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COMPARATIVE ENERGY TRANSFORMATION MANAGEMENT: POLAND AND GERMANY'S PATH TO SUSTAINABILITY

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Purpose: This article examines the approaches to energy transition management in Poland and Germany. Its primary objective is to analyze the lessons that can be derived from each country's experience to inform and guide their respective future transformation processes.
Design/methodology/approach: To initiate the research, a baseline literature review was undertaken, employing a combination of critical review methodologies, online searches, and the exploration of multidisciplinary academic databases such as Scopus and Google Scholar. To gain a comprehensive understanding of the issue under analysis, the study adopted a multi-method research design. This approach integrated various analytical techniques to examine the energy transition processes in both countries, including comparative analysis, secondary data analysis, policy analysis, and case study analysis.
Findings: The research indicates that energy transition governance in Poland and Germany reflects two distinct yet instructive models, shaped by historical legacies, socio-political contexts, and economic priorities. The study seeks to extract lessons from each country's experience that can inform and support their respective future transformation pathways.
Originality/value: This paper contributes to the scientific discourse by offering a comparative analysis of energy transformation management in Poland and Germany, two countries with contrasting historical, socio-political, and economic contexts. It advances existing research by identifying key governance models, policy instruments, and institutional frameworks that shape national energy transitions. By synthesizing lessons learned from both cases, the study provides a nuanced understanding of context-specific and transferable strategies for effective energy governance. This comparative perspective enriches the literature on sustainable energy transitions and offers actionable insights for policymakers navigating similar transformation challenges.
Keywords: Energy Transition in Poland, Energy Transition in Germany, Management, Governance, Transition governance models.
Category of the paper: research paper.

1. Introduction

The energy transition represents one of the most critical challenges of the 21st century, shaping the future of the global climate system, economy, and energy security. Its effectiveness and pace are fundamental in mitigating the adverse effects of climate change and ensuring stable socio-economic development. The shift away from coal and the broader energy transition pose significant challenges for industrialized countries, particularly those whose economies have historically been reliant on fossil fuels. Poland and Germany exemplify this dynamic, as the coal industry has played a fundamental role in their economic development and energy security for decades. The historical trajectory of coal mining in Germany and Poland underscores the sector's crucial role in industrialization, economic stability, and energy security. Throughout the nineteenth and twentieth centuries, both countries structured their economies around coal, shaping their respective industrial landscapes. The coal industry was instrumental in the industrial development of Germany and Poland, with two primary regions—Germany's Ruhr Valley and Poland's Silesia—serving as focal points for this expansion. In Germany, the Ruhr Valley was a cornerstone of the country's industrialization throughout the nineteenth and early twentieth centuries. By the mid-twentieth century, it accounted for more than 80% of Germany's hard coal production, supplying energy for the metallurgical sector, heavy industry, and post-war reconstruction (Wesseling et al., 2017). Similarly, Silesia, located in southern Poland, emerged as the country's industrial hub, with coal mining playing a pivotal role in its economic development. Throughout the twentieth century, Silesia remained at the centre of Poland's extractive sector, contributing the majority of the nation's coal production (Bondaruk, 2023). By the mid-twentieth century, structural inefficiencies within the coal industry in both Germany and Poland had begun to emerge. Increasing operational costs, competition from cheaper coal imports, and the depletion of high-quality coal reserves contributed to the sector's declining profitability. Changing economic conditions, growing environmental concerns, and international climate commitments necessitated structural transformations within the coal industry in both countries. Environmental considerations have played a significant role in shaping the trajectory of the coal sector's transformation. Both the Ruhr Valley and Silesia have experienced adverse consequences due to extensive coal extraction, including land subsidence, water contamination, and deteriorating air quality. The Ruhr Valley has become a centre for post-mining land reclamation initiatives, while air pollution levels in Silesia remain among the highest in Europe, generating increasing societal and political pressure to accelerate the energy transition. Germany and Poland have adopted distinct approaches to restructuring their coal industries. The German energy transition has been embedded within a broader energy and climate policy framework. The Energiewende program (Jacobsson, Lauber, 2006) has encompassed economic diversification through the development of new industrial sectors, investments in renewable energy—particularly wind and solar power—programs for the

retraining and reintegration of former coal workers, and large-scale environmental reclamation projects aimed at revitalizing former mining areas. Poland's energy transition has been more gradual and remains ongoing. Between 1994 and 2005, 38 coal mines were closed, financed by the Liquidation Fund and the state budget. However, Poland continues to face significant social and political resistance to coal phase-out, coupled with a slower expansion of renewable energy sources. Coal remains the dominant component of the country's energy mix, delaying the transition toward a more sustainable energy system. This paper undertakes a comparative analysis of the governance models of energy transition in Poland and Germany, examining the historical context of the transition, the legal framework and legislative initiatives governing coal phase-out, the timeline for fossil fuel reduction in both countries, financial mechanisms supporting the transition, public consultation and stakeholder engagement efforts, and broader governance structures facilitating the transition process.

