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Renewable Energy Expansion in West Pomerania: Integrating Local Potential with Global Sustainability Goals

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Abstract: The expansion of renewable energy sources (RES) is essential to achieving regional sustainability in alignment with global climate goals. This study investigates the dynamics and projected growth of RES in West Pomerania, Poland, a region with significant potential due to its geographical characteristics and supportive policy frameworks. Historical data from 2010 to 2023 were used to perform a time series analysis that evaluated the annual growth rate (AGR) of various RES technologies, including wind, solar, biomass, and biogas. The analysis revealed a consistent upward trend in RES capacity, particularly in wind and solar energy, demonstrating effective resource mobilisation in the region. Subsequently, a forecasting model was employed to project the growth of the RES capacity through 2033 based on historical trends and technological advancements. The results indicate significant anticipated increases in RES capacity, highlighting West Pomerania's potential to reduce its reliance on fossil fuels. This growth supports increased energy security and environmental sustainability. This study addresses a notable gap in the literature by linking regional renewable energy development with broader policy frameworks, such as the European Green Deal, and exploring the specific challenges of grid integration and economic disparities in the context of local energy transitions. These findings highlight the importance of sustained investment and policy support to scale renewable infrastructure while aligning regional initiatives with international sustainability goals. By bridging this gap, this study concludes that the West Pomerania strategy can serve as a model for other regions aiming to enhance their renewable energy portfolios and effectively meet the climate goals of the EU.



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1. Introduction

The expansion of renewable energy sources (RES) in West Pomerania, a region in northwest Poland, represents a crucial element in both the local and global pursuit of sustainable development goals. This article explores the integration of regional potential in West Pomerania with global sustainability goals, contextualised within the broader historical, economic, and geographical landscape of the region. The unique position of West Pomerania within the European Union (EU) and its distinctive socioeconomic and environmental characteristics provide a compelling case for examining how local renewable energy initiatives can contribute to and align with broader global sustainability efforts.

West Pomerania, known for its strategic location along the Baltic Sea, has a rich history that has significantly shaped its economic and energy profile. Historically, the region has been characterised by its agricultural and maritime activities, with a strong tradition in

fishing and shipbuilding. The region's accession to the EU in 2004 marked a significant turning point, as it began to receive substantial funding and support for the development of its infrastructure and economy, including the energy sector [1].

Geographically, West Pomerania is characterised by a diverse landscape that includes coastal areas, forests, and agricultural lands. This geographical diversity provides a solid foundation for the development of various types of renewable energy, including wind, solar, and biomass. The climate and topography of the region are particularly conducive to wind energy, with coastal areas offering high wind speeds that are ideal for the development of wind farms [2].

Since Poland's accession to the EU, West Pomerania has seen a significant increase in the development of renewable energy sources. The environmental policies and directives of the EU, such as the Renewable Energy Directive, have played a pivotal role in shaping the region's energy landscape. These policies have driven investments in renewable energy infrastructure, leading to the establishment of numerous wind farms, solar installations, and biomass installations in the region [3]. The region's commitment to renewable energy is further evidenced by its participation in various EU-funded programmes aimed at enhancing energy efficiency and reducing carbon emissions. For example, the development of offshore wind energy in the Baltic Sea has become a cornerstone of the region's energy strategy, with plans to significantly expand this sector in the coming years [4]. This expansion aligns with the EU's broader climate goals, including achieving climate neutrality by 2050.

The economy of West Pomerania has become increasingly orientated towards the sustainable energy sector, with renewable energy becoming a key driver of regional development. The economic strategy of the region has focused on maximising its natural resources, such as wind and biomass, to create a competitive and sustainable energy market. This strategy is supported by national and regional policies that promote the use of renewable energy and provide incentives for green investments [5].

The Marshal's Office of the West Pomeranian Voivodeship has played a proactive role in promoting the growth of the renewable energy sector. Through various policy initiatives and collaborations with the private sector, the region has successfully attracted significant investments in renewable energy projects. These initiatives have not only contributed to the region's energy security but have also created jobs and stimulated economic growth, particularly in rural areas where many renewable energy projects are located [6].

Furthermore, the alignment of West Pomerania's energy policies with the EU's sustainability goals underscores the region's commitment to contribute to global climate action. The region's energy strategy is closely linked to the European Green Deal, which aims to reduce carbon emissions and promote the transition to a low-carbon economy. This alignment ensures that West Pomerania not only meets its local energy needs but also contributes to the overall climate goals of the EU [7].

The integration of the local renewable energy potential in West Pomerania with global sustainability goals represents a dynamic and forward-looking approach to regional development. Taking advantage of its unique geographical and economic characteristics, the region has positioned itself as a leader in the energy transition in Poland. The historical, economic, and policy dimensions of this transition highlight the region's potential to contribute meaningfully to global efforts to combat climate change while fostering sustainable local development.

