panels.

NGOs advocate for renewable energy at both local and regional levels through public consultations, education, and support for various initiatives. They focus on overcoming legal obstacles that hinder farmers' ability to become prosumers, as well as increasing public awareness about alternative energy sources derived from agriculture. The main challenges faced include a lack of knowledge and public ignorance regarding renewable energy, which NGOs address through outreach and training programs.

Poland's first startup village and examples of farmers successfully utilizing heat from energy crops and installing photovoltaic panels

Innovative solutions that have proven effective include more efficient photovoltaic panels, heat pumps, thermal insulation of buildings, and energy production from agricultural waste. Overall, NGOs play a vital role in educating farmers, fostering cooperation with local governments, and promoting the adoption of renewable energy technologies in the agricultural sector.

Insights from Policymakers' Responses on Promoting Renewable Energy in the Poland South Baltic Region

Policymakers in the South Baltic region have established a framework of strategic documents and regulations to support the adoption of renewable energy sources, recognizing its importance for the Polish economy. Existing policies positively influence farmers' decisions by encouraging investments in renewable energy, which help reduce agricultural production costs, particularly in animal and horticultural sectors. However, there remains a gap in farmers' understanding of the benefits and importance of renewable energy investments.

Challenges faced by policymakers include addressing insufficient awareness among farmers about renewable energy opportunities and developing effective initiatives to promote adoption. In response, they are focusing on developing demonstration farms to showcase successful practices and conducting training sessions to disseminate information about the benefits of renewable energy solutions.

Policymakers are planning to introduce modifications to current policies to further encourage renewable energy use on farms, with an expectation that these changes will lead to increased energy capacity from renewable sources. They actively collaborate

with stakeholders, including farmers, energy suppliers, and NGOs, to promote renewable energy through knowledge exchange and joint initiatives.

The effectiveness of policies promoting renewable energy adoption is monitored through key performance indicators, including the capacity for energy production from renewable sources in megawatts (MW). Policymakers also note the involvement of the Ministry of Energy and the Ministry of Finance in shaping these policies, with an emphasis on complementary regulations.

EU funds and incentives are available to support renewable energy implementation, such as the National Fund for Environmental Protection and Water Management's "Energy for the Countryside" initiative and measures under the Rural Development Program. These resources are utilized by farmers to enhance their renewable energy projects and improve energy efficiency on their farms. Overall, policymakers are committed to fostering an environment conducive to renewable energy adoption in the agricultural sector, facilitating long-term sustainability and energy independence.

[123]

Lithuania' s results

Farmers demographics in Lithuanian South Baltic region

The demographic profile of farmers in the South Baltic region of Lithuania reveals several key patterns in terms of gender, age, land size, and farm operations. This data offers important insights into the makeup of the farming population and the distribution of farming activities in the region.

The demographic landscape of farmers in Lithuania' s South Baltic region presents a clear picture of a predominantly male workforce, with 82% of farmers being men and 18% being women, reflecting the gender trends commonly seen in agriculture.

The age distribution shows a significant concentration of farmers in the middle-aged bracket, with 42% aged between 35 and 44 years, followed by equal representation of younger farmers aged 25-34 and older farmers aged 45-54, each making up 20% of the total. This indicates a dynamic mix of relatively young and experienced individuals involved in farming. A smaller proportion of the farming population is over 55, with only 16% aged 55-64 and just 2% above 65 years old, hinting at a gradual generational shift within the sector.

In terms of land size, most farms fall within the small to medium range, with 28% of farmers operating on 101-300 hectares, and 20% working on farms between 51 and 100 hectares. Farms ranging between 26 and 50 hectares represent 18%, while smaller farms, under 10 hectares, account for 16% of the total. Large-scale farms, those exceeding 501 hectares, are relatively rare, with just 4% of the respondents managing such vast areas. This distribution shows that most farms are of a moderate size, contributing significantly to the region' s agricultural output.

The duration for which these farms have been in operation varies, with the largest group, 34.7%, having run their farms for 11-20 years. Newer farms are also prominent, with 28.6% of farmers having worked for 5-10 years, and 16.3% for less than 5 years, highlighting a vibrant mix of both established and newer farmers. A smaller segment of the farming community has been in the field for over 21 years, reflecting long-standing operations that contribute to agricultural continuity in the region.

When examining the focus of agricultural activities, it becomes evident that crop cultivation is the dominant practice, with 58% of farmers engaged in this area. Livestock farming and mixed operations are equally represented at 16%, while 20% of the farms report other specialized activities. This data points to a diverse agricultural landscape, with many farmers engaged in more than one type of farming.

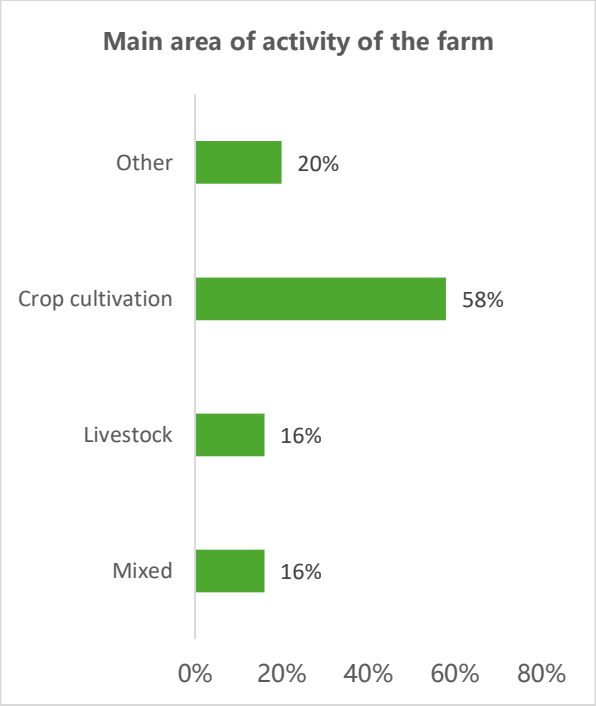


Figure 16

Overall, this data highlights the diversity and balance within Lithuania's farming sector, which integrates newer farmers with experienced operators across a range of farm sizes and activities.

Farms structure, ownership and workforce used

The ownership and workforce dynamics of farms in Lithuania' s South Baltic region reveal a strong preference for individual and family-run operations. Sole proprietorships are the dominant structure, accounting for 60% of the farms, followed closely by private family farms at 38%. Only a small fraction of farms, around 2%, operate as family partnerships, indicating that most decisions and management processes are concentrated within the family unit rather than larger collaborative efforts.

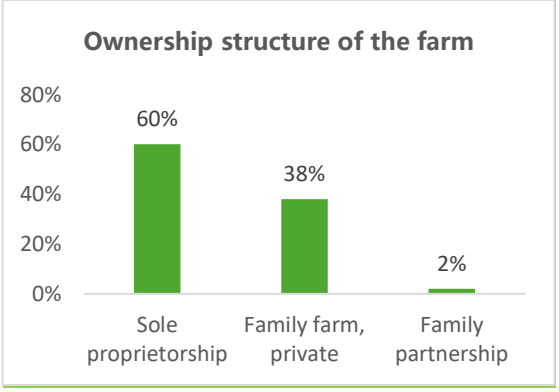


Figure 17

In terms of labor, nearly half of the farms (48%) rely on family members for their workforce, underscoring the importance of family labor in sustaining farm operations. However, 16% of farms are managed solely by the farmer, reflecting a degree of independence in their management approach. A notable 26% of farms utilize a combination of family members and hired labor, balancing internal and external resources to meet their workforce needs. Additionally, 10% of farms exclusively employ hired labor, indicating that a portion of farms may be moving toward more scalable or commercially oriented operations that rely less on family members.

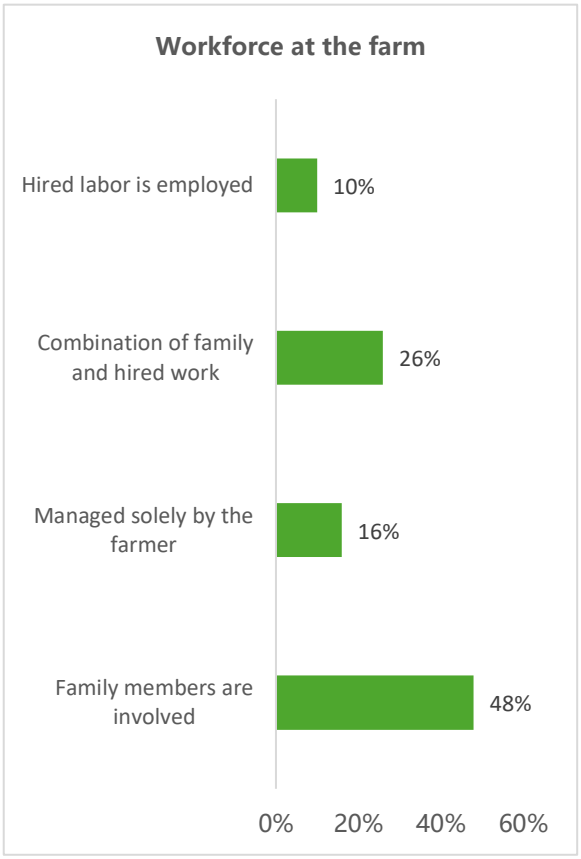


Figure 18

The distribution of land ownership further highlights the autonomy of the farming community, with 59% of respondents owning their property outright, ensuring greater control and long-term security over their operations. Another 39% have a combination of ownership and leasehold arrangements, which may reflect efforts to expand operations or access additional land. A small minority, just 2%, operate on a leasehold basis, suggesting that land leasing is not a widely practiced approach in this region.

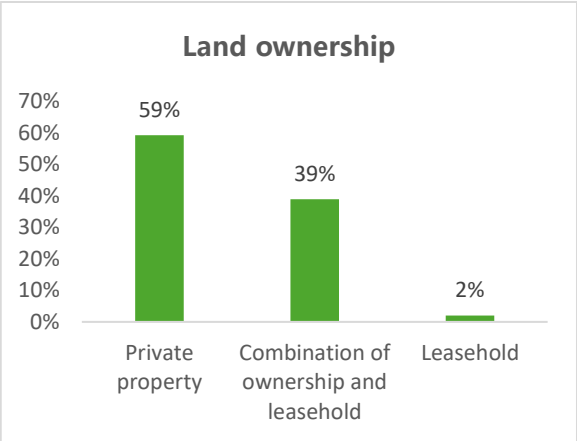


Figure 19

These figures point to a farming community that prioritizes private ownership and family involvement, with flexibility in workforce and land management approaches.

Overview of Sustainable Energy Installations in Lithuania South Baltic Region Farms

This section examines the adoption of renewable energy systems among farmers in Lithuania' s South Baltic region, focusing on the challenges they face, the types of systems used, and the support needed for wider adoption. The data highlights both the barriers preventing farmers from implementing renewable energy and the ongoing issues faced by those who have already made the switch. Some percentages exceed 100% because respondents could select more than one option for certain questions, allowing them to identify multiple challenges or types of support that would help them adopt renewable energy systems.

The data reveals that 38% of farmers in Lithuania' s South Baltic region have installed renewable energy systems on their farms, while 62% have not yet adopted such systems.

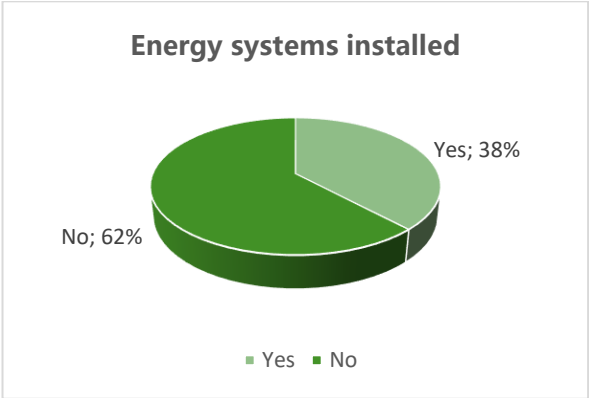


Figure 20

Among those who have, all of them (100%) reported using solar panels, with no adoption of solar thermal energy, geothermal energy, wind turbines, or biomass systems. This indicates a strong preference for solar power over other renewable technologies.

Farmers who installed renewable energy systems faced several implementation challenges, with regulatory or permitting challenges being the most significant, affecting 59% of respondents. High initial costs were also a major obstacle for 32%, followed by technical issues (18%) and a small proportion encountering difficulties in finding qualified installers (5%).

When it comes to ongoing challenges, 22% of farmers reported facing operational issues, while 26% stated they had no such problems. The majority, 52%, indicated that ongoing challenges were not applicable to them, likely because they hadn' t adopted renewable energy systems.

For those who have not adopted renewable energy, the primary barriers are high initial costs (55%) and insufficient government incentives (46%). System reliability concerns affected 18%, while 15% pointed to both limited information and legal issues as

challenges. Lack of technical knowledge was a minor barrier for 6%, and space limitations were reported by 3%.

100% reported using solar panels, with no adoption of solar thermal energy, geothermal energy, wind turbines, or biomass systems

Farmers also highlighted the support they would need to overcome these barriers. Financial incentives or grants were the most requested form of support, identified by 55% of respondents. Government assistance with permits was desired by 43%, while 26% expressed the need for access to reliable information. Technical workshops (13%) and joint initiatives with other farmers (17%) were seen as additional helpful measures.

