SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 229

STRUCTURAL GRID LIMITATIONS AND SOLAR OVERSUPPLY: LESSONS FROM POLAND

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Purpose: The author aims to highlight a significant global issue: the difficulty of integrating photovoltaic (PV) electricity sources into power line systems (grid). In Poland, 30,357 applications for the connection of photovoltaic systems to the electricity grid were rejected between 2022 and the first quarter of 2023.
Design/methodology/approach: The author analyzed available reports and articles on the topic of blocking access of energy transmission produced by photovoltaics to national power grids. While the article focuses on Poland, it also provides examples of other countries facing similar challenges.
Findings: It appears that the European continent has not yet recognized the erroneous sequence in which investment in electricity is being conducted. This situation can be attributed to the fact that the existing grid infrastructure is outdated and does not have the necessary capacity to accommodate the increased electricity generation from photovoltaic systems. It is unreasonable to expect the grid to adapt without modification. In the absence of such modifications, the grid will be incapable of facilitating the transition to green energy, which will have a damaging effect on the country's energy security.
Social implications: Operators encounter difficulties in maintaining energy balance, which results in an increase in the number of shutdowns. In such cases, the deactivated installation is unable to generate electricity, thereby preventing prosumers from self-consuming the energy produced or benefiting from the support system designed for this purpose. Such a situation is the broader social and economic discouragement of renewable investments.
Value: The paper is addressed to the academic community, which can not only publicize the problem but also, due to its scientific potential and research facilities, provide scenarios for solving the discussed problem.
Keywords: renewable energy sources (RES); grid infrastructure; energy policy; grid capacity limitation; climate crisis.
Category of the paper: Viewpoint.

1. Introduction

According to the Institute of Renewable Energy Solar energy is widely recognized in the European Union as being crucial for the creation of a safe and sustainable energy system in the future. All future energy scenarios developed in the European Union to meet the 2050 climate goals provide a key role for solar energy. The Solar Europe Now campaign has been initiated by over 90 companies and research institutions from 15 EU countries, who have also signed its declaration. As posited by the signatories, solar energy is regarded as instrumental in achieving the objective of climate neutrality by the year 2050 (Gręda, 2021).

The EU has been increasing its Renewable Energy Sources targets not only because of the need to create a safe and sustainable energy system.

Other motivational factors include the limitation of the world's traditional energy resources (Kakaras et al., 2012), climate protection (Ge et al., 2020), rising electricity prices (Ember, 2021), and increasing demand for electricity.

And finally, as we read in Communication on REPowerEU: "EU leaders agreed in the European Council to phase out Europe's dependency on Russian energy imports as soon as possible" (REPowerEU, 2022). Russia's aggression against Ukraine has contributed to the decision that the 2030 Renewable Energy Sources target for the EU was raised from 27% set in 2014 to 45% in 2022 (Renewable Energy Directive, 2024). Succeeding in this goal will achieve energy stability in EU countries.

Photovoltaics is one of the green technologies that can be deployed most quickly as compared to wind sources windmills, heat pumps, and biogas installations (Martinopoulos, 2020). For this reason, the European Commission has set a REPowerEU target of installing new photovoltaic panels with more than double the current capacity by 2025 (European Green Deal, 2019).

Another factor in favor of investing in the photovoltaic market is climate change. An example of weather changes in Poland from 1961 to 2020 is given in Figure 1. As stated in the report European State of The Climate, prepared by Copernicus, "Globally, the last eight years have been the warmest on record, and 2022 was the fifth warmest year on record. In Europe, summer was the warmest on record, at 1.4°C above average, and 0.3-0.4°C above the previous warmest summer, in 2021. Most of western Europe saw heatwave conditions and temperatures in the United Kingdom reached above 40°C for the first time (European State of Climate, 2022). This situation was accurately summarized in The Washington Post: „Scientists said that could drive more renewable energy generation in countries not traditionally considered awash in solar resources" (Dance, 2024).