2. Materials and methods

To initiate the research, a baseline literature review was conducted using a combination of critical literature review methods, online literature searches, and an examination of multidisciplinary academic databases, including Scopus and Google Scholar. The search strategy employed key terms such as "Energy Transition", "Energy Transition Governance in Poland", and "Energy Governance Transition in Germany" to ensure a broad yet focused collection of relevant sources. For the mapping the methodology of VOS-viewer has been used. VOS-viewer is a special tool that uses the software for visualizing and constructing bibliometric networks, which include for example journals, researchers, or individual publications, and they can be constructed based on citation, bibliographic coupling, co-citation, or co-authorship relations The literature review identified energy transition as a systematic shift towards clean and sustainable energy sources. Furthermore, it highlighted significant differences in Energy Transition Governance between Poland and Germany.

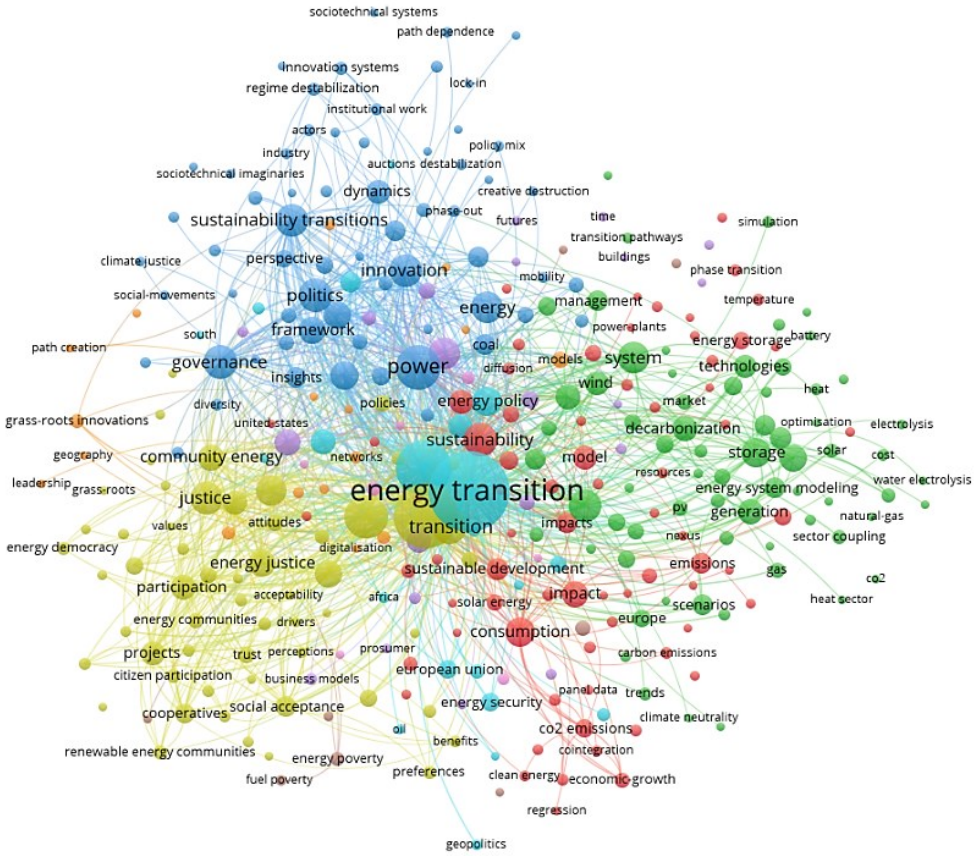

Figure 1. Literature review of the energy poverty in Germany.

Source: VOS viewer.

The literature on Germany's energy policy highlights the profound transformation driven by the Energiewende, a comprehensive strategy to shift from fossil fuels to cleaner, more sustainable energy sources. A visual representation of this transition typically includes a multicoloured graph depicting the changing shares of energy sources over time, with each colour corresponding to a specific energy type. In the graph, dark grey typically represents coal, historically a cornerstone of Germany's energy system, particularly in industrial regions such as the Ruhr Valley. The literature emphasizes a marked decline in coal usage over time, reflecting Germany's official commitment to phase out coal-fired power by 2038, with the potential to accelerate this deadline to 2035. This trend is directly tied to the Energiewende and Germany's broader decarbonization goals. Green represents the rapid expansion of renewable energy sources, including wind, solar, and biomass. Academic sources note that the share of renewables has grown steadily and significantly, supported by strong policy incentives and national targets—such as achieving 80% renewable electricity by 2030. The graph illustrates this rise, underscoring Germany's commitment to replacing coal and nuclear with clean alternatives. Yellow areas typically indicate natural gas, which is acknowledged in the literature as a transitional fuel. As coal is phased out, natural gas provides a flexible and relatively lower-emission alternative to maintain energy system stability. The graph likely shows a temporary increase or plateau in gas usage, illustrating its short- to medium-term role within the transition