In conclusion, the data underscores the importance of financial support and streamlined regulatory processes in increasing renewable energy adoption among farmers. Addressing these challenges could lead to broader use of sustainable technologies in the agricultural sector.

Overview of farmers knowledge and perceptions of renewable energy

This data explores how farmers in Lithuania' s South Baltic region acquire information about renewable energy systems, the resources they find valuable, the challenges they encounter, and their interest in knowledge-sharing networks. The data provides insights into the awareness and educational needs of farmers, which are critical for promoting the adoption of sustainable practices in agriculture. Some percentages exceed 100% because respondents could select more than one option for certain questions, allowing them to identify multiple challenges or types of support that would help them adopt renewable energy systems.

When it comes to discovering renewable energy systems, farmers primarily rely on internet searches (42%) and government programs (33%). Additionally, 29% of farmers gain insights from other farmers in their region, while agricultural advisory services contribute to 17% of their knowledge. A small percentage, only 2%, reported having limited knowledge of renewable energy at the farm level, indicating that most farmers are at least somewhat informed about the topic.

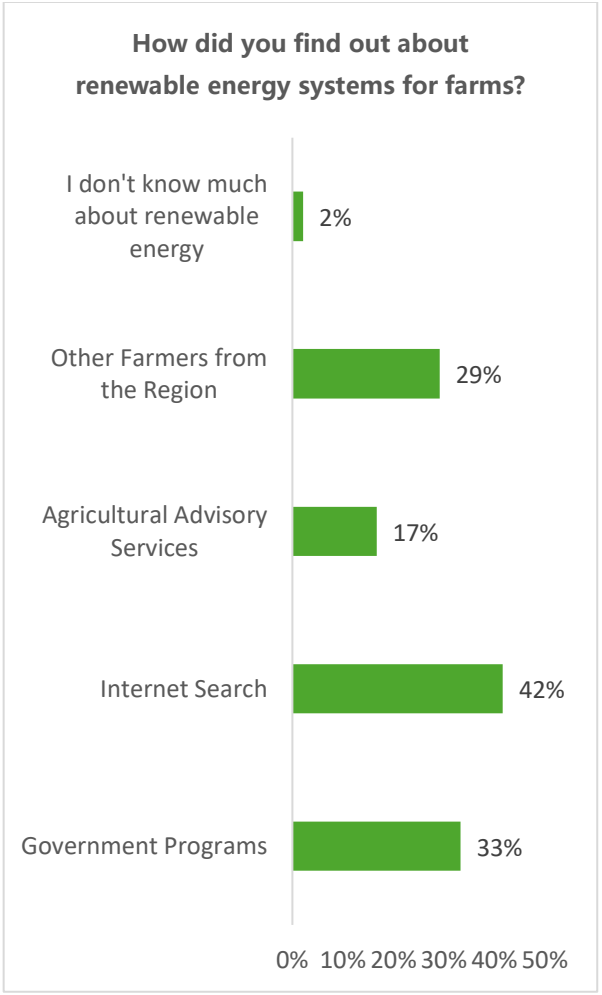


Figure 21

In considering renewable energy options, farmers expressed a strong preference for various sources of information. Demonstrations by other farmers (40%) and workshops and seminars (40%) are viewed as particularly valuable, alongside consultations with experts (33%) and articles and blogs available online (35%). Government publications, while useful, were less sought after, with only 17% of farmers indicating their importance.

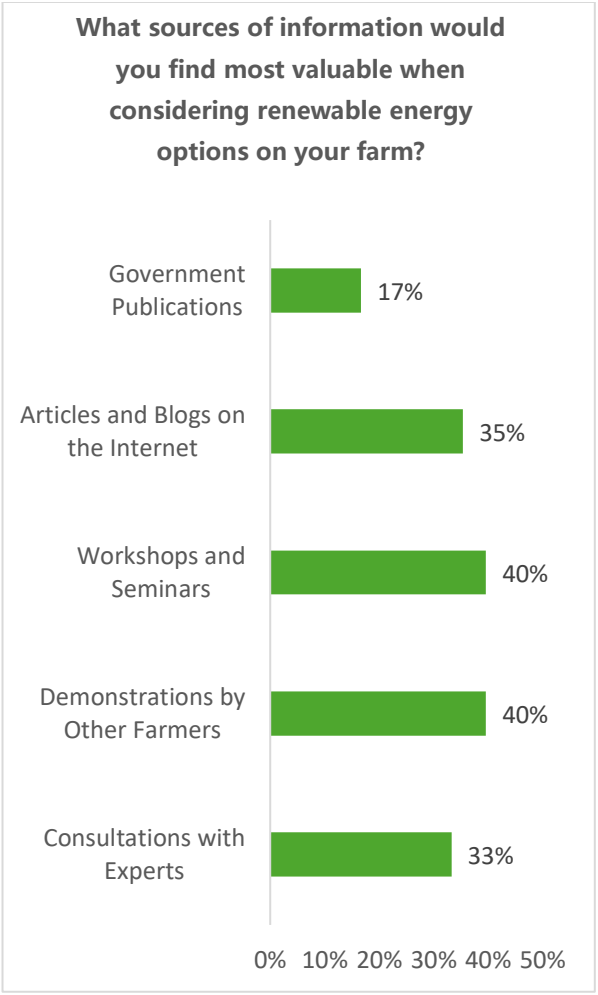


Figure 22

Farmers also identified specific challenges when researching or implementing renewable energy systems. The most significant barrier is the difficulty in distinguishing reliable sources of information, which affects 43% of respondents. Additionally, 32% noted a lack of accessible and understandable information, and 27% pointed to inadequate information regarding financial aspects. There is also a notable gap in understanding available technologies (23%) and maintenance requirements (18%).

Specific challenges or gaps in information that farmers encountered when researching or implementing renewable energy	
Difficulty in distinguishing reliable sources	43%
Inadequate information regarding financial aspects	27%
Lack of accessible or understandable information	32%
Limited information on available technologies	23%
Insufficient information on maintenance requirements	18%
General awareness issues	7%

Table 10

To increase awareness and knowledge among farmers about renewable energy, several initiatives were proposed. Regional workshops and training were seen as crucial by 40% of respondents, as were increased communication activities and broad government information campaigns (40%). Collaboration platforms for information exchange were also valued by 26%, while 30% expressed interest in learning from cases and success stories of local farmers. Educational campaigns within farming communities received support from 13% of respondents.

Table 11

Initiatives or resources that could increase awareness and knowledge of farmers about renewable energy	
Collaboration platforms for information exchange	26%
Regional workshops and training	40%
Cases and success stories of local farmers	30%
Increased communication activities and broad government information campaigns	40%
Educational Campaigns in Farming Communities	13%

Lastly, the data shows a strong interest in knowledge-sharing networks, with 63% of farmers expressing a desire to participate in forums for exchanging information about sustainable energy. Only 12% were not interested, while 26% remained undecided.

In conclusion, the findings highlight the importance of accessible information and practical demonstrations in fostering renewable energy adoption among farmers. Addressing the challenges related to reliable information and creating supportive educational initiatives could significantly enhance the understanding and implementation of sustainable practices in agriculture.

Awareness and Opinions Regarding Government Support for Renewable Energy in Farming

This data examines farmers' awareness and perceptions of government incentives for renewable energy systems in Lithuania' s South Baltic region. The data highlights the influence of these incentives on adoption decisions, the challenges associated with accessing support, and the suggested improvements to enhance governmental assistance. It is important to note that some percentages exceed 100% due to respondents being able to select multiple answers, reflecting the diverse challenges and suggestions provided by the farming community.

A significant 71% of farmers are aware of government incentives or programs aimed at supporting the implementation of renewable energy on their farms.

However, despite this awareness, only 45% indicated that these incentives influenced their decision to adopt renewable energy systems, while a majority of 55% reported that the incentives did not play a role in their choices. This discrepancy suggests that although farmers know about available support, it may not be sufficient to encourage adoption.

Regarding the challenges related to government support, 40% of respondents noted a lack of transparency in incentive programs as a major obstacle. Other significant issues include long and complex application processes (36%), difficulty accessing government support (32%), and insufficient awareness of available programs (20%). Limited financial support was also cited by 20% of farmers, indicating that the perceived inadequacy of these programs may hinder broader adoption of renewable energy.

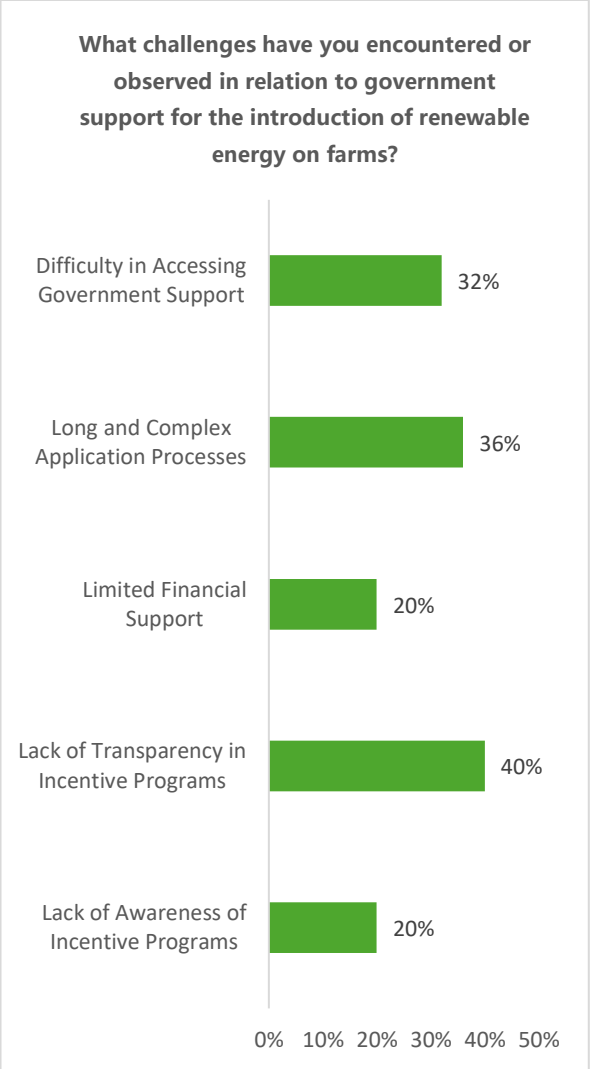


Figure 23

Farmers provided several suggestions for improving government policies and initiatives. The most frequently recommended change is to streamline application processes, with 48% of respondents identifying this as a key area for improvement. Better communication and awareness campaigns (38%) and increased financial incentives or subsidies (34%) are also viewed as essential steps to enhance support for farmers. Additionally, tailored support for small farmers was identified by 34% of respondents, while cooperation programs with agricultural organizations received less attention at 16%.

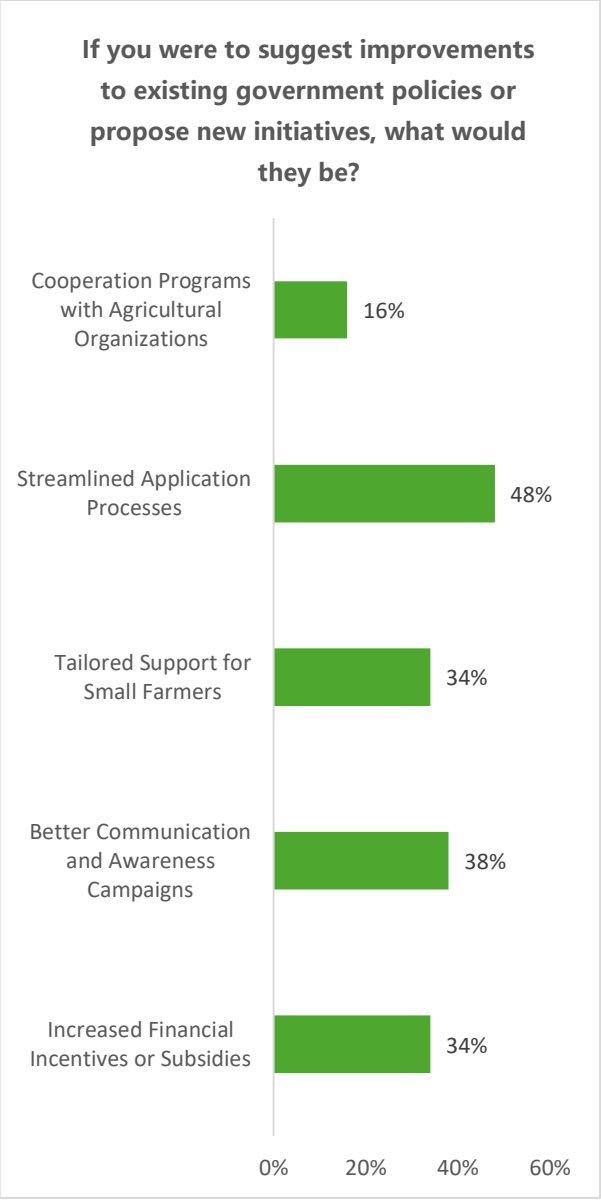


Figure 24

When asked about the effectiveness of current government policies in meeting the diverse needs of farmers regarding renewable energy use, only 12% of respondents expressed confidence in their effectiveness. In contrast, 33% believed the policies did not meet farmers' needs, and a notable 55% remained undecided, suggesting uncertainty about the adequacy of existing support mechanisms.