In Europe, not only do we have serious reasons to invest in photovoltaics, but we also have favorable climate conditions and attractive grant programs for these investments (Figure 1).

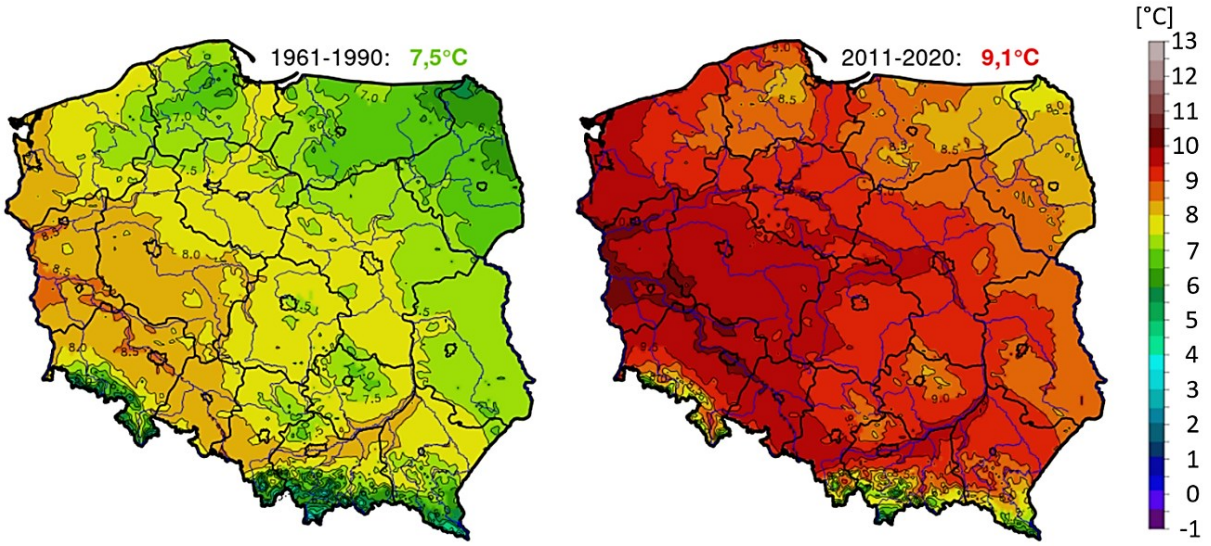

Figure 1. Average annual temperature in Poland in years 1961-1990 and 2011-2020.
Source: Nauka o Klimacie, 2023, 02.2025.

In recent years, Europe has experienced several major blackouts, highlighting vulnerabilities in its energy infrastructure and prompting serious concerns about the continent's capacity to handle such crises. As the transition to sustainable energy intensifies, solar power has become a vital part of this change, due to its environmental advantages and its current cost-effectiveness as a method of generating electricity (Rataj, 2025).

Despite the growing body of literature on renewable energy expansion and climate policy, there is a noticeable lack of focused research on the grid connection barriers—particularly refusals to connect renewable energy installations to the power grid—as a systemic challenge to energy transition (Castronuovo, Canavero, 2009; Gajdzik et al., 2023). Much of the existing academic discourse emphasizes financial, technological, or regulatory support for renewable generation, while insufficient attention is given to the technical and administrative limitations of grid infrastructure and the resulting bottlenecks in deployment (Del Río, Mir-Artigues, 2014; Johnstone, Newell, 2018). This gap is especially pronounced in the context of Poland and Central-Eastern Europe, where detailed empirical data and cross-country comparisons are scarce (CEENERGYNEWS, 2024).

The primary purpose of our study is to demonstrate how aging and inadequately scaled transmission, and distribution infrastructure have become a structural barrier to distributed solar deployment, undermining both national and EU‑wide decarbonization targets. By exposing these under‑examined connection bottlenecks and contextualizing them alongside permitting delays and curtailment practices in Germany, Italy, France, the UK and the US, we aim to establish a foundation for future academic research dedicated to aligning renewable-generation growth with grid modernization.