framework. Other sources, such as nuclear power and hydropower, are shown in blue or light grey. While nuclear energy once played a substantial role, Germany's energy policy has moved decisively toward phasing it out, with the last nuclear plants closed in 2023. These sources now represent a minimal share in the energy mix, as reflected by their relatively small and declining presence in the graph. Key policy milestones and targets—such as the 2038 coal exit or the 2030 renewable electricity goal—are often marked in red or bold colours to draw attention to the timeline of change. These visual markers highlight critical turning points in the transition and are commonly used in graphs and reports to emphasize progress and urgency. Overall, the graph serves as both a visual summary of Germany's evolving energy landscape and a timeline of strategic policy shifts. The colour-coded sections effectively communicate the shift from a coal- and nuclear-dominated mix toward a renewable-driven energy system.

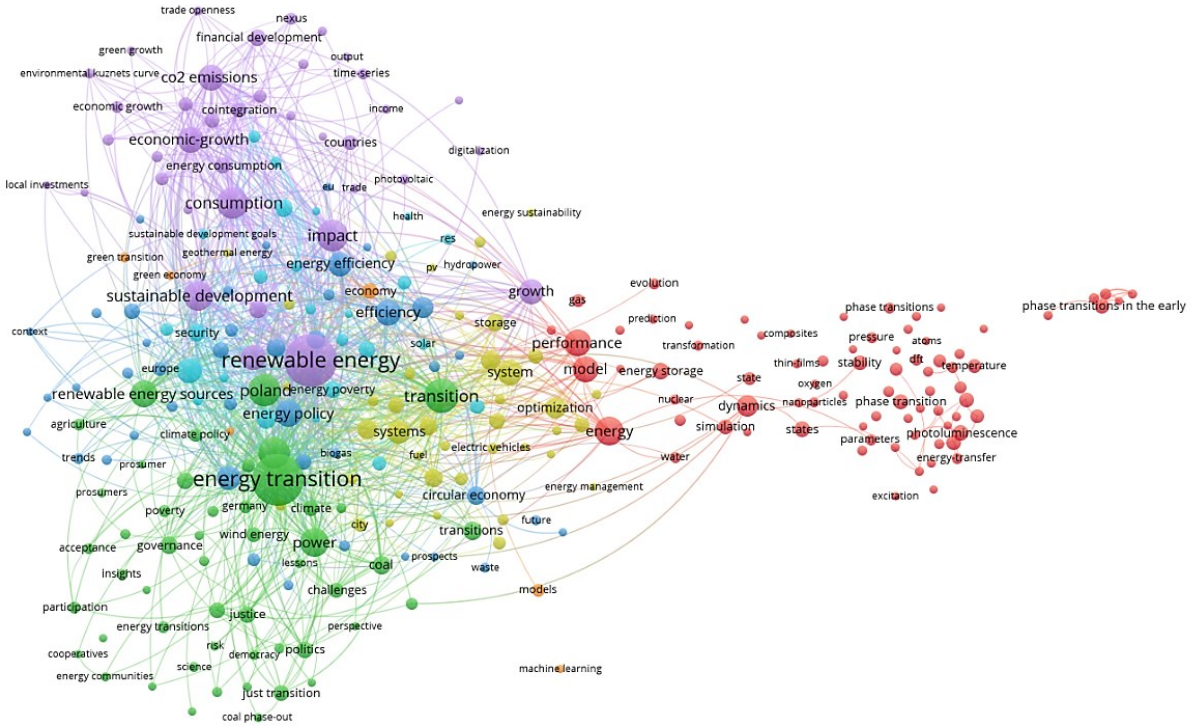

Figure 2. Literature review of the energy poverty in Poland.

Source: VOS viewer.

The literature on Poland's energy transition highlights the complexity and gradual pace of the country's shift toward a low-carbon energy system. A typical graphical representation of this transition uses colour-coded segments to depict the changing composition of Poland's energy mix, revealing the country's ongoing reliance on coal and the challenges involved in moving toward renewable sources. In Poland's energy graph, coal is represented by dark grey, reflecting its dominant role in the national energy mix. Coal continues to be the backbone of Poland's electricity generation, largely due to its importance for energy security and the socio-economic dependence of certain regions on coal mining. The graph illustrates a slow but steady decrease in coal usage, indicating efforts to diversify energy sources. However, literature points out that coal's share remains substantial in the short to medium term and is only expected to