Finally, there is a strong demand for additional government-funded resources, with 78% of farmers indicating that they would benefit from such assistance related to the regulatory aspects of installing and maintaining renewable energy systems. Only 8% felt they would not benefit, while 14% were undecided.

In conclusion, while there is substantial awareness of government incentives among farmers in the South Baltic region, the actual influence of these incentives on adoption decisions is less pronounced. Addressing the challenges related to transparency, complexity, and financial support, along with implementing the suggested improvements, could significantly enhance the effectiveness of government policies.

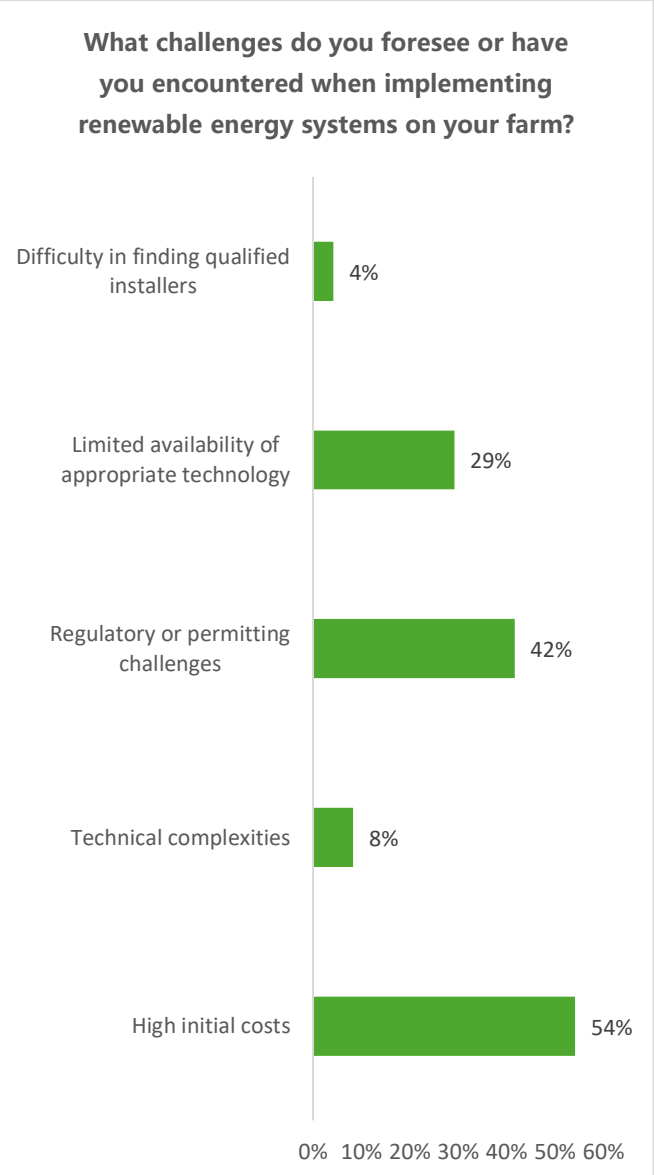
Challenges in installing renewable energy in Lithuania South Baltic region

The survey results explore the challenges faced by farmers in Lithuania' s South Baltic region in implementing renewable energy systems, the benefits they experience from using these technologies, and the resources they believe would help them overcome obstacles. The data provides valuable insights into the current state of renewable energy adoption and the support needed for further integration. It is worth noting that some percentages exceed 100% in certain categories because respondents could select multiple options, reflecting the complex nature of the challenges and support needs faced by farmers in the region.

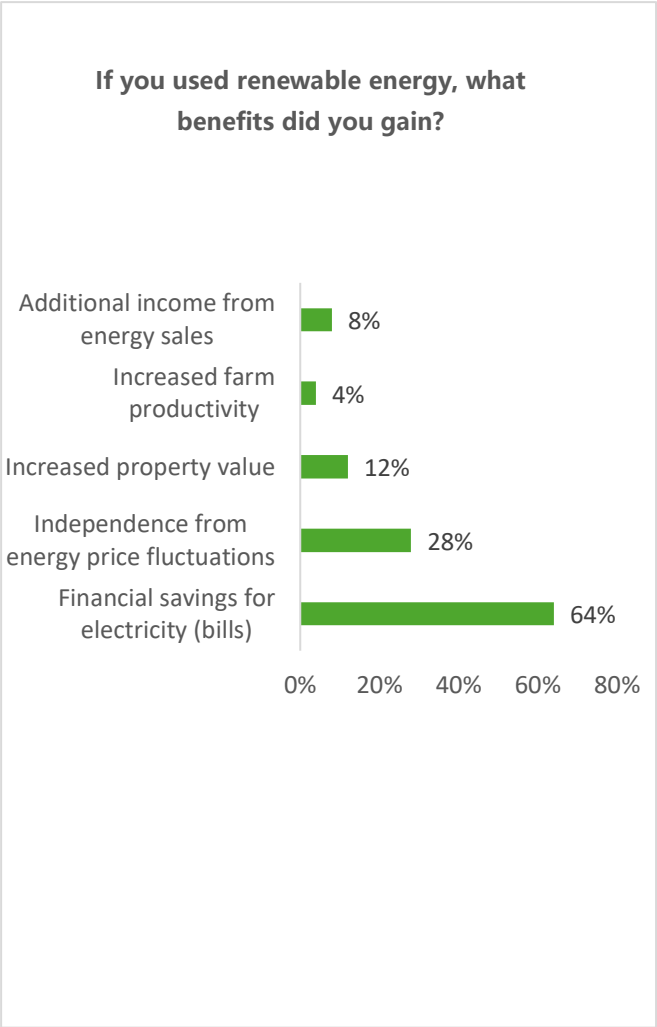
Farmers identified several significant challenges in implementing renewable energy systems. The most pressing issue is high initial costs, cited by 54% of respondents, indicating

that financial barriers remain a substantial hurdle. Regulatory and permitting challenges are also notable, affecting 42% of farmers, while limited availability of appropriate technology was mentioned by 29%. Technical complexities were encountered by a smaller portion of farmers (8%), and only 4% reported difficulty in finding qualified installers. These figures reflect a multifaceted set of barriers that can impede the adoption of renewable energy technologies.

Figure 25



Despite the challenges, those who have adopted renewable energy systems reported several benefits. The most significant advantage cited was financial savings on electricity bills, enjoyed by 64% of respondents. This underscores the economic incentive for farmers to consider renewable energy solutions. Additionally, 28% of farmers noted increased resilience and independence from energy price fluctuations as a key benefit, while 12% experienced an increase in property value. However, only 4% reported increased farm productivity, and a modest 8% indicated additional income from energy sales, suggesting that the primary gains are more immediate and tangible rather than long-term operational improvements.



To address the obstacles they face, farmers highlighted several resources and support mechanisms that could aid in the adoption of renewable energy systems. The most critical need identified is financial aid or grants, which 52% of respondents emphasized as essential. Streamlined regulatory processes were also noted by 47% of farmers, indicating a demand for clearer and more accessible pathways for implementing renewable energy. Access to reliable information and resources was deemed important by 34%, while technical expertise and training were requested by 15%. Joint initiatives with other farmers received support from 13%, indicating a desire for collaboration within the farming community.

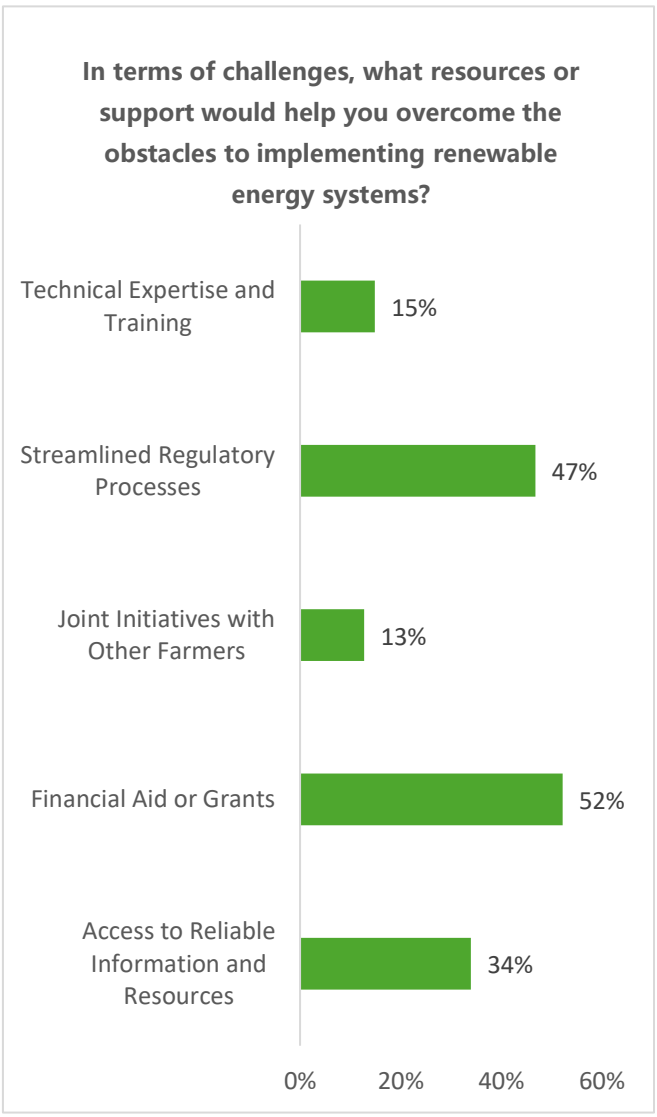


Figure 26 (left), Figure 27 (right)

Regarding the effectiveness of current support structures, only 13% of farmers felt that these frameworks adequately address their diverse challenges and needs concerning renewable energy use. In contrast, 25% expressed dissatisfaction, while a substantial 62% remained undecided, reflecting uncertainty about the adequacy and responsiveness of existing support systems.

Assessing Renewable Energy Engagement and Support Among Farmers in the Lithuanian South Baltic Sea Region

The survey results analyze farmers' perceptions of renewable energy initiatives in Lithuania's South Baltic region, specifically focusing on the awareness of feed-in tariffs, engagement with investors, collective actions among farmers, the use of decentralized generators, interest in feasibility studies, and the presence of legal regulations that support agricultural expansion. The findings reveal a mixed understanding of these factors and highlight areas for improvement in supporting renewable energy adoption.

When asked about the availability of feed-in tariffs for small and large-scale installations, a mere 6% of farmers confirmed their existence, while 35% indicated that no such tariffs are in place. A significant majority, 59%, expressed uncertainty about the presence of feed-in tariffs, suggesting a lack of awareness or communication regarding these financial mechanisms designed to attract investments in renewable energy.

Engagement with potential investors is also limited, with only 37% of farmers currently in talks about implementing or improving renewable energy systems on their farms. Conversely, 63% reported no ongoing discussions with investors, highlighting a gap in collaboration that could hinder the advancement of renewable energy projects in the region.

In terms of collective actions, 67% of farmers indicated that there are joint efforts among farmers to adopt renewable energy solutions, suggesting a willingness to collaborate and share resources.

However, this is somewhat offset by the low engagement in decentralized generators, with only 12% of farmers using such systems throughout the year, indicating a reliance on traditional energy sources.

Interest in conducting feasibility studies to enhance renewable energy usage is notably high, with 67% of farmers expressing a desire to pursue these assessments. This reflects a proactive attitude towards exploring potential improvements in energy efficiency and sustainability on their farms.

Additionally, 52% of respondents confirmed the existence of legal regulations that encourage farmers to expand their businesses or provide incentives, while 48% disagreed, indicating a divided perception on the effectiveness of these regulations.

In conclusion, the data reveals significant gaps in awareness regarding financial incentives like feed-in tariffs and limited engagement with investors, which may impede the adoption of renewable energy systems. While there is strong interest in collaboration and conducting feasibility studies, the low usage of decentralized generators suggests that many farmers remain dependent on conventional energy sources. Enhancing communication about available incentives and fostering investor relationships could be crucial steps toward increasing renewable energy adoption in the region.

Stakeholder Perspectives on Renewable Energy Adoption in the Lithuanian South Baltic Sea Region

In this section, we will explore the perspectives of other stakeholders regarding renewable energy adoption in the Lithuania South Baltic Sea region, informed by the responses to both questionnaire and open-ended questions. Stakeholders include policy makers, energy providers, financial institutions, NGOs, and representatives from research and academia. By analyzing their viewpoints, we can gain a comprehensive understanding of the broader landscape affecting farmers' efforts to implement renewable energy systems, identify potential gaps in support, and recognize collaborative opportunities that may enhance the overall effectiveness of renewable energy initiatives in the region. This stakeholder analysis will help elucidate the interplay between farmers' needs and the roles these entities play in fostering an environment conducive to sustainable energy practices.