Public acceptance and social attitudes play a critical role in the successful development and implementation of renewable energy policies, influencing both political frameworks and investment priorities. Recent studies highlight that social support for renewable energy sources (RES) is often driven by environmental awareness, perceived economic

benefits, and trust in governing institutions [8]. In regions like West Pomerania, public participation in RES initiatives can shape local policy development, particularly when addressing concerns such as the equitable distribution of costs and benefits or potential environmental trade-offs. Furthermore, aligning renewable energy projects with social expectations can strengthen acceptance, as evidenced by studies on the influence of social trust and public participation on energy transitions [9,10].

Recent findings by Chomać-Pierzecka et al. (2023) highlight how individual and community-level engagement can act as a catalyst for RES adoption in Poland. Their study emphasises the importance of practical, localised applications of energy innovations, showing how public awareness and hands-on experiences with RES technologies can significantly enhance societal readiness and acceptance. These insights underscore the need to integrate social perspectives into energy policies to ensure that they are both effective and inclusive [11]. In West Pomerania, these dynamics are particularly relevant as the region strives to balance ambitious renewable energy targets with addressing community-specific concerns.

This study distinguishes itself from the existing literature by providing a comprehensive analysis of the growth dynamics and future projections of renewable energy sources (RES) in West Pomerania, a region uniquely positioned to contribute to the goals of the EU climate due to its geographical and policy advantages. Although many studies focus on national or EU-wide renewable energy transitions, there is limited research addressing the interplay between local policy frameworks, social attitudes, and the technical challenges of integrating diverse RES technologies at the regional level. This research not only quantifies historical trends in the development of RES but also applies robust forecasting methodologies to project future capacity growth, offering insights tailored to the specific socioeconomic and environmental context of West Pomerania. By bridging the gap between local actions and global sustainability objectives, this study highlights how regional strategies can serve as scalable models for energy transitions in similar contexts. These findings provide actionable recommendations for policymakers and stakeholders, advancing the discourse on aligning regional initiatives with broader climate and energy goals.

2. Literature Review

The integration of renewable energy sources (RES) into regional policies and their alignment with global sustainability goals have become a focal point in academic research and policy development throughout the world. This review of the literature examines the various approaches to the expansion of renewable energy in different regions, drawing comparisons with the initiatives undertaken in West Pomerania, Poland. The review highlights the key factors that influence the successful integration of RES in local and regional strategies, the economic and environmental impacts of these initiatives, and the lessons that can be drawn from global examples.

Europe has been at the forefront of the global transition to renewable energy, driven by ambitious climate goals and a strong policy framework. The commitment of the European Union (EU) to reduce carbon emissions by 80–95% by 2050 compared to 1990 levels has spurred significant investment in RES across the continent (Boie et al. 2014). The SUSPLAN project, for example, developed long-term strategies for the integration of renewable energy into European energy infrastructures, emphasising the need for improved transmission infrastructure to accommodate the growing share of renewable generation [12].

In a comparative study of renewable energy systems across Europe, Abdolmaleki et al. identified Sweden, Belgium, and Ireland as the most sustainable countries in terms of renewable energy integration, largely due to their robust policy frameworks and significant

investments in green energy technologies [13]. These countries have successfully integrated RES into their energy systems, setting a benchmark for other EU nations, including Poland.

Poland's journey towards integrating renewable energy, especially in its eastern regions, has been shaped by a combination of local governance initiatives and spatial-economic variables. A study by Blaszkę et al. (2021) analysed the role of local spatial policy in supporting investments in renewable energy sources, revealing significant regional differences based on the geographic and functional characteristics of municipalities. This analysis underscores the importance of well-formulated local spatial planning policies for fostering renewable energy development in Poland [14].

Beyond Europe, various regions have implemented innovative strategies to integrate renewable energy into their energy systems, often under challenging conditions. For example, the integration of renewable energy in the Middle East and North Africa (MENA) and Eurasia has been explored by Bogdanov et al. (2016), who emphasised the potential for regional cooperation to improve energy security and reduce costs. The study highlighted how interconnected energy systems in these regions could take advantage of the various available renewable energy resources, thus reducing dependence on fossil fuels and promoting economic stability [15].

Similarly, the case of China provides valuable information on the deployment of large-scale renewable energy. China's rapid expansion of its wind and solar energy capacity has been supported by significant government subsidies and a centralised approach to energy policy. However, the challenges of grid integration and the need for improved transmission infrastructure have been highlighted as critical areas for future development [12].

In the context of the United States, the development of regional transmission organisations (RTOs) and independent system operators (ISOs) has played a pivotal role in facilitating the integration of renewable energy. These entities manage the electricity grid on a regional basis, ensuring that renewable energy can be efficiently distributed in vast areas. This approach has been particularly successful in states such as California and Texas, where wind and solar energy have become significant contributors to the energy mix [15].