The structure of this paper follows a problem-solution-discussion format, focusing on the real-world impact of energy policy and infrastructure on climate goals. A brief Introduction Explains the European Union's climate goals, increasing solar investments, and warming trends

supporting PV adoption. Section 2, The Energy Resources in Poland, describes Poland's energy mix and the growing role of photovoltaics. Section 3, Methodology, section 4, Refusals to Connect to the Power Grid, details the grid's inability to accommodate new PV systems and provides European and global context. Section 5, Conclusion, argues for urgent grid modernization as a prerequisite to renewable energy development.

2. The energy resources in Poland

Renewable Energy Sources (RES) are based on natural, ecological, and inexhaustible resources. By producing energy, RES does not affect climate change and the greenhouse effect. Unfortunately, in Poland, more than 60% of the generated electric energy is still produced from coal (Figure 2).

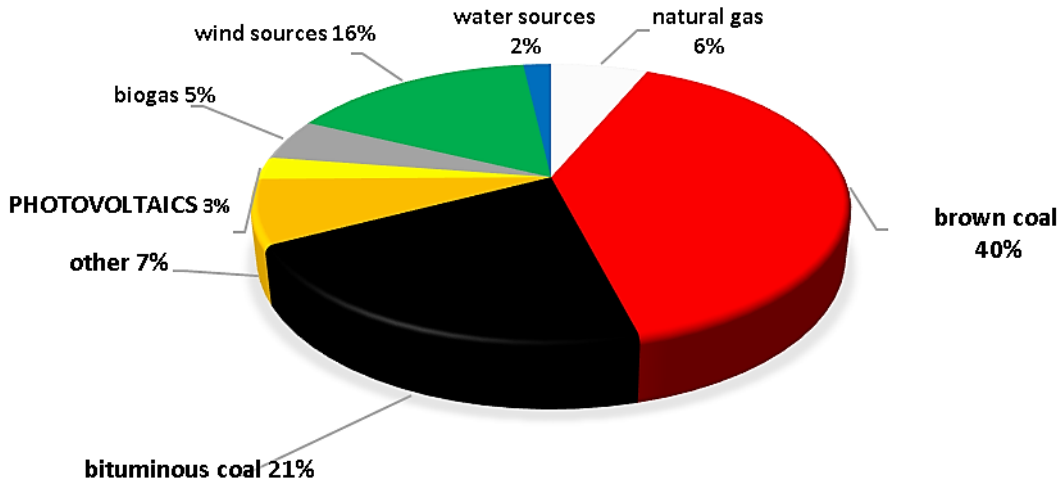

Figure 2. Structure of electricity in Poland in January-March 2023.

Source: Based on ARE, 2023, 12.2024.

The largest amount of energy was generated by brown coal 40%. In second place is bituminous coal, with 21%, and wind was third on the podium, with 16%. In total, energy produced from Renewable Energy Systems from January to March 2023 in Poland accounted for 26% of all energy generated. As a result of such a production structure, the price of electric energy in Poland is the highest in the European Union.

SolarPower Europe identifies European Union solar leaders in 2022-2023 (Figure 3). Germany is Europe's biggest solar market in 2022-2023, followed by Spain, Italy, and Poland in fourth place.