Insights from Energy Suppliers on Renewable Energy Services for Farmers in the Lithuanian South Baltic Region

The energy providers in the South Baltic region of Lithuania primarily focus on solar energy production and have been in this business for over a decade. In recent years, there has been a noticeable increase in demand for these services. However, the provider reports limited collaboration with farmers now, citing technical issues such as collector connection failures as the main challenge encountered.

Other energy providers support the integration of renewable energy into Lithuania' s energy ecosystem. For farmers, they primarily offer grid connections for renewable energy systems, including solar and wind installations.

Energy providers believe that all renewable energy technologies could be beneficial for farmers. They stay informed about advancements in the sector through online resources and communication with industry experts.

Currently, there are no specific programs or incentives offered to encourage farmers to adopt renewable energy technologies, and the company has no immediate plans to introduce such initiatives. Their current strategy focuses on maintaining stable electricity supply as stated by the small energy provider.

Large energy providers work closely with farmers throughout the renewable energy adoption process. They provide technical assessments, assist with grid connection applications, and offer guidance on the most efficient ways to integrate renewable energy solutions into their operations. This company ensures that farmers are fully informed about the necessary steps to connect their renewable energy systems to the national grid. Currently incentives have played a crucial role in increasing the adoption of renewable energy among farmers. Financial support from EU and national programs has made renewable energy systems more affordable, helping farmers overcome initial cost barriers. As a result, more farmers are installing

renewable systems and contributing to the country's renewable energy goals.

Overall, while there is significant potential for renewable energy adoption among farmers in the Lithuanian South Baltic region, greater collaboration and tailored programs will be necessary to fully realize these opportunities.

Insights from Financial Institutions' Responses on Supporting Renewable Energy for Farmers in the Lithuanian South Baltic Region

Financial institutions in the South Baltic region of Lithuania provide guarantees and loans to support farmers interested in implementing renewable energy projects. However, they acknowledge that the flexibility of these financial products could be improved to better meet the diverse needs of farmers. Financial risks associated with renewable energy projects are assessed carefully, as is the case with any other investment.

One of the primary objectives is to increase the capacity for green energy production in agriculture, and institutions actively collaborate with energy suppliers, such as "Ignitis Renewables," to facilitate this goal. These financial organizations not only provide loans but also offer consultations on sustainable business opportunities and develop investment loans geared towards green initiatives.

There is a noticeable growth in the demand for such projects, indicating a positive trend in their financial outcomes. While there are no immediate new financial instruments, discussions are ongoing about introducing additional strategies to further encourage farmers to adopt renewable energy. Factors that would influence increased support include the growing importance of green energy and potential adjustments in national policies that align with sustainability goals.

Insights from Research and Academia Responses on Renewable Energy in Agriculture in the Lithuanian South Baltic Region

Research and academic initiatives in the South Baltic region of Lithuania related to renewable energy in agriculture primarily focus on cultivating energy crops on agricultural land. The main goal is to grow biomass, which can help reduce the use of non-renewable resources and increase carbon sequestration in the soil. These efforts involve close collaboration with farmers, policymakers, and other stakeholders, where regular consultations, seminars, and the establishment of demonstration sites are key elements of knowledge exchange.

Practical recommendations for farmers and other practitioners are developed based on research results, although some contributions remain indirect. One of the important outcomes of research has been identifying suitable plant species and clones for energy crop cultivation. However, challenges remain, particularly in determining the economic benefits of such initiatives for farmers, as regional differences significantly influence outcomes.

Future research directions include continuing to identify the optimal species for energy crops and further investigating the most effective technologies. Despite uncertainties

regarding economic impact, the expectation is that ongoing and future research will have a positive effect on farmers, policymakers, and the broader community. Nonetheless, there are still knowledge gaps, particularly regarding the optimization of technologies for renewable energy in agriculture, which require further exploration.

Insights from NGOs Responses on Renewable Energy in Agriculture in the Lithuanian South Baltic Region

Several NGOs across Lithuania are actively involved in various initiatives and programs aimed at promoting the use of renewable energy among farmers. The programs that many of these organizations engage with include those funded by European Union structural funds, such as the Rural Development Program (KPP) and the European Agricultural Fund for Rural Development (EŽŪFKP). These initiatives offer financial support for projects focused on innovation, sustainable farming, and renewable energy adoption. Additionally, national programs such as the Environmental Protection Project Management Agency (APVA) and the National Climate Change Program provide similar financial backing for projects that reduce greenhouse gas emissions and promote renewable energy.

To meet the unique needs of farming communities, these programs are tailored to include technical support and capacity-building activities. NGOs work closely with farmers to implement renewable energy systems such as solar panels, wind turbines, and biogas plants. Farmers benefit from both financial aid and educational campaigns that help them understand the advantages of adopting these technologies. Moreover, the collaboration between farmers and NGOs includes personalized consultations, assistance in project planning, and support in navigating the bureaucratic processes needed to acquire permits and funding.

> Successful initiative involves a berry processing company that installed a biomass boiler, utilizing waste from its production process to generate energy

One of the biggest challenges faced by the NGOs is overcoming the bureaucratic hurdles and financial barriers encountered by farmers. For example, farmer Petras A., who attempted to install a solar energy system on his farm, faced lengthy bureaucratic delays when applying for the necessary permits. This significantly prolonged the project and increased costs. Similarly, young farmer Romas K., who wanted to implement a biogas system, was hindered by a lack of sufficient funding, even with the NGOs help in preparing the necessary financial applications.

Despite these challenges, there are notable success stories. One example is a farming community in Žemaitija, where a farmer named Jonas V. successfully installed solar panels that not only meet his farm's energy needs but also allow him to sell excess energy back to the grid. This project was partially

funded by EU structural funds with the assistance of local NGOs. Another successful initiative involves a berry processing company that installed a biomass boiler, utilizing waste from its production process to generate energy. This project not only reduced the company's energy costs but also contributed to waste reduction and sustainability.

NGOs promote renewable energy at both local and regional levels by organizing seminars and workshops for farmers, where they introduce the benefits of renewable energy technologies and explain the processes involved in implementing them. These educational efforts are often complemented by public information campaigns using media, social networks, and printed materials such as brochures. NGOs also act as intermediaries between farmers and businesses that offer renewable energy solutions, facilitating partnerships that make the adoption of these technologies more accessible.

However, one of the major challenges for NGOs lies in raising awareness and providing farmers with the necessary technical knowledge to adopt renewable energy systems. Many small-scale farmers lack the expertise to independently install and maintain such systems, requiring NGOs to invest substantial time and resources in training and consultation services. Furthermore, many existing support mechanisms are often more accessible to large-scale farms, making it harder for smaller farmers to receive financial aid. NGOs have also struggled with shifting government policies and regulations, which create uncertainty for farmers who may be hesitant to invest in renewable energy due to potential changes in laws that could disrupt their long-term plans.

Innovative approaches have emerged from these challenges. Pilot projects demonstrate the effectiveness of renewable energy technologies on farms, while farm visits to facilities that have successfully implemented such systems allow farmers to see firsthand how these technologies work. By sharing success stories and practical examples through the media and other platforms, NGOs aim to inspire more farmers to embrace renewable energy solutions.

Despite these efforts, NGOs continue to face significant obstacles, particularly related to policy and financial frameworks. NGOs argue that for the adoption of renewable energy to become widespread, policies must be consistent and favorable to farmers, offering them the stability needed to invest in long-term sustainable solutions. One common sentiment among NGOs is that profitability remains the driving factor for farmers when considering renewable energy investments. Farmers must be confident that these investments will pay off in the long run, which requires clear and consistent policy support from the government. Without such support, many farmers remain skeptical about committing to renewable energy projects, despite the long-term environmental and economic benefits.

In conclusion, NGOs play a vital role in promoting renewable energy in agriculture by providing technical support, educational resources, and financial guidance to farmers.

However, the success of these initiatives largely depends on the collaboration between NGOs, government authorities, and farmers, with a particular focus on overcoming the bureaucratic and financial challenges that continue to hinder the wider adoption of renewable energy in the agricultural sector.

Insights from Policymakers' Responses on Promoting Renewable Energy in the Lithuanian South Baltic Region

The current renewable energy policies in the South Baltic Sea region face significant challenges that affect farmers' decisions regarding energy implementation. Farmers express dissatisfaction with short-term programs that impose unreasonable requirements, emphasizing the need for models designed by agricultural stakeholders rather than bureaucrats. State support is crucial to ensure financial viability for biomass production, allowing farmers to operate sustainably.

While there are some advancements, such as the Ministry of Energy providing 30% reimbursements for solar energy installations, purchasing electricity from abroad detracts from local support. Future solar energy project calls present potential opportunities, but success relies on effective collaboration among farmers, energy suppliers, and non-governmental organizations. To enhance the renewable energy landscape, reform and genuine engagement with stakeholders are essential.

[123]

Germany’ s results

Farmers demographics in Germany South Baltic region

The demographic profile of farmers in the South Baltic region of Germany reveals several key patterns in terms of gender, age, land size, and farm operations. This data offers important insights into the makeup of the farming population and the distribution of farming activities in the region.

The gender distribution among respondents in Germany reveals a predominance of male participants, accounting for 76% of the total responses. Female respondents represent 22%, indicating a notable but significantly smaller share. Additionally, 2% of respondents chose not to disclose their gender. This data suggests that male representation in farming and related sectors is dominant, which aligns with trends observed in other regions.

The age distribution among respondents highlights that the largest group falls within the 55-64 years old category, comprising 34% of the total. This is followed by 24% in the 45-54 years old range, indicating a substantial representation of mid-to-late career individuals. The 35-44 years old group

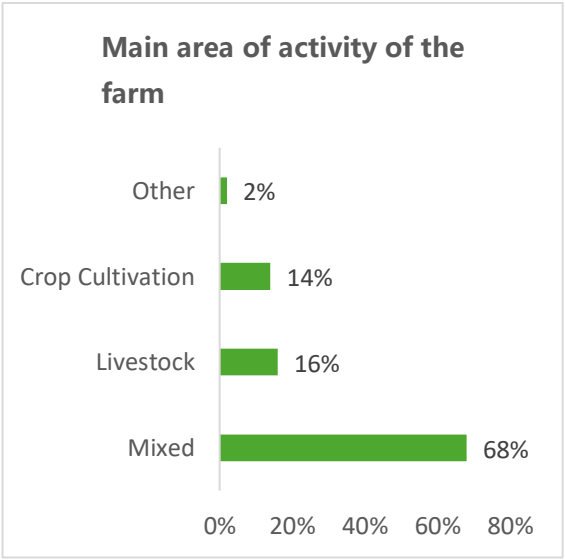
accounts for 18%, reflecting a smaller but significant portion of relatively younger farmers. Meanwhile, those aged 65-74 make up 16%, showing continued activity among older participants, while the youngest group, aged 25-34, represents only 8%. This distribution underscores the aging demographic of farmers, with a noticeable gap in the participation of younger individuals, which could have implications for the future sustainability and generational transition in farming.

The analysis of farm sizes reveals that the majority of respondents, 61%, manage farms larger than 501 hectares, highlighting a strong presence of large-scale operations. Farms sized between 301 and 500 hectares account for 31%, representing a significant portion of medium-sized farms. Smaller farms are less common, with 4% operating on 101-300 hectares, and only 2% each for farms sized 10-25 hectares and less than 10 hectares. This distribution emphasizes the dominance of large and medium-sized farms among the respondents, with minimal representation from smaller-scale agricultural operations. This trend may have implications for resource allocation, management practices, and the adoption of advanced farming technologies.

The analysis of years in business reveals that the largest group of respondents, 42%, have been operating for more than 30 years, showcasing a strong presence of well-established enterprises. Another significant portion, 32%, reported running their businesses for 21-30 years, reflecting substantial experience in their fields. Businesses operating for 11-20 years and 5-10 years each account for 10%, highlighting a balanced representation of mid-term operations. Lastly, 6% of respondents have been running their businesses for less than 5 years, indicating a smaller but notable presence of newer ventures. This distribution underscores the predominance of experienced businesses while also showing some generational continuity with newer entries.

The main activities at the farms show that the majority, 68%, focus on mixed farming, reflecting a combination of various agricultural practices. Livestock farming constitutes 16%, highlighting a significant focus on animal-related activities. Crop cultivation accounts for 14%, representing farms that primarily grow crops as their main output. A smaller portion, 2%, is categorized under "other," which includes specialized activities such as milk production. This distribution underscores the diversity of farming practices, with a predominant emphasis on mixed farming approaches that integrate multiple activities for efficiency and sustainability.