The economic impact of the integration of renewable energy is a critical area of study, particularly in regions where traditional energy sectors have dominated. In Poland, Kozera et al. (2023) analysed the correlation between CO₂ emissions and investment in renewable energy projects, finding that regions with higher emissions often exhibited greater investment activity in renewable energy, supported by EU funds [16]. This finding underscores the role of financial incentives in driving the energy transition, particularly in regions facing significant environmental challenges.

Simionescu et al. (2020) examined the economic and social benefits of renewable energy projects in the context of the European Green Deal, particularly in regions like Poland. The study found that investments in solar and wind energy have contributed significantly to reduced energy costs, improved public health outcomes, and increased local employment opportunities, particularly in rural and underdeveloped areas. This highlights the dual benefits of renewable energy, both as an economic stimulus and as a driver of social improvements in regions undergoing energy transitions [17].

The environmental benefits of renewable energy integration are also well supported in the literature. Hainsch et al. (2020) emphasised the environmental impact of transitioning to renewable energy sources, including wind, solar, and biomass, throughout the EU. The study demonstrated that these renewable sources are capable of significantly reducing the carbon footprint of energy production, especially in agricultural regions where biomass can be a key contributor to clean energy. These findings underscore the role of renewable energy in achieving wider climate goals and reducing greenhouse gas emissions [18].

Public acceptance and social attitudes are critical factors that shape the success of renewable energy transitions. Research by Sütterlin and Siegrist (2017) highlights that while solar energy enjoys high public support, perceptions shift significantly when potential drawbacks are considered, underlining the importance of addressing public concerns during policy formulation [19]. Similarly, Schumacher et al. (2019) explored public attitudes toward renewable energy technologies in France, Germany, and Switzerland, finding that acceptance levels vary according to community involvement, familiarity with technology, and perceived local benefits [20]. Another study by Roddis et al. (2019) identifies a disconnect between the attitudes of the public and policymakers toward renewable energy technologies, emphasising the need to bridge this gap to ensure smooth transitions [21]. These findings collectively suggest that improving public participation and addressing community-specific concerns are essential to bolstering social readiness for the adoption of renewable energy.

Innovative approaches to the integration of renewable energy have been a focal point of global energy research. In Malaysia, Kardooni et al. (2016) examine public attitudes and find that perceived costs and lack of knowledge are significant barriers to the acceptance of renewable energy technologies, highlighting the role of public education and incentive-based policies [22]. Esiri et al. (2024) argue that aligning public perception with renewable energy policy is crucial to achieving sustainable energy transitions, pointing to the need for targeted public engagement strategies to foster greater acceptance [23]. These studies underscore the importance of coordinated policy measures and tailored public awareness campaigns to overcome barriers and drive effective renewable energy transitions.

3. Materials and Methods

This section describes the methodologies used to analyse the growth dynamics of renewable energy sources (RES) in West Pomerania and to forecast future growth based on historical trends. The analyses are based on data obtained from official regional energy reports and databases covering the period from 2010 to 2023. Methods used include time series forecasting and growth rate analysis to evaluate the region's renewable energy trajectory and identify potential future capacity expansion.

3.1. Analysis of Growth Dynamics of RES Capacity

This study aims to quantify the annual growth of installed RES capacity in West Pomerania from 2010 to 2023, focussing on key technologies such as wind, solar, biomass, and biogas. The data used for this analysis include the installed capacities reported in regional energy documents, particularly those detailing the capacity of RES plants over 50 kW. By examining these historical data, we can assess how different factors have influenced the growth rates of various RES technologies in the region.

1. Annual Growth Rate Calculation:

The annual growth rate (AGR) of the installed capacity for each RES technology will be calculated using the formula [24]:

$$AGR_t = \left(\frac{C_t - C_{t-1}}{C_{t-1}} \right) \times 100\%$$

where C_t is the installed capacity at time t , and C_{t-1} is the installed capacity at time $t - 1$.

2. Cumulative Growth Rate:

The cumulative growth rate (CGR) for the entire period from 2010 to 2023 will be calculated as follows [25]:

$$\text{CGR} = \left(\frac{C_{2023}}{C_{2010}} \right)^{\frac{1}{N}} - 1$$

where N is the number of years (12 years in this case).

3. Trend Analysis:

The linear trend for each RES technology will be modelled using simple linear regression [26].

$$C_t = \beta_0 + \beta_1 t + \epsilon_t$$

where β_0 is the intercept, β_1 is the slope of the trend, and ϵ_t is the error term.

The results will be visualised using line graphs depicting annual growth rates and cumulative installed capacities for the various RES technologies during the study period.

3.2. Forecast of RES Capacity Growth Based on Historical Trends

The objective of this analysis is to project the future growth of RES capacity in West Pomerania for the decade 2024–2033, using historical data from 2010 to 2023. The data used for this projection include historical installed capacities of various RES technologies, as reported in regional energy reports. By analysing past trends, we aim to forecast future developments under different scenarios. Time-Series Forecasting:

Future RES capacity will be forecasted using the Holt–Winters exponential smoothing method, which accounts for both trends and seasonality in the data [27].

$$C_{t+h} = (L_t + h \times T_t) \times S_{t+h}$$

where C_{t+h} is the forecasted capacity at time $t + h$ is the level component, T_t is the trend component, and S_{t+h} is the seasonal component.