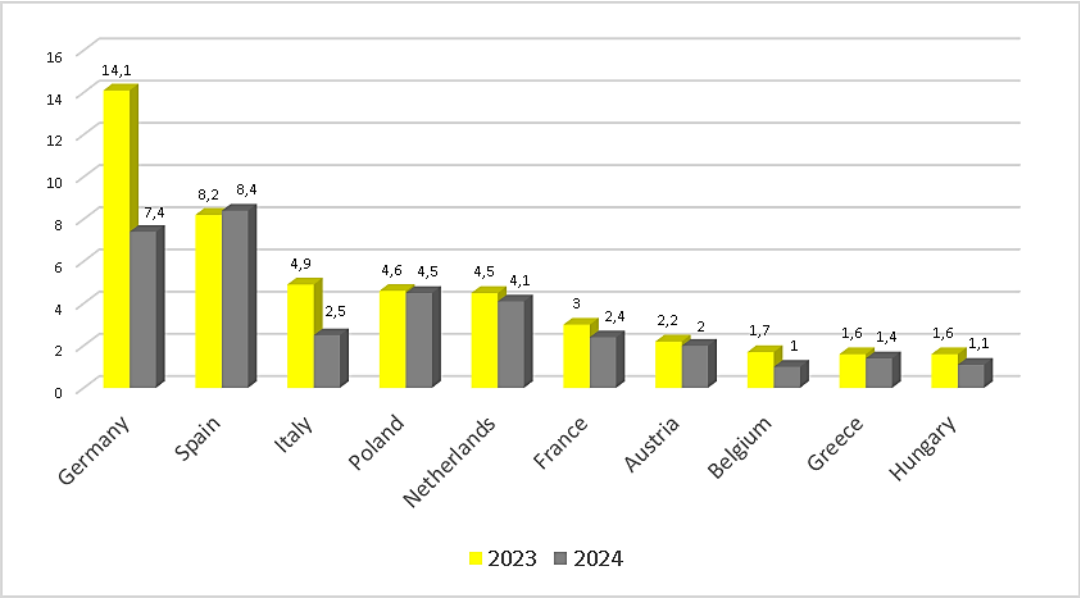

Figure 3. Top 10 EU solar leaders in 2022-2023 (numbers represent GW).

Source: Solar Power Europe, 2024, 12.2024.

Photovoltaics have the largest share of the green Renewable Energy Sources in Poland (Figure 4). In the face of rising electricity prices, interest in investing in renewable energy installations continues to grow.

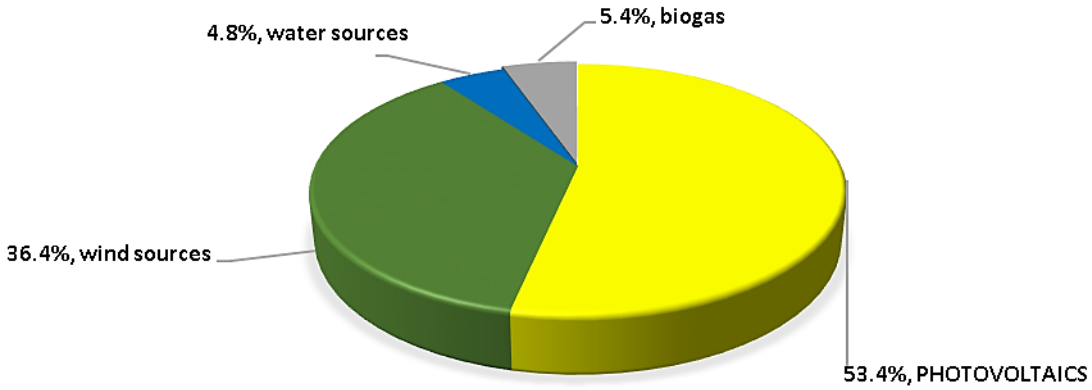

Figure 4. Renewable Energy Sources in Poland in 2022.

Source: EON, 2024, 12.2024.

As much as 53.4% of the renewable electricity generated in Poland is from solar power. Next in line is wind 36.4%). A smaller contribution to green energy in Poland is water 4.8%) and biomass and biogas 5.4%).

According to the Renewable Energy Institute, the photovoltaic market in Poland will continue to maintain its growth in the coming years.