decline significantly in the longer future. The green section of the graph marks the contribution of renewable energy sources, such as wind and solar. Although Poland has taken steps to promote renewables, their overall share remains modest. The literature indicates a slow and incremental increase in the adoption of renewables, aligning with the national goal of reaching 32% renewable electricity by 2030. Compared to countries like Germany, Poland's progress is slower due to its entrenched reliance on coal and the political and economic complexities of energy reform. Natural gas, typically shown in yellow, is gaining significance as a transitional energy source in Poland's strategy. It is viewed as a temporary solution that can help reduce carbon emissions while maintaining energy security during the coal phase-out. The graph likely shows a steady rise in natural gas use, particularly with investments in new gas-fired power plants. However, some sources caution that this may prolong the transition to a fully renewable system if over-relied upon. Other energy types, such as nuclear power and hydropower, are represented by blue or light grey. Poland is in the process of developing its first nuclear power plants and expanding offshore wind capacity, indicating a broader diversification of the energy mix. The literature suggests that these sources, while still limited in share, are projected to grow steadily and play a more substantial role post-2030. The graph reflects this by showing a gradual increase in their presence. Key policy goals and transition milestones are usually emphasized using red. Notable markers include the target of reducing coal-based electricity to 30% by 2030 and the strategic timeline set out in the Energy Policy of Poland until 2040 (PEP2040). These milestones are crucial indicators of progress and are visually accentuated in the graph to track Poland's advancement—or delays—in achieving its energy goals. Overall, Poland's energy transition graph visually encapsulates the country's cautious but determined shift toward sustainability. Despite significant reliance on coal, gradual diversification efforts and policy milestones signal a growing momentum for change, albeit at a more conservative pace than seen in some of its European counterparts.

To develop a more comprehensive understanding of the analysed issue, the study employed a multi-method research approach, integrating several analytical techniques to examine the energy transition in both countries:

- Comparative Analysis was employed to systematically assess the policies, strategies, and outcomes of the energy transition in Poland and Germany. This approach encompassed political, economic, and social dimensions, allowing for a holistic evaluation of transformation processes.
- Secondary Data Analysis supplemented the research by reviewing existing reports, government documents, national and regional energy strategies, and statistical data from authoritative sources such as Eurostat, the International Energy Agency (IEA), and the BP Statistical Review of World Energy. This data-driven approach facilitated an empirical evaluation of key trends and policy impacts.

- Policy Analysis was conducted to evaluate the effectiveness of governmental strategies in Poland and Germany, with particular attention to regulatory frameworks and climate policies. This analysis included an assessment of legislative measures such as the European Commission's "Fit for 55" package, Germany's Energiewende, and Poland's Energy Policy 2040. The objective was to examine the broader policy implications for energy sector transformation and long-term sustainability goals.
- Case Study Analysis focused on a comparative examination of two post-mining regions: Silesia in Poland and the Ruhr Valley in Germany. This analysis provided insights into regional adaptation strategies, socio-economic restructuring, and the challenges associated with transitioning away from coal-dependent industries.

By integrating these methodological approaches, the study aimed to develop a nuanced and evidence-based understanding of the energy transition in both national and regional contexts. To compare the models of energy transition management in Poland and Germany, the following key factors were taken into consideration:

- The historical context of the energy transition in both countries.
- The legal framework and legislative initiatives governing coal phase-out.
- The role of public consultation and stakeholder engagement efforts in shaping energy policies.

This comparative framework enabled a structured assessment of the governance models shaping the energy transition in Poland and Germany, providing valuable insights into policy effectiveness and implementation challenges.

3. Energy Transformation Management in Poland and Germany

Historical context of the transition in Poland and Germany

The historical trajectory of coal mining in Germany and Poland highlights the sector's critical role in industrialization, economic stability, and energy security. Both nations heavily relied on coal throughout the 19th and 20th centuries, shaping their respective economic landscapes However, as global economic and environmental priorities shifted, coal-dependent economies faced significant challenges, leading to restructuring and an eventual decline in coal production. While Germany pursued an early transition in response to economic pressures and environmental concerns (Renn, Marshall, 2020). Poland's transition—particularly in the Silesian region—has been more gradual due to the continued socio-economic reliance on coal (Grudziński, Olkuski, 2019). Two key regions stood at the forefront of the economic and industrial expansion in both Germany and Poland: the Ruhr in Germany and Silesia in Poland. In Germany, the Ruhr region was the backbone of the country's industrialization in the 19th