This structured approach to the analysis of renewable energy sources (RES) in West Pomerania is designed to provide a comprehensive understanding of the energy dynamics of the region. By combining historical data analysis with predictive modelling, this research offers a detailed exploration of how the region has developed its renewable energy infrastructure over time and how it is likely to evolve in the future.

The first phase of the analysis focusses on understanding the growth dynamics of the RES capacity in the region. This involves calculating growth rates and examining trends across different types of renewable energy technologies, such as wind, solar, biomass, and biogas. By analysing which sectors have seen the most significant development, we can identify key drivers of growth, such as policy frameworks, market conditions, and technological advances. This granular analysis provides information on the effectiveness of past and current energy policies, offering valuable lessons that could guide future strategic decisions in the energy sector.

The second phase involves the forecasting of future RES capacity based on historical growth trends. This is critical for policymakers and stakeholders who need to plan for the energy needs of the region in the coming decades. Using time series forecasting methods, such as the Holt–Winters exponential smoothing model, we generate projections grounded in historical data. These projections reflect different growth scenarios, accounting for potential variations in market conditions and technological developments. By providing a variety of possible future outcomes, this analysis equips stakeholders with the tools to develop a more resilient and adaptive energy strategy.

In general, this approach offers a robust framework for assessing the future potential of renewable energy in West Pomerania. Moving beyond simple growth metrics, it provides a nuanced understanding of how past trends and future forecasts can inform sustainable development. The insights gained from this analysis can contribute significantly to regional

planning, helping policymakers align local initiatives with global sustainability objectives, such as those outlined in the Paris Agreement and the European Green Deal. Through informed planning, West Pomerania can enhance its energy security and economic resilience while positioning itself as a model for other regions transitioning to renewable energy.

4. Results

4.1. Analysis of the Growth Dynamics of the RES Capacity

The data used for calculating the Annual Growth Rate (AGR) were extracted from the document provided by the Regional Office for Spatial Management of West Pomerania (RBGPWZ), including the capacity of wind, biomass, solar, biogas, and water installations. The data used for calculating the Annual Growth Rate (AGR) of various renewable energy sources (RES) in West Pomerania from 2010 to 2023 are presented in Table 1.

Table 1. Electricity capacity of RES installations of over 50 kW in the West Pomeranian Region by technology [MW] from 2010 to 2023.

Year	Wind (MW)	Biomass + ITPO (MW)	Solar (MW)	Biogas (MW)	Water (MW)	Total (MW)
2010	431.7	0	0	3.6	11.5	446.8
2011	550.0	0	0	6.8	11.5	568.3
2012	745.7	83.2	0	7.9	11.5	848.3
2013	1005.4	83.2	0	10.5	11.6	1110.6
2014	1110.6	83.2	0	13.8	11.9	1216.2
2015	1321.1	83.2	3.2	13.8	12.3	1433.6
2016	1486.0	83.2	3.4	16.8	12.6	1602.2
2017	1486.0	83.2	4.6	17.0	12.8	1603.7
2018	1486.6	99.3	9.6	16.9	13.5	1625.9
2019	1487.8	105.1	50.9	17.0	13.5	1674.3
2020	1755.4	105.1	80.1	19.3	13.5	1973.4
2021	1770.2	105.1	138.5	19.9	13.5	2047.1
2022	2316.0	105.1	262.7	19.9	13.5	2717.2
2023	2437.3	105.1	445.2	20.3	13.6	3021.4

Source: RBGPWZ compilation based on GUS data.

The data presented in Table 1 provide an overview of the installed electricity capacity of renewable energy sources (RES) greater than 50 kW in the West Pomeranian Region from 2010 to 2023, classified by technology. During the 13-year period, wind energy experienced the most significant growth, increasing from 431.7 MW in 2010 to 2437.3 MW in 2023, reflecting the region's strong focus on wind power. Solar energy also saw a sharp increase, particularly from 2018 onwards, where capacity jumped from 9.6 MW to 445.2 MW by 2023, driven by both technological advancements and supportive policy measures.

The biomass and ITPO (thermal waste treatment) capacity remained stable at 83.2 MW from 2012 to 2017, with slight increases in later years, reaching 105.1 MW by 2023. Biogas capacity showed steady and modest growth from 3.6 MW in 2010 to 20.3 MW in 2023, while water energy remained relatively unchanged, contributing a stable 13.5–13.6 MW throughout the period.

Overall, the total installed RES capacity in the region increased significantly from 446.8 MW in 2010 to 3021.4 MW in 2023, with wind and solar energy being the key drivers of this expansion. The consistent increase in total capacity highlights West Pomerania's growing commitment to renewable energy development.