Figure 28



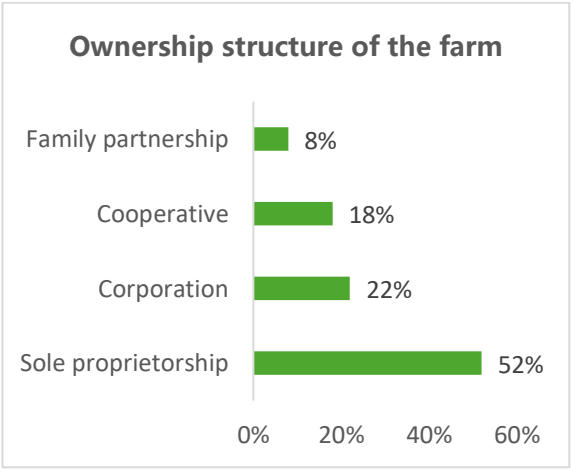
In conclusion, the demographic profile of farmers in Germany's South Baltic region highlights a predominantly male workforce, with a strong focus on mixed farming practices. The age distribution reflects an aging demographic, with many farmers nearing retirement age and limited participation from younger generations, which may pose challenges for generational renewal. The dominance of large-scale farms, alongside well-established operations that have been running for decades, showcases the region's reliance on experienced and expansive farming enterprises. The diversity of farming activities further enriches the agricultural landscape, but targeted initiatives to encourage younger farmers and support smaller-scale operations could help ensure the long-term sustainability of farming in the region.

Farms structure, ownership and workforce used

The demographic analysis of farmers in Germany's South Baltic region continues with an examination of the ownership structure, workforce dynamics, and land ownership characteristics.

The ownership structure of farms in Germany's South Baltic region is predominantly characterized by sole proprietorships, which account for 52% of respondents. Corporations represent 22%, indicating a significant presence of more formalized business structures. Cooperatives, which emphasize collective ownership and shared resources, make up 18%. Lastly, family partnerships account for 8%, showcasing the role of family-operated enterprises in the agricultural landscape. This distribution highlights the diverse organizational models in the region, with a strong inclination toward individual ownership alongside collaborative and formalized structures.

Figure 29



The workforce structure of farms in Germany's South Baltic region shows that 46% of respondents employ hired labor, reflecting a significant reliance on external workers. Additionally, 36% operate with a combination of family members and hired labor, indicating a balanced approach to workforce management. Meanwhile, 18% of farms rely solely on family members for their operations. This distribution highlights the diverse approaches to workforce utilization in the region, with a strong emphasis on integrating hired labor into farm operations.

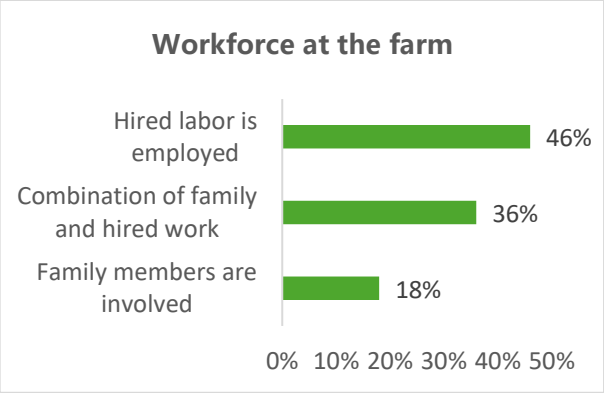


Figure 30

The analysis of real estate arrangements among respondents reveals that the majority, 80%, operate under a combination of ownership and leasehold, reflecting a mixed approach to managing land and property resources. Private property accounts for 18%, showcasing a significant portion of farms relying solely on owned assets. Leasehold arrangements are the least common, representing only 2% of respondents. This distribution highlights the flexibility of combining ownership and leasing as a predominant strategy in managing real estate for farming operations in the region.

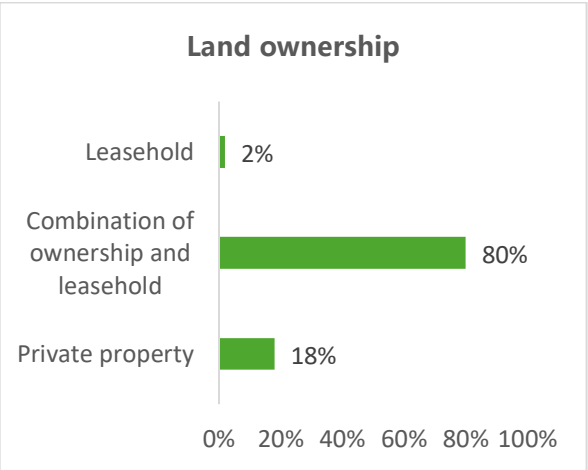


Figure 31

In conclusion, the structural and operational characteristics of farms in Germany's South Baltic region demonstrate a diverse yet predominantly individualistic approach. Sole proprietorships dominate ownership structures, while workforce strategies show a significant reliance on hired labor alongside family involvement. Real estate arrangements further emphasize flexibility, with a majority combining ownership and leasehold. These insights reflect the adaptability and varied organizational models that define farming operations in the region.

Overview of Sustainable Energy Installations in Germany South Baltic Region Farms

This section examines the adoption of renewable energy systems among farmers in Germanys' South Baltic region, focusing on the challenges they face, the types of systems used, and the support needed for wider adoption. The data highlights both the barriers preventing farmers from implementing renewable energy and the ongoing issues faced by those who have already made the switch. Some percentages exceed 100% because respondents could select more than one option for certain questions, allowing them to identify multiple challenges or types of support that would help them adopt renewable energy systems.

The adoption of renewable energy systems among farms in the region is notable, with 74% of respondents confirming the installation of such systems. This indicates a strong commitment to sustainable energy practices within the agricultural sector. However, 26% of farms have not yet installed renewable energy systems, highlighting potential opportunities for further adoption and support to encourage wider

implementation. These results underscore the growing integration of renewable energy in farming operations while also pointing to areas where additional efforts may be needed.

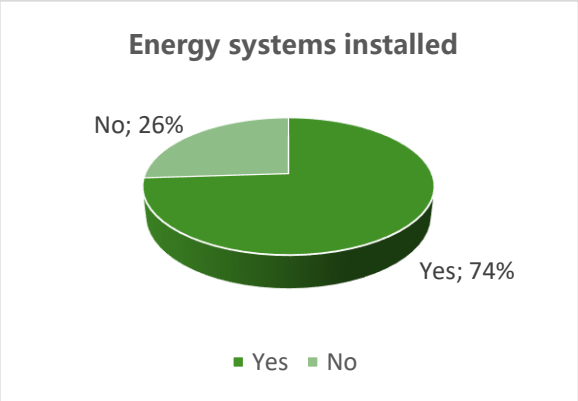


Figure 32

The analysis of renewable energy systems installed on farms shows that solar panels dominate the landscape, with 54% of respondents utilizing this technology. Biomass energy accounts for 33%, highlighting its versatility and popularity. Wind turbines are also a notable contributor, used by 9% of farms. Less commonly adopted systems include solar thermal energy and geothermal energy, each making up 2%. This distribution underscores the strong reliance on solar and biomass energy systems, while smaller-scale technologies remain less prevalent.

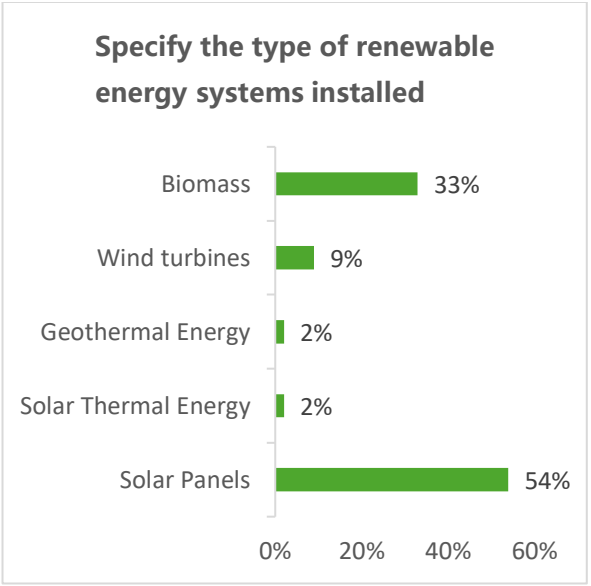


Figure 33

The rollout of renewable energy systems on farms has faced a variety of challenges. The most significant barrier, reported by 26% of respondents, is high initial installation costs, closely followed by regulatory or approval challenges at 23%. Technical difficulties were noted by 13%, while 11% highlighted regulatory or permitting challenges as a key issue. A further 7% of respondents experienced difficulties in finding qualified installers, with an additional 4% reporting challenges related to skill shortages. Other less common issues, including limited availability of suitable technology, funding proposals, and mindset-related barriers, collectively account for 14%. These findings emphasize the financial, regulatory, and technical obstacles that farms encounter when adopting renewable energy systems.

The analysis of challenges in maintaining or operating renewable energy systems reveals that 44% of respondents are not facing any ongoing issues, indicating smooth integration for a substantial portion of farms. However, 34% report experiencing challenges,

highlighting significant barriers that still affect a considerable number of operations. Additionally, 22% of respondents indicated that the question was not applicable to their situation, reflecting varying levels of engagement with renewable energy systems. These findings demonstrate that while many farms have successfully implemented renewable energy systems, targeted support may be needed to address the difficulties faced by a notable segment of respondents.

The specific challenges encountered in maintaining or operating renewable energy systems highlight key barriers faced by farms. High maintenance costs are the most frequently reported issue, affecting 43% of respondents, followed closely by technical problems, which impact 33%. Legal or regulatory challenges were noted by 19%, reflecting the complexities of compliance and approvals in the sector. Additionally, 5% of respondents identified difficulties in procuring spare parts as a challenge, emphasizing supply chain limitations. These findings underscore the need for financial support, technical assistance, and streamlined regulatory processes to enhance the efficiency and sustainability of renewable energy systems on farms.

The analysis of additional support needed for adapting renewable energy systems highlights several key areas of focus. Financial incentives or grants are the most commonly requested form of support, mentioned by 40% of respondents, emphasizing the importance of reducing upfront costs. Assistance with government permits is another significant need, noted by 19%, alongside access to reliable information and resources, cited by 15%. Technical workshops and training are requested by 8% of respondents, while 7% seek more comprehensive assistance with permits. Joint initiatives with other farmers (6%) and government-led support for permits (5%) also emerged as valuable avenues for collaboration and facilitation. These findings underscore the importance of financial aid, streamlined regulatory processes, and knowledge-sharing initiatives to encourage broader adoption of renewable energy systems.

In conclusion, the adoption of renewable energy systems among farmers in Germany's South Baltic region demonstrates significant progress but also highlights persistent challenges and areas for improvement. While the majority of farms have embraced renewable energy, high installation costs, regulatory hurdles, and technical difficulties remain major barriers. Maintenance challenges, such as high costs and technical issues, further complicate operations for some. The findings underscore the importance of financial incentives, streamlined regulatory processes, and access to reliable information and training to support broader adoption and long-term success of renewable energy systems in the agricultural sector.

Overview of farmers knowledge and perceptions of renewable energy

This data explores how farmers in Germany' s South Baltic region acquire information about renewable energy systems, the resources they find valuable, the challenges they encounter, and their interest in knowledge-sharing networks. The data provides insights into the awareness and educational needs of farmers, which are critical for promoting the adoption of sustainable practices in agriculture. Some percentages exceed 100% because respondents could select more than one option for certain questions, allowing them to identify multiple challenges or types of support that would help them adopt renewable energy systems.

The analysis of awareness sources for renewable energy systems highlights that the most common methods of learning about these technologies are through Internet searches (33%) and interactions with other farmers from the region (30%). Government programs account for 14% of the awareness sources, while agricultural advisory services contribute 12%. Notably, 11% of respondents indicated that they are not familiar with renewable energy at the farm level. These findings underscore the importance of both digital resources and peer networks in spreading awareness, while also suggesting a need for enhanced outreach through government and advisory channels to reach those who are less informed.

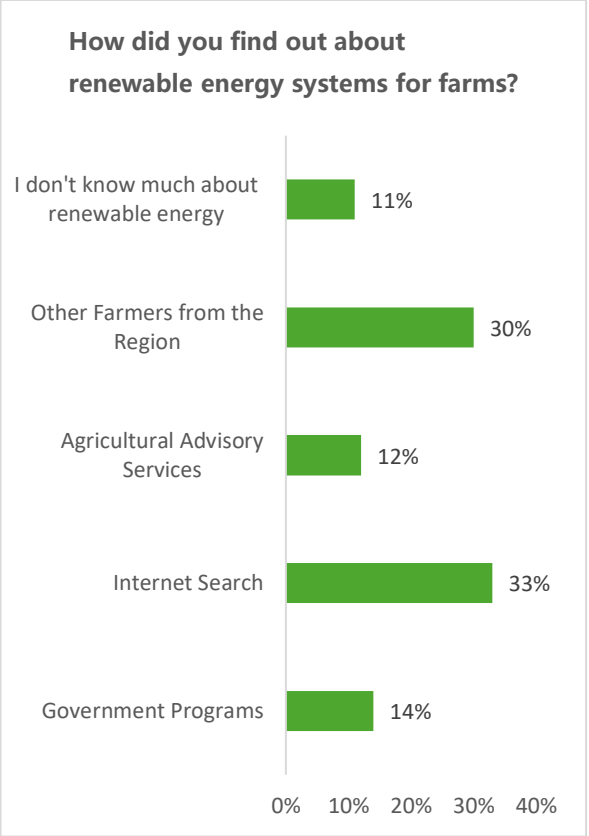


Figure 34

The analysis of valuable sources of information for renewable energy options highlights that expert advice is the preferred source, cited by 37% of respondents. Demonstrations by other farmers and online articles or blogs are equally valued, each accounting for 24%, reflecting the importance of both peer examples and digital resources. Government publications are considered valuable by 11% of respondents, while workshops and seminars are noted by 4%. These findings emphasize the importance of combining professional expertise, peer networks, and accessible online resources to effectively support farmers in exploring renewable energy options.