and early 20th centuries. By the mid-20th century, it accounted for over 80% of Germany's hard coal production, supplying energy for steel manufacturing, heavy industries, and post-war reconstruction (Matthes, 2017). The economic dominance of coal mining transformed the Ruhr into an industrial giant, with cities like Essen, Dortmund, and Bochum emerging as key centers of mining and steel production (Cheung et al., 2017). Similarly, Silesia, located in southern Poland, became the country's industrial core, with coal mining playing a decisive role in economic development. Throughout the 20th century, Silesia was the centre of Poland's mining sector, responsible for the vast majority of the country's coal extraction (Cappellano et al., (2024). At its peak in 1990, Poland operated 71 coal mines, employing nearly 400,000 workers, and most of these mines were concentrated in Upper Silesia. Both regions developed strong economic identities around coal, but their transitions away from coal have followed different paths. By the mid-to-late 20th century, structural inefficiencies in coal mining became evident in both Germany and Poland. Rising operational costs, competition from cheaper imports, and the depletion of high-quality coal deposits led to increasing financial strain on domestic coal industries (Weidner, Mez, 2008). The Ruhr region faced mounting economic constraints in the 1960s, exacerbated by competition from cheaper imported coal, particularly from the United States and Australia (Wigand, Amazo, 2017). The discovery of alternative energy sources such as nuclear power and natural gas further reduced the economic viability of coal mining (Wirth, Schneider, 2015). Additionally, Germany's commitment to international climate agreements, including the Paris Agreement, accelerated efforts to phase out coal (Eloy, 2016). In Poland, similar economic inefficiencies emerged, particularly in Silesia. The sector struggled with overproduction, high operational costs, outdated infrastructure, and reliance on state subsidies (Fischer et al., 2016). Environmental concerns also played a crucial role in shaping the coal transition. Both the Ruhr and Silesia suffered from severe ecological damage, including land subsidence, water contamination, and deteriorating air quality (Jungjohann, Morris, 2014). The Ruhr region became a focal point for environmental restoration efforts, with large-scale land rehabilitation projects and investments in alternative industries. Meanwhile, in Silesia, pollution levels remained high due to continued coal dependence (Rogala, Cieślik2020). The region is home to some of the most polluted cities in Europe, including Katowice and Rybnik, where air quality concerns have led to growing public and political pressure to accelerate the energy transition (Rogall, 2020). Despite these concerns, resistance to coal phase-out remains strong due to its economic significance in Poland (Topaloglou et al., 2024).

4. Legal Context and legislative initiatives on transition in Poland and Germany

The transition from coal dependency to a low-carbon economy is one of the most significant energy transformations in Europe. Both Poland and Germany have adopted structured policies to phase out coal, aligning their strategies with European Union climate targets. However, these two countries face distinct economic, political, and social challenges in implementing their energy transitions. While Germany has established a comprehensive legal framework for coal phase-out, with a clear timeline and strong economic compensation mechanisms, Poland's transition remains gradual, balancing energy security concerns, economic stability, and EU climate commitments (Agora Energiewende, 2015). Both Poland and Germany have implemented national policies and legislative frameworks to guide their coal phase-out processes. However, Germany's legal approach is characterized by legally binding phase-out dates and financial compensation mechanisms, whereas Poland's strategy is more flexible, accommodating the ongoing reliance on coal for energy security.

Germany has implemented a series of ambitious legislative and policy frameworks to drive its energy transition and achieve climate neutrality such as:

- **Federal Climate Protection Act (2019)**

Known as the Bundes-Klimaschutzgesetz, this act legally binds Germany to meet both national and EU climate targets. It affirms Germany's pledge to pursue greenhouse gas neutrality by 2050, as announced at the UN Climate Summit in 2019. The act provides a roadmap for emissions reductions across sectors and guides the country's Climate Action Programme to 2030.This groundbreaking act of legislation establishes a legally binding framework for Germany's climate policy, anchoring the country's national and EU climate obligations into law. It reflects Germany's commitment to achieving greenhouse gas neutrality by 2050.

The act sets sector-specific annual emission reduction targets for areas such as energy, industry, transport, buildings, agriculture, and waste management. These targets are monitored and enforced by an independent Council of Experts on Climate Change, which evaluates annual emissions reports and advises on corrective measures if targets are missed.

Key features of the Act include:

- A binding reduction path for greenhouse gas emissions up to 2030, aiming for a 55% reduction compared to 1990 levels.
- Annual reporting and transparency mechanisms to ensure accountability across all sectors.
- Empowerment of federal ministries to take responsibility for emissions in their sectors and implement necessary actions.
- Legal recourse and mandatory adjustments if sectors fail to meet their targets.

The Federal Climate Protection Act also supports Germany's broader Climate Action Programme 2030, which includes investments in renewable energy, public transport, energy-efficient buildings, and sustainable mobility. Overall, the act not only strengthens climate governance in Germany but also provides long-term policy certainty for stakeholders involved in the energy transition.

- **Coal Exit Act (2020)**

Officially named the *Gesetz zur Reduzierung und zur Beendigung der Kohleverstromung*, the Coal Exit Act lays out a legally binding roadmap for the complete phase-out of coal-fired power generation in Germany by 2038. This law represents a cornerstone of Germany's broader climate strategy, signalling a decisive move away from fossil fuels toward a more sustainable and renewable-based energy system. The act stipulates a gradual reduction of coal capacity, with intermediate targets and milestones. It includes differentiated timelines for phasing out hard coal and lignite (brown coal), the latter of which is more carbon-intensive and concentrated in specific regions like Lusatia and the Rhineland.

Key components of the Coal Exit Act include:

- €40 billion support package for the most affected coal-dependent regions. This funding is aimed at:
  - Economic restructuring and job creation in new industries.
  - Infrastructure development and education initiatives.
  - Attracting innovation and clean technology investments.
- Compensation mechanisms for utility companies and workers affected by early plant closures.
- Auction schemes to incentivize power plant operators to voluntarily shut down coal capacity in a cost-effective and competitive manner.
- Modernization and transition support for combined heat and power (CHP) systems to convert them to more climate-friendly technologies.
- Legal commitments to review the coal phase-out timeline by 2026, with the possibility of bringing forward the 2038 deadline, particularly in light of evolving EU climate targets and Germany's own energy market developments.