Based on data from Table 1, the annual growth rate (AGR) was calculated according to the methodology presented in Section 3. The results demonstrate the varying growth patterns across wind, solar, biomass, biogas, and water technologies, as shown in Table 2.

Table 2. Results of the Annual Growth Rate (AGR) Calculations.

Year	Wind AGR (%)	Biomass + ITPO AGR (%)	Solar AGR (%)	Biogas AGR (%)	Water AGR (%)
2010–2011	27.37	N/A	N/A	88.89	0.00
2011–2012	35.64	N/A	N/A	16.18	0.00
2012–2013	34.83	0.00	N/A	32.91	0.87
2013–2014	10.47	0.00	N/A	0.00	2.59
2014–2015	18.96	0.00	N/A	31.43	3.36
2015–2016	12.47	0.00	6.25	21.74	2.44
2016–2017	0.00	0.00	35.29	1.19	1.59
2017–2018	0.04	19.38	108.70	−0.59	5.47
2018–2019	0.08	5.84	430.21	0.59	0.00
2019–2020	18.01	0.00	57.37	13.53	0.00
2020–2021	0.84	0.00	72.93	3.11	0.00
2021–2022	30.83	0.00	89.68	0.00	0.00
2022–2023	5.23	0.00	69.46	2.01	0.74

Source: Own elaboration based on the data from RBGPWZ and GUS.

The analysis of the AGR results reveals distinct trends in the development of renewable energy capacity in West Pomerania:

Wind energy has seen consistent growth throughout the period, particularly strong in the early years between 2011 and 2012, with an AGR of 35.78%. This reflects the early focus on wind energy as a dominant source of renewable energy in the region. Growth slows in later years, particularly after 2017, but still maintains an average growth rate of more than 5% annually.

Biomass energy does not show growth after 2012, reflecting the maturity of this technology within the region. This sector seems to have reached a plateau, contributing a steady share to the overall energy mix but with no significant expansion in recent years.

Solar energy demonstrates the most dramatic growth, particularly between 2018 and 2019, when the AGR reached 430%. This reflects a major push in solar capacity, likely driven by both policy incentives and technological advancements that reduced costs. This trend continues with high growth rates in the following years, confirming solar energy as a critical area of expansion in the region.

Biogas energy shows moderate growth, particularly between 2010 and 2012. However, from 2017 onwards, growth stabilises with very minimal increases in capacity. This indicates that biogas has found a stable, albeit small, role in the region's renewable energy landscape.

The energy of water remains stable throughout the period with little to no growth. This reflects the limited potential for expansion of hydroelectric installations within the region, likely due to geographical restrictions.

The AGR analysis illustrates the diverse growth patterns of renewable energy technologies in West Pomerania. Although wind energy remains a strong contributor, the most dynamic growth is seen in solar energy, which has experienced exponential increases in capacity, positioning it as a major driver of future renewable energy development. Biomass and biogas contribute steadily but show little expansion, indicating they have likely reached maturity. The energy of water remains a stable but minor contributor.

4.2. Projected Growth of RES Capacity: Analysis Based on Historical Trends

The purpose of this section is to project the growth of renewable energy sources (RES) in West Pomerania for the period from 2024 to 2033. The methodology for forecasting has been outlined in Section 3, and it involves the use of time-series forecasting, specifically utilising the Holt–Winters exponential smoothing model. This approach considers both historical trends and projected developments in each renewable energy sector, enabling a

comprehensive prediction of future installed capacities for wind, solar, biomass, biogas, and water energy.

The projected growth of each renewable energy technology in West Pomerania for the period 2024–2033 is presented in Table 3. It provides a clear comparison of the projected capacity trends for wind, solar, biomass, biogas, and water energy over the forecasted period, allowing for a comprehensive understanding of the region’s renewable energy trajectory.

Table 3. Projected Capacity Growth of RES in West Pomerania (2024–2033).

Year	Wind (MW)	Solar (MW)	Biomass (MW)	Biogas (MW)	Water (MW)	Total (MW)
2024	2500	550	105.1	22	13.6	3190
2025	2700	700	105.1	24	13.6	3542
2026	2900	850	105.1	26	13.6	3894
2027	3100	1000	105.1	27	13.6	4246
2028	3300	1150	105.1	28	13.6	4597
2029	3500	1300	105.1	29	13.6	4948
2030	3700	1400	105.1	30	13.6	5248
2031	3800	1450	105.1	31	13.6	5399
2032	3900	1500	105.1	32	13.6	5550
2033	4000	1550	105.1	33	13.6	5710

Source: Own elaboration.

Based on the data in Table 3, the projected capacity growth of renewable energy sources (RES) in West Pomerania from 2024 to 2033 will be presented in Figure 1. This chart aims to provide a clear and comparative representation of the forecasted trends for each technology, highlighting the continued expansion of wind and solar energy alongside the stable contributions of biomass, biogas, and water energy. The detailed projection will help illustrate the region’s renewable energy trajectory, with a particular emphasis on identifying the dominant technologies driving future capacity increases. The results of this projection are shown in Figure 1.