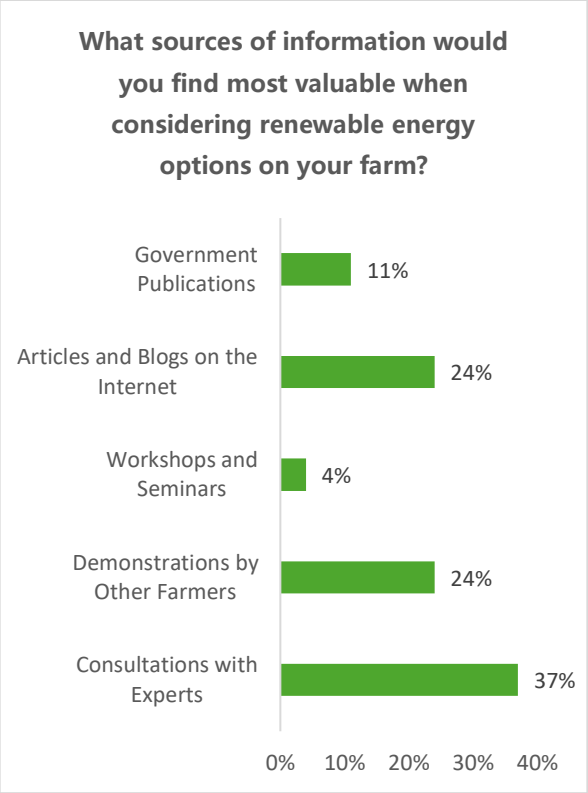


Figure 35

The analysis of challenges and information gaps faced by farmers exploring renewable energy systems reveals several key barriers. The most significant issue is insufficient information on financial aspects, cited by 39% of respondents highlighting the need for clearer guidance on costs and funding opportunities. Lack of accessible and understandable information affects 21% of respondents, while 18% report insufficient information on maintenance requirements. Difficulty distinguishing reliable sources and limited information on available technologies are each noted by 8%, pointing to the need for trustworthy and comprehensive resources. Additionally, 7% of respondents identified general awareness issues, including planning and approval challenges. These findings emphasize the importance of addressing both technical and informational barriers to support farmers in adopting renewable energy solutions.

Specific challenges or gaps in information that farmers encountered when researching or implementing renewable energy	
Difficulty in distinguishing reliable sources	8%
Inadequate information regarding financial aspects	38%
Lack of accessible or understandable information	21%
Limited information on available technologies	8%
Insufficient information on maintenance requirements	18%
General awareness issues	7%

Table 12

The analysis of key initiatives to enhance awareness and knowledge of renewable energy systems among farmers highlights several priorities. Cases and success stories of local farmers stand out at 27%, demonstrating the importance of relatable examples that showcase tangible benefits and practical applications. Educational campaigns in farming communities, increased communication activities and broad government information campaigns, and collaboration platforms for information exchange are equally valued at 19% each, reflecting a strong demand for targeted education, clear communication strategies, and opportunities for peer-to-peer knowledge-sharing. Lastly, regional workshops and training account for 16%, emphasizing the need for hands-on, localized learning experiences to address specific challenges. Together, these initiatives present a comprehensive approach to improving renewable energy adoption within the farming sector.

Initiatives or resources that could increase awareness and knowledge of farmers about renewable energy	
Collaboration platforms for information exchange	19%
Regional workshops and training	16%
Cases and success stories of local farmers	27%
Increased communication activities and broad government information campaigns	19%
Educational Campaigns in Farming Communities	19%

Table 13

The analysis of farmers' interest in participating in knowledge exchange networks or forums on renewable energy adaptation reveals a strong inclination towards collaboration. A majority, 54% of respondents, expressed interest in joining such initiatives, highlighting the value they see in shared learning and experiences. However, 30% of respondents indicated concerns or uncertainty, categorized as "unsafe," suggesting that more assurance or information may be needed to address hesitations. Meanwhile, 16% of respondents stated they are not interested in participating. These findings underline the importance of creating accessible, secure, and supportive platforms to encourage broader farmer engagement in knowledge-sharing networks. In conclusion, this section highlights the critical role of awareness, education, and collaboration in promoting renewable energy adoption among farmers in Germany' s South Baltic region. Farmers primarily rely on internet searches and peer networks for information, emphasizing the importance of digital resources and community interactions. Expert advice and demonstrations by other farmers are among the most valued sources of information, further underscoring the need for professional expertise and peer learning. Key barriers, including insufficient financial information and challenges in accessing understandable resources, reflect the necessity for clearer guidance and targeted support. Initiatives such as success stories, educational campaigns, government-led communication, and collaboration platforms are vital to improving knowledge and awareness. The strong interest in knowledge exchange networks, expressed by over half of respondents, further highlights the potential for fostering community-driven learning and engagement in renewable energy practices.

Awareness and Opinions Regarding Government Support for Renewable Energy in Farming

This data examines farmers' awareness and perceptions of government incentives for renewable energy systems in Germany' s South Baltic region. The data highlights the influence of these incentives on adoption decisions, the challenges associated with accessing support, and the suggested improvements to enhance governmental assistance. It is important to note that some percentages exceed 100% due to respondents being able to select multiple answers, reflecting the diverse challenges and suggestions provided by the farming community.

A significant 71% of farmers are aware of

government incentives or programs aimed at supporting the implementation of renewable energy on their farms.

The analysis of responses regarding the influence of government incentives on the adoption of renewable energy systems reveals a nearly even split. Approximately 49% of respondents indicated that these incentives influenced their decision to adopt renewable energy systems, while 51% stated that they were not influenced by them. This highlights the varied impact of government incentives and suggests the need for more targeted approaches to encourage broader adoption among farmers.

A significant 71% of farmers are aware of government incentives or programs aimed at supporting the implementation of renewable energy

The analysis of challenges related to government support for renewable energy adoption on farms highlights several key barriers. Limited financial support emerges as the most significant issue, affecting 27% of respondents, followed by long and complex application processes, which account for 20%. Difficulty in accessing government support was reported by 14% of respondents, while 11% cited a lack of transparency in incentive programs. Insufficient awareness of available programs was noted by 9%, underscoring the need for better communication and outreach efforts. Additionally, 19% of respondents mentioned other unspecified challenges, reflecting a range of diverse issues. This data emphasizes the importance of simplifying processes, increasing transparency, and improving financial and informational support to enhance the effectiveness of government initiatives.

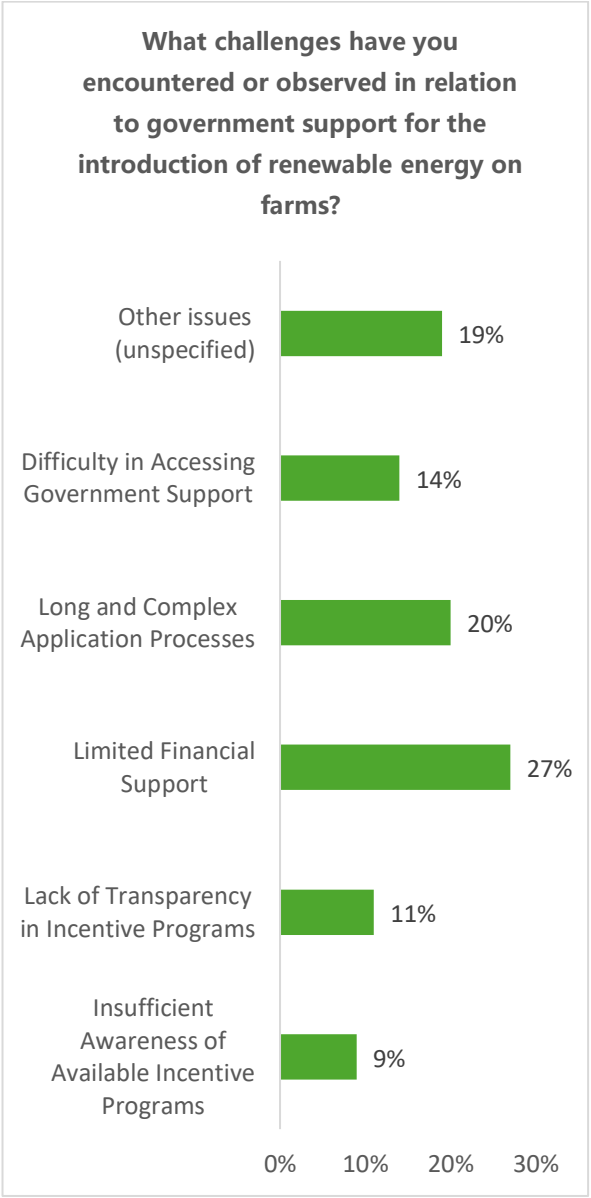


Figure 36

Farmers in Germany' s South Baltic region have expressed clear preferences for improving government policies or proposing new initiatives to support renewable energy adoption on farms. The most commonly suggested improvement is increased financial incentives or subsidies, highlighted by 42% of respondents, emphasizing the need for enhanced financial support. Streamlined application processes follow at 25%, underscoring the importance of simplifying bureaucratic hurdles. Better communication and awareness campaigns are suggested by 18% of respondents, reflecting a demand for clearer and more accessible information. Tailored support for small farmers accounts for 9%, pointing to the necessity of addressing the specific needs of smaller-scale operations. Finally, 6% of respondents advocate for cooperation programs with agricultural organizations, highlighting the value of collaborative efforts in fostering renewable energy adoption.

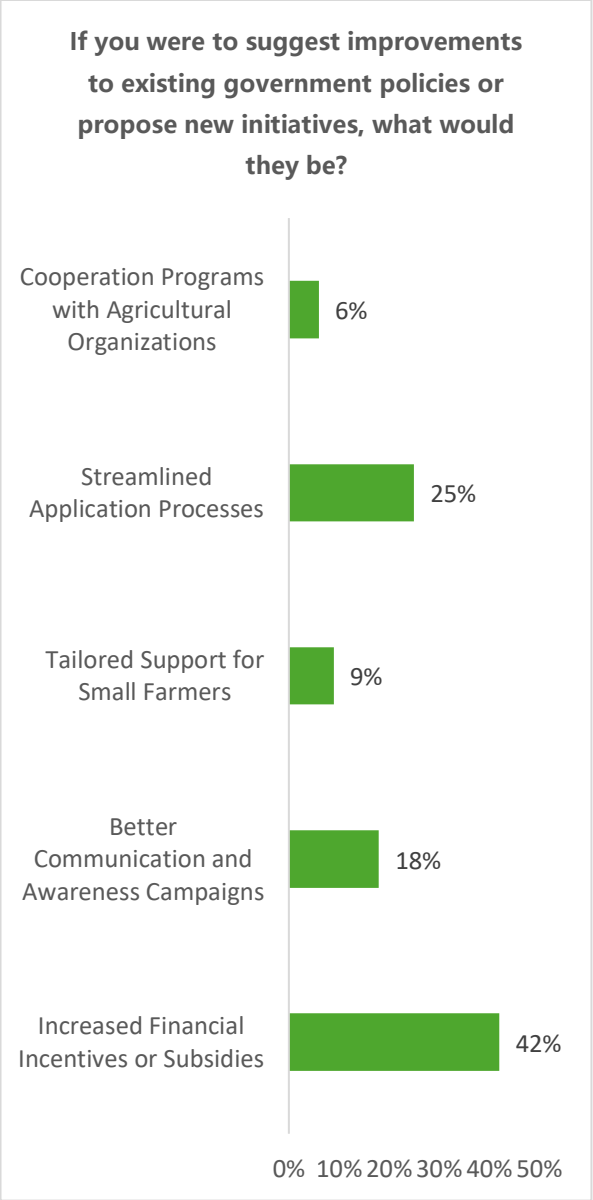


Figure 37

The analysis of responses regarding the effectiveness of current government policies in addressing the diverse needs of farmers in the Southern Baltic Sea region reveals notable dissatisfaction and uncertainty. Only 4% of respondents believe that the policies are effectively meeting the needs of farmers, while a significant majority, 55%, expressed that the policies do not meet their requirements. Additionally, 41% of respondents are undecided, indicating uncertainty or a lack of clear information regarding the effectiveness of current policies.

These results highlight a pressing need for enhanced policy measures, improved communication, and targeted initiatives to address the specific challenges faced by farmers in the region regarding renewable energy adoption.

The data indicates a strong interest among farmers in additional government-funded resources or assistance to navigate regulatory challenges related to renewable energy systems. Specifically, 46% of respondents believe they would benefit from such support, underscoring the significant demand for targeted financial or procedural aid. Meanwhile, 6% of respondents feel they would not benefit, suggesting that some farmers may already have the necessary resources or face minimal regulatory challenges. A notable 48% of respondents remain undecided, reflecting either a lack of familiarity with the topic or uncertainty about how government assistance could address their needs. These findings highlight the importance of clear communication and tailored government initiatives to meet farmers' expectations and reduce barriers to adopting renewable energy systems.