3. Methodology

The selection of sources and countries analyzed in the article was driven by two main criteria: (1) the relevance of the data to the issue of grid connection constraints for renewable energy, and (2) the availability of up-to-date, credible reports and publications that reflect both national and international perspectives. While the focus was primarily on Poland due to its urgent infrastructural challenges and high number of connection refusals in 2022 and early 2023.

For the characterization, we chose countries that are leaders in solar power deployment (Poland, Germany, Italy, France, Spain), and country facing critical grid challenges that mirror Poland's (United Kingdom, United States).

The research was conducted through desk-based analysis. This included industry reports, government publications, academic articles, media interviews, and data provided by organizations such as Eurelectric, PVTech, Berkeley Lab, and the European Solar Power Market Outlook.

The publication dates of sources used in the article range primarily from 2022 to 2025. This time frame was selected to ensure the relevance and accuracy of the data, especially given the rapid developments in renewable energy deployment and grid management strategies in recent years.

4. Refusals to connect to the power grid

As indicated by eurelectric.org, the European continent encompasses 10 million kilometers of power lines. This distance is equivalent to 13 round trips to the moon and back. Notwithstanding the impressive outcomes, Europe is curbing solar generation due to an excess supply.

Provisions of the Energy Law in Poland require electricity system operators to connect renewable energy installations to the grid first. However, it turns out that in the whole investment process, obtaining the appropriate connection conditions becomes the biggest problem. Renewable energy sources, specifically photovoltaic farms, but also wind farms, hydroelectric power plants, energy storage, are mainly receiving refusals.

In 2022 and the first quarter of 2023 in Poland in total 30 357 applications for connection photovoltaics sources of energy to the electricity grid were rejected (Raport Rynek Fotowoltaiki w Polsce, 2023). In Poland, the necessity for the modernization of the grid is driven by two primary factors. Firstly, the country is currently undergoing a significant transformation in its energy sector, which necessitates the updating of infrastructure to accommodate the emerging

renewable energy sources and the increasing demand for electricity. Secondly, the age of the existing grid is a contributing factor to its modernization requirements. Most components are over 25 years old, with a substantial proportion exceeding 40 years.

Mark Hutchinson, director for Asia at the Global Wind Energy Council, in an interview with the Financial Times on 11 June 2023 said: "I don't know of any country where the grid is not currently some level of obstacle to the energy transition" (Hutchinson, 2023). What is unfortunately very true. A good example of this are solar energy European leaders shown in Figure 3. What challenges are they facing? We can find the answer to this question in *EU Market Outlook For Solar Power:* "the large amount of solar projects under development in the country are facing tight permitting challenges".

In Italy: "the authorization of projects remains a challenge. Permitting can take a long times, depending on the region" (EU Market Outlook For Solar Power, 2023).

PV-Tech also flags grid connection bottlenecks in France: "the speed with which new solar projects are being commissioned is faster than the pace at which the grid can be expanded", undermining deployment (PVTech, 2024).

This is not a problem only for European Union countries. Thomas Johnson, editor of the journal *New Civil Engineer,* wrote: "The United Kingdom is currently experiencing a connectivity logjam of projects, which is restricting renewable energy projects from connecting to the grid. As of October 2023, there were 1492 projects, or 371 GW, waiting in the queue" (Johnson, 2023).

As stated in the publication *Queued Up*, at the conclusion of 2023, the number of active grid connection requests exceeded twice the total installed capacity of the power plant fleet in the United States (BerkleyLab, 2025).

Eninrac reports that permitting in the European Union often takes 7-10 years—or more—and EPC (Engineering, Procurement, and Construction) delays of 12-18 months are common in Spain and Germany (Insights, 2025).

We can learn important lessons from the example of German initiatives. Germany have taken a multi-pronged approach to managing the oversupply of solar power—combining grid curtailment, market reforms, energy storage roll-outs and demand-side measures.