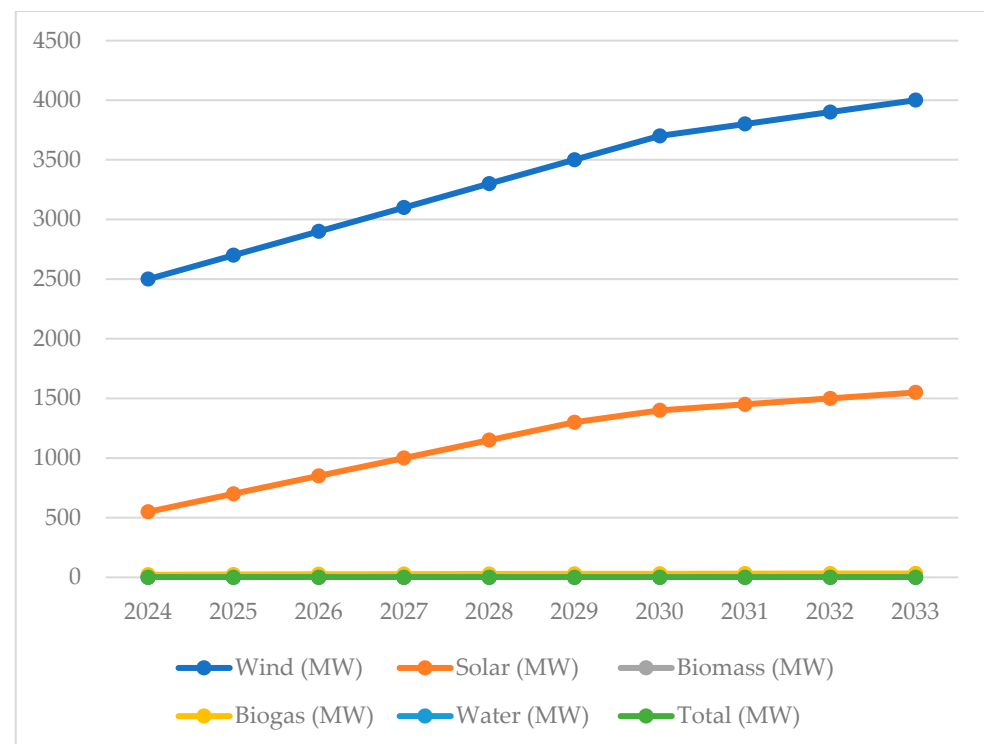


Figure 1. Projected Capacity Growth of RES in West Pomerania (2024–2033).

The forecasted results underscore the significant role that wind and solar energy are expected to play in West Pomerania's renewable energy future. By 2033, wind energy is projected to reach 4000 MW, making it the most dominant renewable energy technology in the region. This growth is reflective of ongoing investments in wind infrastructure and the favourable conditions in the region for wind power generation. Despite a slight slowdown in growth rates compared to previous years, wind energy will continue to be a major driver of the expansion of renewable energy in West Pomerania.

Solar energy, on the other hand, is projected to experience the most rapid growth, with installed capacity expected to increase from 445.2 MW in 2023 to 1550 MW by 2033. The exponential increase in solar capacity reflects both technological advancements and decreasing costs, making solar energy an increasingly viable and scalable solution to meet the region's energy demands. The projection also aligns with global trends, where solar energy is expected to become a cornerstone of the renewable energy transition due to its flexibility and potential for large-scale deployment.

Biomass and biogas, while continuing to contribute to the renewable energy mix, are forecasted to see much slower growth compared to wind and solar. The biomass capacity is expected to remain stable at 105.1 MW throughout the forecast period, indicating that the sector has reached a plateau. This may be due to resource constraints or environmental concerns that limit further expansion. Biogas energy is projected to see slight growth, with capacity increasing from 20.3 MW in 2023 to 33 MW by 2033. Although this represents a modest increase, biogas is likely to remain a niche technology, particularly in rural areas where it can be integrated with agricultural activities.

Water energy is projected to remain constant at 13.6 MW, with no significant expansion anticipated due to geographic limitations. The stability of water energy reflects its established role in the renewable energy mix, but the lack of growth potential suggests that it will not be a major contributor to future capacity increases.

5. Discussion

The study of the growth dynamics of renewable energy sources (RES) and the forecast of capacity in West Pomerania provides valuable information on the trajectory of the development of renewable energy in the region and its alignment with global trends. As renewable energy continues to grow globally, the findings of this study can be placed within the broader context of other regional and national case studies.