Importantly, the act also ensures that the coal exit is aligned with energy security and grid stability, especially during the transition period when Germany is also decommissioning its nuclear power plants. The scale of the transition—reflected in the allocation of nearly 11% of the federal budget in 2020—underscores the socio-economic and political significance of this policy.

- **Renewable Energy Sources Act (EEG 2023)**

The *Erneuerbare-Energien-Gesetz (EEG)*, originally enacted in 2000, has long been the legislative backbone of Germany's renewable energy expansion. Over the years, it has been revised multiple times to adapt to changing market conditions, technological advancements, and climate policy goals. The 2023 amendment of the EEG marks one of the most ambitious

iterations to date, reflecting Germany's intensified commitment to accelerating the energy transition.

The EEG 2023 sets a bold new target: by 2030, 80% of Germany's electricity consumption must be covered by renewable energy sources, such as wind, solar, biomass, and hydroelectric power. This is a critical milestone on the path to achieving greenhouse gas neutrality by 2045.

Key features and objectives of the EEG 2023 include:

- Accelerated expansion of wind and solar power, with legally defined annual capacity addition targets (e.g., 10 GW/year for onshore wind and up to 22 GW/year for solar PV).
- Simplified permitting procedures to remove bureaucratic barriers and speed up project development, especially for wind farms and rooftop solar installations.
- Grid modernization and digitalization measures to ensure that renewable energy can be efficiently integrated into the public electricity grid and distributed nationwide.
- A shift from fixed feed-in tariffs to market-based premiums, promoting cost-efficiency and competition among energy producers.
- A strengthened focus on citizen participation and community energy, allowing local cooperatives and individuals to benefit more directly from renewable energy projects.
- Support for innovative technologies and flexibility solutions, such as energy storage, smart grids, and hydrogen production from surplus renewables (power-to-x technologies).
- Integration of climate justice and social equity principles, including mechanisms to limit energy costs for consumers and provide support for low-income households.
- **Energy Policy of Poland until 2040 (PEP2040)**

The *Polityka Energetyczna Polski do 2040 roku (PEP2040)* represents Poland's most comprehensive and strategic approach to energy planning in over a decade. Officially adopted in 2021, it sets the foundation for a long-term, gradual transformation of Poland's energy sector in alignment with European Union climate and energy goals.

At the heart of PEP2040 lies the principle of a just and inclusive energy transition, ensuring that no region or social group is left behind. This is particularly relevant for Poland, a country historically reliant on coal, where large parts of the workforce and regional economies are still deeply embedded in fossil fuel industries.

Key pillars of the PEP2040 include:

1. Diversification of the Energy Mix

PEP2040 charts a clear shift away from coal and towards low- and zero-emission energy sources. By 2040, coal's share in electricity generation is expected to fall significantly, replaced by:

- Offshore wind energy, with a planned capacity of up to 11 GW by 2040.
- Onshore renewables, including solar PV and biomass.

- The commissioning of Poland's first nuclear power plant in 2033, with further units to follow, forming a stable low-emission energy backbone.

2. Energy Security and Supply Stability

The strategy prioritizes the reliability and resilience of Poland's energy system, especially in the context of growing energy demand and shifting geopolitical conditions. This includes:

- Modernizing and expanding the electricity grid.
- Building energy storage capacity and smart grid infrastructure.
- Enhancing gas infrastructure as a transition fuel.

3. Economic Competitiveness and Innovation

PEP2040 underscores the importance of a competitive energy sector that supports economic growth and job creation. It promotes:

- Investment in research and innovation, particularly in clean technologies.
- The development of domestic supply chains for renewable energy components.
- Support for energy-intensive industries in reducing their carbon footprint while maintaining global competitiveness.

4. Just Transition for Coal Regions

Recognizing the socio-economic challenges of moving away from coal, the policy includes targeted support for coal-dependent regions like Silesia. This includes:

- Retraining programs for workers.
- Support for small and medium enterprises (SMEs).
- Investments in education, infrastructure, and alternative industries.

5. Energy Efficiency and Consumer Empowerment.

Improving energy efficiency across all sectors is a key goal. The policy aims to:

- Reduce primary energy consumption.
- Promote energy-saving technologies in buildings and industry.
- Increase consumer participation in energy production through prosumer initiatives (e.g., rooftop solar).

- **National Energy and Climate Plan (NECP) 2021–2030**

Poland's Updated National Energy and Climate Plan (NECP) for 2021-2030 is a strategic framework designed to align national energy and climate policy with the broader European Green Deal and EU climate targets, while carefully considering Poland's unique economic and energy landscape. It builds on the original NECP of 2019, strengthening ambitions across key areas in response to the European Union's increased climate targets for 2030.