In conclusion, the data reveals a mixed awareness and perception of government support for renewable energy adoption among farmers in Germany's South Baltic region. While a significant majority are aware of available incentives, the influence of these programs on adoption decisions remains divided. Key challenges, such as limited financial support, complex application processes, and insufficient transparency, highlight areas for improvement in government initiatives. Farmers emphasize the need for increased financial incentives, streamlined processes, and better communication to address their concerns effectively. Furthermore, the low confidence in the effectiveness of current policies underscores the importance of tailoring government efforts to meet the diverse needs of farmers, while the strong interest in additional support reflects the opportunity to enhance adoption through targeted measures and improved outreach.

Challenges in installing renewable energy in Germany South Baltic region

The survey results explore the challenges faced by farmers in Germanys' South Baltic region in implementing renewable energy systems, the benefits they experience from using these technologies, and the resources they believe would help them overcome obstacles. The data provides valuable insights into the current state of renewable energy adoption and the support needed for further integration. It is worth noting that some percentages exceed 100% in certain categories because respondents could select multiple options, reflecting the complex nature of the challenges and support needs faced by farmers in the region.

The primary challenges identified by farmers in implementing renewable energy systems on their farms are high initial costs, reported by 35% of respondents, reflecting the significant financial barrier to entry. Regulatory or permitting challenges were highlighted by 28%, indicating the complexity and length of approval processes as a

substantial obstacle. Technical complexities were cited by 19% of respondents, emphasizing the operational and technical hurdles associated with renewable energy systems. Additionally, 12% reported difficulty in finding qualified installers, underlining the importance of skilled labor in supporting renewable energy adoption. Lastly, 6% mentioned the limited availability of appropriate technology, signaling the need for broader access to innovative and suitable solutions to meet diverse farm needs. These findings underscore the multifaceted nature of challenges faced by farmers in adopting renewable energy systems and highlight key areas for improvement in support and infrastructure.

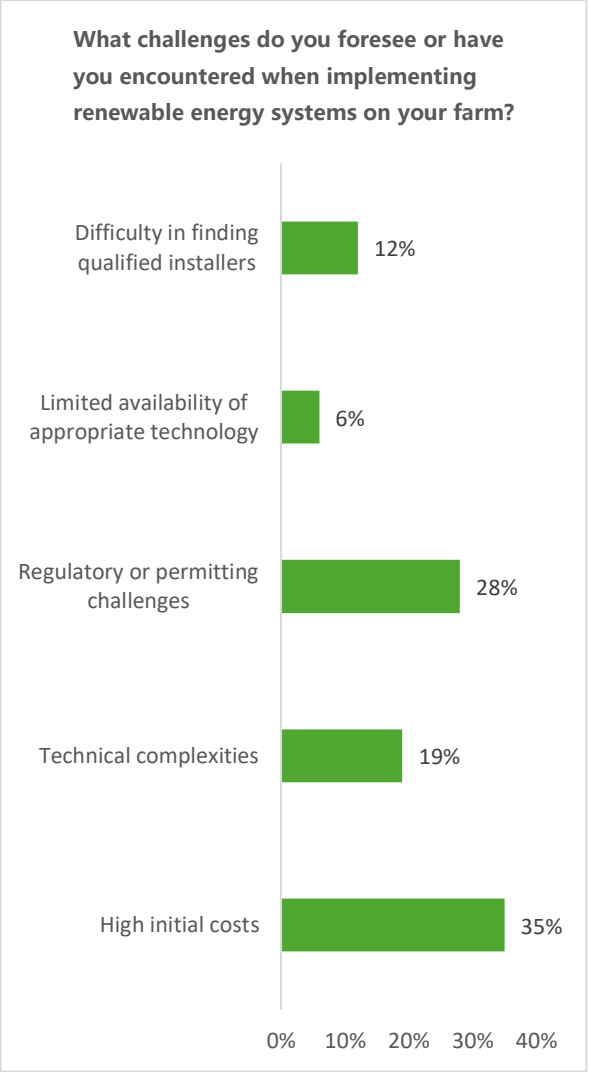


Figure 38

The adoption of renewable energy systems on farms has yielded a range of significant benefits for farmers in the South Baltic region. The most reported advantage, cited by 59% of respondents, is financial savings on electricity bills, highlighting the cost-effectiveness of renewable energy in reducing operational expenses. Additional income from energy sales emerged as another key benefit, noted by 21% of respondents, demonstrating the potential for renewable energy systems to provide diversified revenue streams. Increased resilience and independence from energy price fluctuations were acknowledged by 9% of farmers, underscoring the value of

stable energy costs in an unpredictable market. Furthermore, 6% of respondents reported increased property value as a direct benefit, reflecting the long-term investment potential of renewable systems. Lastly, 5% of farmers indicated improved farm productivity, showcasing the broader operational advantages associated with renewable energy adoption. These findings highlight the economic and strategic benefits of renewable energy for modern agriculture.

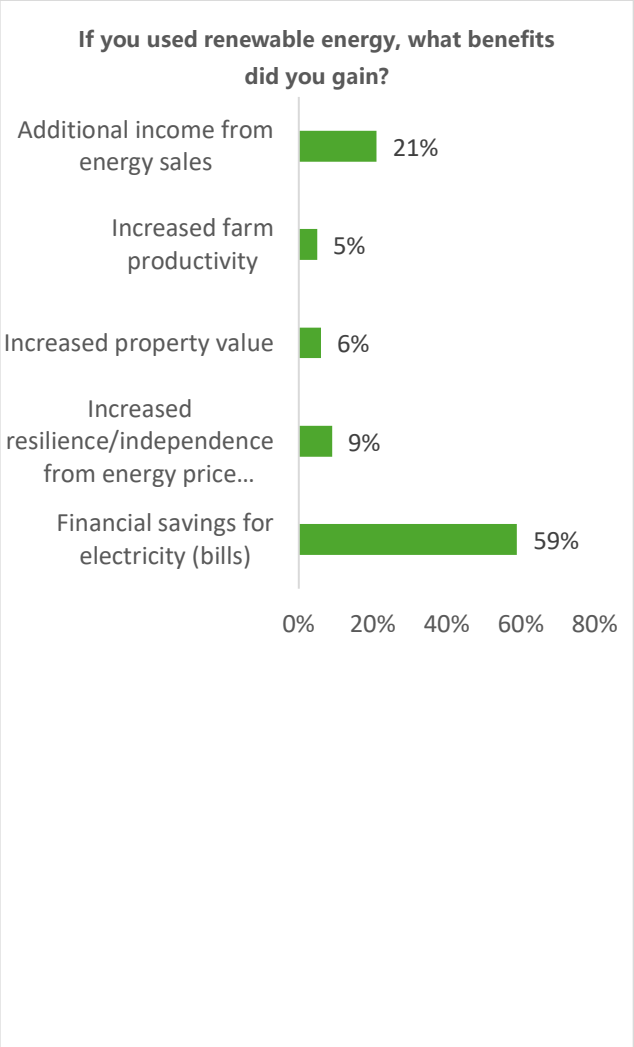


Figure 39

The analysis highlights the key resources and support needed to overcome challenges in implementing renewable energy systems on farms. Financial aid or grants stand out as the most critical requirement, with 61% of respondents emphasizing their importance in addressing cost-related barriers. Streamlined regulatory processes are also seen as a significant enabler, cited by 21% of respondents, underscoring the need to simplify bureaucratic hurdles. Access to reliable information and resources mentioned by 9% reflects a demand for clear and accessible guidance to make informed decisions. Technical expertise and training, noted by 7%, indicate the value of knowledge-building to navigate technical complexities. Lastly, 2% of respondents see joint initiatives with other farmers as a potential avenue for collaboration and shared learning to support renewable energy adoption.

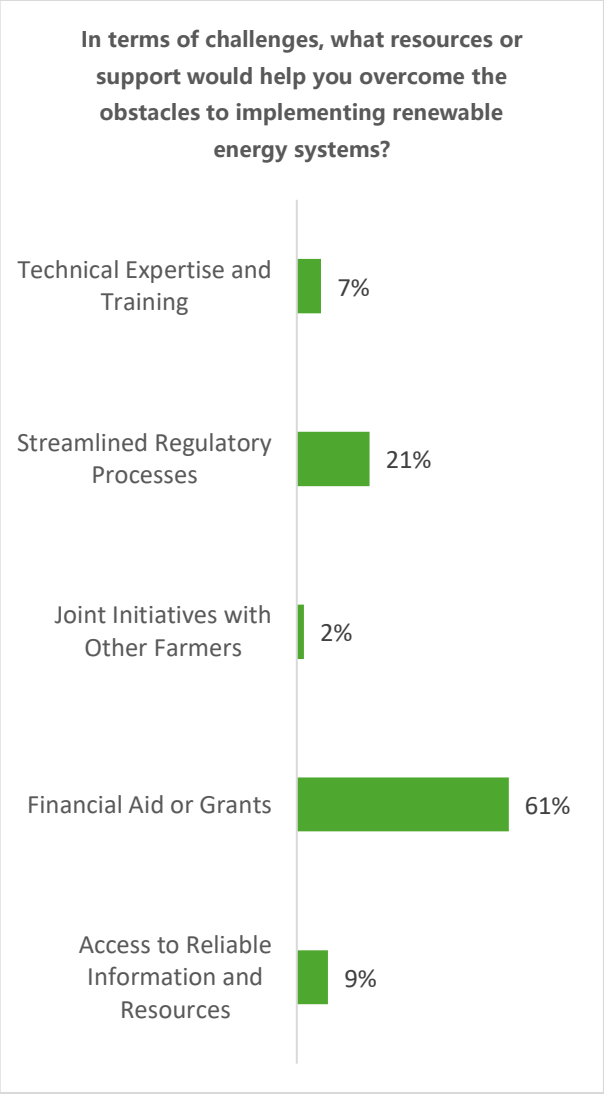


Figure 40

The data reveals significant dissatisfaction with the current support structures addressing the challenges and needs of farmers in the Southern Baltic Sea region concerning renewable energy adoption. Only 2% of respondents believe these structures are effective, indicating a severe lack of confidence in the existing systems. A majority, 67%, express that the support is inadequate, highlighting widespread discontent and unmet needs among farmers. Meanwhile, 31% of respondents remain undecided, reflecting either a lack of information or uncertainty about the impact of the current support mechanisms. These findings underscore the urgent need for revising and improving support systems to better align with the diverse challenges faced by farmers in adopting renewable energy solutions.

Assessing Renewable Energy Engagement and Support Among Farmers in the Germany' s South Baltic Sea Region

The survey results analyze farmers' perceptions of renewable energy initiatives in Germany's South Baltic region, specifically focusing on the awareness of feed-in tariffs, engagement with investors, collective actions among farmers, the use of decentralized generators, interest in feasibility studies, and the presence of legal regulations that support agricultural expansion. The findings reveal a mixed understanding of these factors and highlight areas for improvement in supporting renewable energy adoption.

The data reveals that a significant majority of respondents, 70%, are aware of the presence of feed-in tariffs for small and large-scale renewable energy installations, aimed at attracting investors to lease roofs or land. This indicates a high level of awareness about financial incentives supporting renewable energy adoption. However, 24% of respondents stated that they have no idea about the existence of such tariffs, highlighting a need for improved communication or outreach efforts to inform stakeholders about available support mechanisms. A small proportion, 6%, indicated that no such tariffs exist, suggesting some confusion or regional disparities in awareness or availability of feed-in tariff schemes. These findings emphasize the

importance of ensuring that all stakeholders are adequately informed about policy tools designed to encourage renewable energy investments.

The data reveals that 54% of respondents are not currently engaged in discussions with investors regarding the implementation or expansion of renewable energy systems on their farms. However, a significant 46% of farmers indicated that they are in talks with potential investors. This suggests a growing interest in renewable energy projects among a considerable portion of the farming community, despite a slight majority not yet pursuing such opportunities. These findings highlight the potential for further collaboration and investment in renewable energy within the region.

The analysis reveals a relatively balanced perspective regarding collective efforts by farmers in the region to introduce renewable energy systems. While 45% of respondents acknowledge the existence of such collaborative initiatives, a slightly higher proportion, 55%, indicate that no collective efforts are underway. This distribution highlights a notable level of regional cooperation but also points to room for improvement in fostering collective action among farmers. Promoting collaboration could enhance the efficiency and effectiveness of renewable energy adoption, leveraging shared resources and knowledge to overcome common challenges.

The analysis of responses regarding the reliance on distributed generators throughout the year reveals that a majority of respondents, 67%, indicated they do not use such systems, while 33% reported that they do rely on distributed generators. This suggests that while a significant portion of farmers do not depend on additional power generation systems, there is a notable minority that integrates these resources into their energy strategies. These findings highlight the varied approaches to energy management within the farming community, with some leveraging distributed generators to address specific energy needs or mitigate potential shortages.

The survey results indicate a divided stance among farmers regarding participation in a feasibility study to improve their renewable energy situation. While 40% of respondents expressed willingness to participate in such a study, highlighting an openness to explore opportunities for optimizing renewable energy use, a majority of 60% declined. This reluctance may reflect skepticism about the potential benefits, concerns about the process, or a lack of awareness about how such studies could address their specific challenges. These findings suggest a need for targeted outreach and education to emphasize the value of feasibility studies in enhancing renewable energy practices on farms.