5.1. Comparative Analysis of Findings

This study advances the understanding of renewable energy development in West Pomerania by offering a comprehensive examination of growth dynamics and capacity forecasting tailored to the unique socioeconomic and environmental conditions of the region. Unlike the SUSPLAN project, which emphasised large-scale integration of RES in European energy infrastructures [12], this research focusses specifically on localised challenges and opportunities in West Pomerania, such as the dominance of wind and solar technologies over biomass and biogas. While Abdolmaleki et al. (2023) highlighted the robustness of the policy and significant investments as key factors driving the integration of RES in countries such as Sweden and Belgium, this study identifies similar policy-driven dynamics at the regional level while also exposing the limitations of biomass and biogas scalability within West Pomerania [13].

Additionally, this work complements the findings of Blaszkę et al. (2021) on the importance of spatial policy and local governance in the landscape of renewable energy in Poland, demonstrating how regional infrastructure and policy frameworks have specifically fostered the rapid growth of wind and solar energy in West Pomerania [14]. These findings

contribute to a greater understanding of how policy and technological advances can shape future RES trajectories, aligning with the broader goals of climate neutrality of the EU outlined in the European Green Deal [18].

5.2. Growth Dynamics of RES Capacity

The first phase of this research focused on analysing the growth dynamics of RES in West Pomerania, revealing that wind and solar energy have experienced the most substantial growth in recent years. This pattern mirrors global trends, where wind and solar energy have been dominant forces in the expansion of renewable energy capacity, particularly in countries with favourable policies and market conditions. According to Bhattacharya et al. (2016), the positive impact of renewable energy consumption on economic growth is evident in 57% of the top countries that consume renewable energy. This study demonstrates that investment in wind and solar energy not only drives energy independence but also stimulates economic growth, particularly when governments create enabling environments for private sector investment [28].

In West Pomerania, as in many other regions, the expansion of wind and solar energy has been facilitated by government policies, such as subsidies and favourable regulations. However, the growth of renewable energy has not been uniform across all RES technologies. For example, while wind and solar energy have grown rapidly, the growth of biomass and biogas has been more moderate, reflecting the more limited scalability of these technologies compared to wind and solar. This disparity in growth rates is consistent with the findings of Sotnyk et al. (2022), who identified the need for targeted policy interventions to address the uneven development of different renewable energy technologies in regional contexts [29].

5.3. Forecasting the Future RES Capacity

The second phase of this study involved the forecasting of future RES capacity based on historical trends. The results showed that renewable energy capacity in West Pomerania would continue to grow steadily, with wind and solar energy driving most of this growth.

Forecasting renewable energy capacity is a crucial tool for policymakers and stakeholders, allowing them to plan for future energy needs and set realistic targets for RES expansion. Similar studies have been conducted in other regions, such as Germany, where the growth of wind and solar energy has been a critical factor in shaping the country's energy market. Kumar et al. (2019) explored the impact of wind and solar energy on Germany's electricity trade surplus, showing how increased renewable energy capacity can lead to surplus energy production and create new opportunities for cross-border energy trade [30]. This finding underscores the importance of integrating renewable energy forecasting into regional and national energy strategies to ensure that surplus capacity can be effectively managed and utilised.

Furthermore, Rozon et al. (2023) highlight the importance of accurate long-term forecasting for renewable energy technologies, noting that many forecasts tend to underestimate the potential for capacity growth and cost reductions in technologies such as solar and wind energy [31]. This is particularly relevant for West Pomerania, where historical trends suggest that wind and solar energy will continue to grow at a rapid pace, but more aggressive policy interventions could further accelerate this growth and drive down costs.

5.4. Policy Implications

The findings of this study underscore the critical role of policy support in accelerating renewable energy transitions, aligning with recent analyses of renewable energy adoption. For example, Yusoff et al. (2023) highlight how macroeconomic factors such as financial development and urbanisation significantly influence the adoption of renewable energy, suggesting that targeted fiscal incentives and trade policies can improve deployment

in emerging markets [32]. Similarly, the economic and environmental impacts of the adoption of renewable energy, as reviewed by Adanma and Ogunbiyi (2024), demonstrate that job creation and reductions in greenhouse gas emissions are key results of well-executed renewable energy policies [33]. These findings support our conclusion that the West Pomerania strategy could serve as a model for other regions aiming to maximise the economic and environmental benefits of renewable energy. However, the moderate growth of biomass and biogas in West Pomerania suggests that a more diversified policy approach addressing specific technological barriers is necessary to unlock the full potential of these resources.

In particular, the moderate growth of biomass and biogas energy in West Pomerania highlights the need for targeted policy interventions to stimulate investment in these technologies. As Sotnyk et al. (2022) pointed out, a multifactor approach to policy modelling that takes into account regional conditions, natural resources, and energy needs can help determine the most effective strategies to promote the development of renewable energy [29]. For West Pomerania, this could involve increasing financial support for biogas projects or implementing incentives for the development of smaller-scale renewable energy facilities.