This updated NECP sets forth a comprehensive set of targets and policy measures to drive the green transformation of Poland's economy, modernize the energy system, and ensure energy sovereignty. It provides a blueprint for decarbonization, energy efficiency, and a just transition over the next decade.

Key Goals and Commitments:

- 50.4% reduction in greenhouse gas emissions by 2030 (vs. 2020 levels). Poland plans a significant emissions cut through the phasing out of coal, scaling up of renewables, and enhanced energy efficiency measures. This marks a substantial step forward, given Poland's traditionally coal-dependent energy mix.
- 56% share of renewables in electricity generation. The plan anticipates rapid growth in solar PV, onshore wind, and offshore wind, as well as a larger role for biomass and biogas in the energy mix. Offshore wind is projected to be a game-changer, with multi-gigawatt scale projects planned in the Baltic Sea.
- 16.7% reduction in primary energy consumption. Efficiency improvements will span across sectors—particularly in residential buildings, transport, and heavy industry—with incentives for retrofitting, energy management systems, and smart metering.
- ~PLN 792 billion (€170+ billion) investment in the energy transition. This unprecedented investment will be channelled into:
  - Clean energy infrastructure (generation, transmission, and distribution).
  - Grid modernization and digitization.
  - Renewable energy deployment and innovation.
  - Support for new green technologies and manufacturing capabilities.
- Strengthening energy security and resilience. The NECP addresses Poland's reliance on fossil fuel imports and promotes a more self-sufficient energy system, bolstered by renewables, modern grid infrastructure, energy storage, and diversified energy sources.
- Support for coal regions and social cohesion. Through a just transition strategy, the plan ensures that communities affected by the decline of coal receive financial, technical, and institutional support. This includes retraining programs, job creation in clean industries, and targeted regional development initiatives.
- Promotion of clean tech and innovation. The plan recognizes the crucial role of innovation in decarbonization, emphasizing R&D in areas like green hydrogen, energy storage, electromobility, smart grids, and carbon capture. It also aims to foster domestic innovation ecosystems and public-private cooperation.

Table 1.
Key legal initiatives on transition in Poland and Germany

Country	Policy/Legislation	Year	Objectives and Key Features
Germany	Federal Climate Protection Act (Bundes-Klimaschutzgesetz)	2019	- Legally binding climate neutrality by 2050. - Sector-specific emission reduction targets (55% by 2030 vs. 1990). - Independent oversight and annual reporting. - Legal recourse for missed targets. - Supports Climate Action Programme 2030.
Germany	Coal Exit Act	2020	- Complete coal phase-out by 2038 with interim milestones. - €40 billion for regional transition support. - Compensation for affected companies/workers. - Auction mechanisms for plant closures. - Review possibility to expedite exit by 2026.

Cont. table 1.

Germany	Renewable Energy Sources Act (EEG 2023)	2023	- Target of 80% renewable electricity by 2030. - Defined annual capacity additions (wind 10 GW, solar up to 22 GW). - Simplified permitting procedures. - Shift to market-based incentives. - Emphasis on citizen participation and community energy. - Support for innovative technologies and social equity.
Poland	Energy Policy of Poland until 2040 (PEP2040)	2021	- Just transition from coal, diversified energy mix (offshore wind up to 11 GW by 2040, nuclear from 2033). - Energy security and grid resilience improvements. - Economic competitiveness and innovation. - Targeted regional support for coal regions. - Enhanced energy efficiency and consumer participation.
Poland	National Energy and Climate Plan (NECP) 2021-2030	2021	- 50.4% GHG emissions reduction by 2030 (vs. 2020). - 56% renewable electricity by 2030 (solar, onshore/offshore wind, biomass). - 16.7% primary energy consumption reduction. - PLN 792 billion (€170+ billion) energy transition investment. - Enhanced energy security, grid modernization, and support for coal regions. - Promotion of innovation (hydrogen, storage, electromobility).

Source: Own study.

While both Germany and Poland have established legislative frameworks for coal phase-out, the effectiveness of policy implementation varies considerably between the two countries, influenced by political will, institutional capacity, and socio-economic dynamics. Germany has made substantial progress in operationalizing its coal exit strategy. The Coal Phase-Out Act and the Climate Protection Act provide a robust legal foundation, ensuring policy continuity and investor confidence. The €40 billion allocated for regional development has enabled some coal regions, like the Ruhr, to pivot towards service industries and renewable energy. Moreover, the share of coal in Germany's electricity mix has steadily declined, with renewables contributing over 50% to electricity generation as of 2023. However, implementation gaps remain. Critics argue that financial compensation has disproportionately favored large energy companies, with insufficient direct support for workers and small communities. Additionally, recent energy security concerns triggered by the war in Ukraine led to the temporary reactivation of some coal plants, raising questions about the resilience of the transition. Poland, on the other hand, faces more structural challenges. Despite policy commitments in the Energy Policy of Poland until 2040 and the National Energy and Climate Plan, coal remains a dominant energy source, contributing over 70% to electricity generation in 2023. While EU-funded programs under the Just Transition Mechanism have begun to support workforce retraining and renewable energy projects in Silesia, progress has been slow and uneven. Delays in regulatory reforms, limited infrastructure for renewables, and a strong coal lobby have hindered effective implementation. Furthermore, Poland's reliance on gas as a transitional fuel may prolong dependence on fossil fuels rather than accelerating the shift to a low-carbon economy. Germany's implementation approach is more structured and measurable, though not without flaws. In contrast, Poland's transition is constrained by political and economic dependencies, making implementation less predictable and slower in pace. Evaluating effectiveness reveals

that legal mandates and financial instruments alone are insufficient without equitable social outcomes and consistent political commitment.