In 2024, German transmission system operators curtailed about 30,304 GWh of renewables (mostly PV) to prevent network congestion, down slightly from 34,297 GWh in 2023. Operators are financially compensated as though generation had continued uninterrupted, but curtailment reduced system stress (PV Magazine, 2025).

From November 2024, most new wind and solar plants must sell power directly on the open market rather than bilaterally to grid operators, aligning incentives to absorb oversupply and reducing reliance on fixed-rate schemes (Reuters, 2024).

A new law, effective March 2025, removes guaranteed feed-in tariffs during negative-price periods for PV systems commissioned after enactment. New installations without smart meters must also cap grid export at 60%, incentivizing self-consumption or storage (Reuters, 2024).

Beyond batteries, pilots of smart inverters and virtual power plants under way to shift demand into solar peaks. These include dynamic pricing schemes and AI-driven forecasts to balance generation and consumption in real time (CLOU GLOBAL, 2025).

5. Conclusion

The dynamic expansion of photovoltaic capacity in Poland has highlighted a significant structural constraint: the national electricity grid is outdated and insufficiently scaled to accommodate the growing volume of distributed solar generation. Between 2022 and early 2023, more than 30,000 PV connection applications were rejected, demonstrating a systemic obstacle that jeopardizes Poland's climate and energy security objectives.

This issue reflects a critical imbalance in policy and investment priorities. While financial incentives have effectively stimulated PV deployment, there has been inadequate parallel investment in grid infrastructure. As a result, the technical capacity of the transmission and distribution systems has not kept pace with renewable energy growth. To ensure system reliability and avoid further curtailments or delays, infrastructure modernization must be prioritized ahead of additional renewable energy rollouts.

Failure to address these infrastructural limitations risks increasing electricity costs and weakening Poland's ability to meet both national and European Union decarbonization targets. Current grid constraints contradict the strategic goals of achieving net-zero emissions by 2050 and hinder the broader transition to a resilient, low-carbon energy system.

The purpose of this article was not to provide a solution to the existing problem, but to point out that such a problem exists and generates further problems and threatens the country's energy security. The author will only allow himself to mention that to overcome these challenges, a realignment of energy sector investments is required. Only through coordinated development of generation and transmission infrastructure can the full potential of solar energy be realized.

Who should react first in this situation? It seems that the academic community should take this responsibility.

Although climatic conditions increasingly favor the deployment of PV systems, the underlying technological and infrastructural readiness must be addressed as a matter of priority to ensure a sustainable and efficient energy transition.

Proposed Research Agenda: the implementation of targeted research pathways will provide academics with clear methodological starting points for addressing the grid-connection challenges that have been identified. Three suggestions are given based on experience while searching for data during the writing of this article.

The development of Standardized Data Frameworks is of paramount importance. The creation of an open-access, harmonised database of grid parameters and connection requests is essential for enabling cross-regional analyses.

Geospatial Grid Modelling – the employment of GIS-based power-flow simulations at regional and substation levels is a methodology that has been proven to facilitate the identification of local bottlenecks and the quantification of curtailment risks.

The techno-economic storage integration process involves the conduct of sensitivity studies on distributed storage and demand response. These studies utilize capacity-expansion and dispatch models to evaluate cost-benefit trade-offs.

This article has some limitations. First, this study is based entirely on a review of secondary sources and literature. This approach limits the empirical depth of the analysis. As a result, certain technical nuances - such as detailed load flow dynamics or localized network performance - cannot be fully verified by this study. Second, the geographic focus of the study limits the generalizability of the conclusions. The analysis focuses on the Polish electricity system and its specific regulatory and infrastructure context, although comparative examples from other countries are cited. Because Poland's energy mix, grid characteristics and policy environment differ from those in other regions, the conclusions drawn here may not be directly applicable elsewhere.

Acknowledgment

I would like to express my gratitude to Grzegorz Rataj Instalcje Elektryczne for their valuable assistance and guidance throughout the process of drafting this article.

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