The data indicates that a significant majority, 90% of respondents, acknowledge the presence of legal regulations or past incentives specifically designed to encourage farmers to expand their activities in the field of renewable energy. This highlights a strong historical or ongoing commitment to promoting renewable energy adoption within the agricultural sector. However, 10% of respondents reported no awareness of such

regulations or incentives, suggesting that while policies exist, their reach or impact may not have been universally felt among all farmers. This underscores the importance of ensuring that regulations and incentives are both accessible and effectively communicated to maximize their benefits.

In conclusion, the survey results highlight both progress and challenges in renewable energy adoption among farmers in Germany's South Baltic region. While awareness of feed-in tariffs and the presence of legal regulations is strong, gaps in communication and engagement remain evident. The data underscores the need for enhanced outreach, better promotion of collaborative efforts, and targeted education to address farmers' diverse energy strategies and willingness to participate in initiatives like feasibility studies. Strengthening these areas could significantly advance renewable energy adoption and optimize its benefits for the agricultural sector.

Stakeholder Perspectives on Renewable Energy Adoption in the German South Baltic Sea Region

In this section, we will explore the perspectives of other stakeholders regarding renewable energy adoption in the Germany South Baltic Sea region, informed by the responses to both questionnaire and open-ended questions. Stakeholders include policy makers, energy providers, financial institutions, NGOs, and representatives from research and academia. By analyzing their viewpoints, we can gain a comprehensive understanding of the broader landscape affecting farmers' efforts to implement renewable energy systems, identify potential gaps in support, and recognize collaborative opportunities that may enhance the overall effectiveness of renewable energy initiatives in the region. This stakeholder analysis will help elucidate the interplay between farmers' needs and the roles these entities play in fostering an environment conducive to sustainable energy practices.

Insights from Energy Suppliers on Renewable Energy Services for Farmers in the Germany South Baltic Region

Energy suppliers in the Germany South Baltic Region play a pivotal role in supporting farmers with renewable energy solutions by providing services such as delivery and purchase contracts for substrates and digestates, managing organic fertilizer databases, and analyzing substrates for targeted applications. They also offer consulting on funding programs to help farmers navigate available incentives. The demand for these services varies based on factors like farm size, existing collaborations, and business focus, making it essential for energy providers to tailor their support. Opportunities for value creation are actively identified within the circular economy by developing interfaces for integrating agricultural byproducts into renewable energy systems.

Suppliers face challenges such as farmers' limited assessment of their production capacities, the dependence on unpredictable weather conditions, and regional and global

market influences. To overcome these obstacles, collaboration with universities and research institutions has been instrumental, as it drives innovation and supports in-house research and development. Emerging technologies, such as the differentiated use of digestates with specific nutrient compositions, are also creating value for farmers while improving environmental outcomes.

Long-term agreements between energy suppliers and farmers have proven effective, providing stability for internal planning and serving as a foundation for technological investments. Biogas and biomethane plants, which utilize agricultural residues, have become key components of the circular economy, offering farmers additional income streams alongside conventional farming activities. The sector has evolved from traditional renewable raw materials (NAWARO) plants to advanced bioenergy facilities processing residual and waste materials, demonstrating significant progress over the past decade. These efforts showcase the potential for deeper integration of renewable energy systems within agricultural operations, enabling sustainable growth and resilience for farmers in the region.

Insights from Financial Institutions' Responses on Supporting Renewable Energy for Farmers in the German South Baltic Region

A national bank plays a pivotal role in financing renewable energy projects in the agricultural sector through its targeted programs such as "Energy from the Land" and "Agri-Photovoltaic Systems." These initiatives provide funding for investments in renewable energy generation, storage, and distribution, with a particular focus on supporting small and medium-sized enterprises (SMEs). The "Agri-Photovoltaic Systems" program under the "Future Fields in Focus" initiative specifically facilitates solar energy solutions designed for agricultural businesses. These programs underscore the institution's commitment to enabling the agricultural sector to transition toward sustainable energy practices. The flexibility in national bank loan structures allows for tailored financing plans that align with individual investments and business requirements, considering factors such as loan terms, promotional programs, and grace periods. By offering promotional loans through partner banks, national bank ensures comprehensive evaluation and approval processes, with partner banks assessing borrowers' projects before submitting applications for refinancing.

The financial institution' s collaborative approach strengthens its position as a key player in promoting sustainability within the agricultural sector. National bank has been a dedicated financing partner for the green sector for over 75 years, maintaining close communication with stakeholders across industries. This long-standing expertise enables it to continuously adapt its funding portfolio to meet the evolving needs of the agricultural and food industries. However, the institution faces significant challenges, particularly due to high EU reference interest rates. These rates result in a difficult balancing act between offering non-subsidized high-interest loans and incurring high subsidy values, which complicates the financing of renewable energy projects under the EEG-supported framework. Such financial constraints highlight the need for further policy and regulatory support to facilitate affordable and accessible renewable energy financing.

National bank operations are rooted in a cooperative framework, with all loans implemented through the house bank principle. Savings banks, cooperative banks, or private commercial banks act as intermediaries, evaluating loan applications and submitting refinancing requests to national bank upon a positive assessment. This system ensures a structured and transparent financing process, allowing borrowers to benefit from national bank promotional programs. Despite the challenges posed by external economic factors, national bank remains committed to its mission of fostering renewable energy adoption in agriculture. By leveraging its wide-ranging promotional spectrum and working closely with stakeholders, the institution continues to drive sustainability initiatives, promoting renewable energy as a cornerstone of the agricultural sector's future.

Insights from Research and Academia Responses on Renewable Energy in Agriculture in the German South Baltic Region

Research and academia are actively working to identify and address the barriers that farmers face when adopting renewable energy systems (RES) in agriculture. Current initiatives aim to provide actionable solutions that make RES adoption more accessible and beneficial for farmers. By employing direct engagement methods such as questionnaires and interviews, researchers strive to understand the challenges and translate findings into practical, easy-to-understand recommendations. One tangible example includes a farmer delegating responsibility for implementing a photovoltaic (PV) system to his successor, showcasing how informed decision-making can lead to actionable change.

Emerging technologies like PV systems are recognized as key opportunities, but challenges such as inconsistent feedback and rapidly changing regulations hinder broader adoption.

Promising advancements include biogas-to-hydrogen conversion and carbon capture and storage (CCS) technologies in agriculture

The conclusion of biogas plant support and insufficient institutional backing for biogas utilization further complicates the landscape. Promising advancements include biogas-to-hydrogen conversion and carbon capture and storage (CCS) technologies in agriculture. These areas represent vital directions for future research.

Academics also stress the importance of stable policies and reliable support mechanisms to foster long-term adoption of RES. They anticipate that renewable energy will continue to play a significant role in transforming agriculture, benefiting not only farmers but also policymakers and the broader community by advancing sustainability and energy resilience. However, gaps in institutional support and the need for further exploration into innovative technologies remain critical areas for continued research.

Insights from NGOs Responses on Renewable Energy in Agriculture in the German South Baltic Region

NGOs in the German South Baltic Region, such as BUND, highlight both opportunities and challenges in promoting renewable energy adoption among farmers. While no specific NGO-led initiatives are currently in place, farmers and investors have been encouraged by economic incentives, such as federal solar packages and regulatory measures allowing the use of 5,000 hectares of arable land for solar parks. However, strict spatial planning regulations limit solar park development to

areas near highways, railways, and federal roads, requiring additional approval processes for projects outside these zones. To address these challenges, NGOs advocate clear expansion targets, location criteria, and centralized tracking systems to streamline project approval and maintain public support for renewable energy.

Municipalities play a critical role in solar park planning but are often overwhelmed by applications and unaware of their authority under the Renewable Energy Act (EEG, 2023) to demand conservation measures beyond legal requirements. NGOs emphasize the potential for ecological enhancements in solar park designs, such as incorporating wildlife corridors, water bodies, and hedgerows, which could benefit both nature and agriculture by improving soil health and biodiversity. Educational projects, like "Ökologische Bauwende in MV" (Ecological Construction Transition in MV), aim to raise awareness about sustainable energy practices. Innovative solutions, including agri-PV systems and building-integrated photovoltaics (BIPV), offer promising approaches to maximize land use efficiency and reduce environmental impacts. These technologies enable dual-use land strategies and leverage existing infrastructures like parking lots and rooftops for energy generation. Despite the environmental impacts associated with renewable energy expansion, NGOs stress the importance of transitioning away from fossil fuels while ensuring that renewable projects are implemented in an environmentally friendly manner. By combining advocacy, education, and collaboration with stakeholders, NGOs aim to foster a sustainable and inclusive renewable energy transition in the region.

Insights from Policymakers' Responses on Promoting Renewable Energy in the German South Baltic Region

Policymakers in the German South Baltic Region are actively promoting renewable energy adoption through frameworks such as the Renewable Energy Sources Act (EEG), which guarantees feed-in tariffs and market premiums, and KfW Renewable Energy Programs, offering low-interest loans and grants. Landgesellschaft MV further supports farmers with technical and regulatory advice, feasibility studies, climate protection concepts, and funding management. These policies have encouraged renewable energy adoption in biogas, solar, and wind energy, yet challenges persist, including complex application processes, co-financing requirements, and balancing land use between agriculture and energy projects. Smaller farms, in particular, face barriers in managing upfront investments despite subsidies.

Efforts to address these challenges include closer collaboration with stakeholders such as farmers, energy providers, and NGOs, focusing on promoting energy-saving measures, CO2 reduction, and integrating

renewable technologies into farm operations. Success is tracked by metrics such as the number of projects funded, CO2 reductions, and renewable technology adoption rates among farmers. EU funding mechanisms, including the European Regional Development Fund (ERDF) and the European Agricultural Fund for Rural Development (EAFRD), play a vital role in supporting these initiatives. Policymakers work closely with the Ministry of Energy and Finance to align regional strategies with EU regulations, ensuring that renewable energy policies are comprehensive and impactful. However, simplifying application processes and ensuring equitable access to resources remain critical areas for improvement.

Solar energy stands out as the most favored technology across the region

Overview of results

Regional Insights on Renewable Energy in Agriculture Across the South Baltic Region (Lithuania, Poland, and Germany)

The adoption of renewable energy systems in agriculture across Lithuania, Poland, and Germany presents a complex blend of shared challenges and country-specific dynamics. Across all three nations, high initial costs emerge as a critical barrier, consistently identified by farmers as a major obstacle to embracing renewable energy technologies. Similarly, regulatory hurdles, such as complex application processes and bureaucratic inefficiencies, persist as a common challenge, underlining the urgent need for streamlined and transparent policy frameworks. Solar energy stands out as the most favored technology across the region, reflecting its versatility and relatively lower barriers to entry for agricultural operations.

However, the pace and scale of renewable energy adoption vary significantly among the three countries, shaped by their distinct socio-economic and agricultural landscapes. Germany leads the region in adoption rates, supported by its long-standing investment in renewable energy infrastructure and robust policies that have encouraged uptake for decades. Larger farm sizes and established financial mechanisms give German farmers a distinct advantage, enabling them to adopt advanced energy systems. In contrast, Lithuania and Poland exhibit slower adoption

rates, with small-scale farms and limited institutional support acting as significant constraints. Lithuanian and Polish farmers often resort to smaller-scale initiatives due to these systemic barriers, highlighting a need for enhanced support structures.

Perceptions of government support further illuminate key differences between the countries. Lithuanian farmers report relatively high awareness of available incentives, but they share frustrations over the accessibility and complexity of these programs. Polish farmers emphasize the need for greater collaboration and cooperative models, which have started to emerge as central themes in their renewable energy discourse. On the other hand, German farmers are more openly critical of their government' s renewable energy policies, frequently citing dissatisfaction with the effectiveness and consistency of the current regulatory landscape. These differences highlight varying levels of trust and engagement with governmental initiatives across the region.

The role of stakeholders also varies, reflecting the unique priorities and needs of each country. Lithuanian NGOs and financial institutions concentrate on empowering small and medium-scale farmers by making renewable energy technologies more accessible and affordable. In Poland, collaborative farmer cooperatives are gaining momentum, addressing shared challenges through collective action. Germany, by contrast, focuses on supporting larger-scale operations, aligning with the country' s agricultural demographics and its more mature renewable energy sector. These varied stakeholder efforts illustrate the region' s diverse approaches to addressing common challenges.

In conclusion, while Lithuania, Poland, and Germany share common barriers to renewable energy adoption, such as financial and regulatory constraints, their progress and approaches differ significantly. Germany' s established infrastructure and policies contrast with the more nascent efforts in Lithuania and Poland. These disparities underscore the importance of tailored strategies that account for each country' s specific agricultural and policy contexts. Enhanced financial assistance, simplified regulations, and regional collaboration could bridge these gaps, fostering a more cohesive and sustainable approach to renewable energy adoption across the South Baltic Region. By addressing both shared and unique challenges, the region can build a resilient and inclusive framework for advancing renewable energy in agriculture.

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* All online pages were available and checked between 04-12/2024.

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