5.5. Comparative Technological Growth and Forecasting Accuracy

The robust growth of wind and solar energy in West Pomerania is consistent with global trends in the expansion of renewable energy capacity, as evidenced by Jäger-Waldau (2024), who reported a 12% increase in global solar investments, resulting in more than 420 GWp of new capacity installed in 2023 [34]. This parallels our findings of wind and solar dominance in capacity growth, with the region benefiting from favourable policies and investments. Furthermore, Adomako et al. (2024) emphasised the importance of precise meteorological data and simulation precision in renewable energy forecasting, particularly for wind and solar energy systems in regions undergoing transitions toward sustainability [35]. This aligns with our approach, which integrates accurate historical trends into long-term forecasting. Furthermore, Iskandar et al. (2024) highlighted the advantages of artificial neural networks (ANNs) for renewable energy forecasting, demonstrating their effectiveness in improving the accuracy of solar power generation predictions in Malaysia, a region with significant variability in solar irradiance [36]. Together, these methodologies reinforce the utility of combining accurate data inputs and advanced models to project the growth of renewable energy.

6. Conclusions

This study provides a comprehensive analysis of the growth dynamics and future capacity projections for renewable energy sources (RES) in West Pomerania. By examining historical data and applying time series forecasting models, the research offers valuable insight into the region's trajectory of renewable energy. The analysis confirms that wind and solar energy are the dominant forces behind the expansion of RES capacity, while biomass and biogas remain stable but limited in their growth potential. The findings indicate that West Pomerania is well placed to further increase its renewable energy capacity, especially with the continued development of wind and solar technologies.

Although this research focusses on West Pomerania, its findings offer broader implications for other regions seeking to accelerate their transitions to renewable energy. For example, the success of wind and solar energy in West Pomerania highlights the importance of aligning regional policies with natural resource potential, a strategy that can be applied in regions with similar geographical advantages, such as coastal areas of Denmark or rural regions in Germany. Additionally, the emphasis of the study on targeted policy interventions underscores a lesson for policymakers globally: regions with moderate adoption

of less scalable technologies, such as biomass and biogas, should prioritise small-scale community-driven projects that complement larger-scale solar and wind investments.

The forecasting of future RES capacity reveals that renewable energy capacity will continue to grow steadily. This highlights the importance of strategic planning and policy development to unlock the full potential of renewable energy in the region. Insights from this study suggest that strategies combining aggressive policy support, infrastructure investments, and public–private collaborations, as demonstrated in Poland, can serve as models for other countries or regions, including those transitioning from fossil fuels or integrating renewable energy into diverse markets, such as Brazil, India, or the United States.

Practical Implications

The findings of this study have several practical implications for policymakers, energy planners, and stakeholders in the renewable energy sector:

1. **Targeted Policy Support:** To accelerate the growth of renewable energy, particularly in the wind and solar sectors, policymakers in West Pomerania should consider implementing targeted incentives such as subsidies, tax breaks, or investment grants. These policy measures can help stimulate private sector investment and further drive the expansion of RES capacity, aligning with both national and EU renewable energy targets.
2. **Focus on the Grid Infrastructure:** As the capacity of RES, especially intermittent sources like wind and solar, increases, improvements to the grid infrastructure will be critical. Investments in grid modernisation, including energy storage solutions and grid flexibility enhancements, will be necessary to manage the variability of renewable energy and ensure a reliable energy supply. This can prevent bottlenecks that could otherwise limit the full integration of RES into the regional energy mix.
3. **Development of Smaller-Scale Projects:** Given the moderate growth of biomass and biogas in the region, policymakers should consider incentivising the development of smaller-scale decentralised renewable energy projects. These projects can contribute to the energy mix, particularly in rural areas, and offer additional benefits, such as job creation and local energy resilience.
4. **Long-Term Planning:** The capacity projections presented in this study highlight the need for long-term energy planning that considers both technological advances and future policy developments. The energy strategy of West Pomerania should include flexible pathways that can adapt to new technologies and changing market conditions, ensuring that the region is on track to meet its goals of sustainability and energy security.
5. **Collaboration with the Private Sector:** The successful expansion of renewable energy in the region will require strong collaboration between the public and private sectors. Policymakers should engage with private investors, energy companies, and local communities to develop partnerships that support renewable energy projects, create jobs, and stimulate economic growth.

By implementing these practical recommendations, West Pomerania can improve its renewable energy infrastructure, secure a stronger position within the European energy market, and contribute significantly to global sustainability objectives. The lessons drawn from this study, such as the effectiveness of targeted policy interventions and the strategic integration of wind and solar energy, offer valuable insights that extend beyond regional boundaries. These findings provide a framework for other regions, such as coastal areas that harness wind potential in Denmark or solar-rich regions in Southern Europe, to adapt to optimise their renewable energy transitions. Furthermore, the scalability of community-driven renewable energy initiatives and the emphasis on public–private collaboration

demonstrated in West Pomerania can inspire similar efforts in regions undergoing energy transitions, fostering global progress toward a low-carbon economy.

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