The outbreak of the war in Ukraine in 2022 demonstrate how external geopolitical shocks can rapidly reshape national energy priorities and governance frameworks, reinforcing the importance of flexible, adaptive transition strategies that balance long-term climate goals with short-term energy security imperatives. For Germany, the sudden loss of Russian gas imports—previously accounting for over half of its supply—prompted emergency measures including the temporary reactivation of coal-fired power plants, expedited construction of LNG terminals in Brunsbüttel and Wilhelmshaven, and a short-term recalibration of its decarbonization timeline. Although the long-term goals of the Energiewende remain intact, the crisis exposed vulnerabilities in Germany's energy system and underscored the need for greater resilience and diversification, including increased investment in hydrogen and energy storage technologies. Poland, on the other hand, had already pursued partial diversification through infrastructure projects such as the Świnoujście LNG terminal and the Baltic Pipe, which became vital strategic assets in the post-2022 context. However, the crisis further solidified coal's role as a "reliable fallback", slowing down short-term decarbonization efforts. At the same time, it spurred intensified efforts to accelerate nuclear deployment and expand offshore wind, positioning energy sovereignty as a key driver of transition policy. Both countries also aligned with the European Commission's REPowerEU plan, which emphasized the urgent need to reduce fossil fuel dependence from Russia while accelerating the rollout of renewables.

5. Consultations & Public Engagement Efforts in Poland and Germany

The role of public engagement in the transition away from coal in both Germany and Poland underscores the complexities of balancing economic, social, and environmental considerations in large-scale energy transformations. The effectiveness of stakeholder participation is crucial in ensuring a just and inclusive transition; however, challenges persist, particularly in regions where coal has historically been an economic mainstay (Matthes, 2017). In Germany, the Commission on Growth, Structural Change, and Employment (Jurca, 2014) played a pivotal role in formulating a consensus-driven approach to coal phase-out. The structured involvement of key stakeholders, including industry representatives, labour unions, and environmental organizations, facilitated a broad-based agreement that incorporated economic, environmental, and social considerations (Morris, 2013). The commission conducted over 100 expert hearings and received input from more than 500 stakeholders, ensuring an inclusive decision-making process (Agora Energiewende, 2019). Despite this, tensions remained, particularly concerning the timeline of coal phase-out and the adequacy of compensation measures for affected industries and workers. Similarly, Poland has adopted a consultative approach, notably through expert committees and roundtable discussions, to address the concerns of various stakeholders.

Public consultation mechanisms, mandated by law, provide communities with opportunities to voice their concerns regarding energy projects (Tol, 2023). However, questions remain regarding the extent to which these consultations influence policy adjustments that adequately address local economic impacts. The 2021 Social Agreement on the Transformation of the Coal Mining Sector, which includes employment guarantees and financial mechanisms for coal companies, represents a significant step in ensuring a fair transition. Nevertheless, the agreement's timeline, which extends coal mining operations until 2049, has been met with criticism from environmental groups advocating for a more ambitious decarbonization strategy (European Climate Foundation, 2022). Public forums and citizen assemblies have played a crucial role in fostering social acceptance of the coal phase-out process in Germany. The inclusion of local communities in transition planning has been shown to increase trust and reduce opposition to policy changes. According to the German Federal Environment Agency (BMWi, 2017), while 72% of respondents supported the transition to renewable energy, concerns over job security and economic instability in coal-reliant regions persisted. The introduction of regional engagement platforms helped mitigate resistance by increasing transparency and enabling affected communities to participate actively in decision-making processes. In Poland, social acceptance of the coal phase-out remains a contentious issue. While stakeholder engagement initiatives, such as workshops and community dialogues, have provided a platform for discussion, the effectiveness of these efforts varies across regions (Ember, 2024). The Social Agreement of 2021 attempts to address these concerns through financial compensation and social protection measures, including mining leave, severance pay, and employment guarantees (Soboń, 2021). However, public perception remains mixed, with ongoing fears of economic marginalization in coal-reliant regions (Mazurkiewicz, 2019). Recurring challenge in both Germany and Poland is the need for greater transparency and accountability in the allocation of financial resources for the energy transition. Germany's €40 billion transition fund, aimed at regional economic development and infrastructure investments, has faced scrutiny over the prioritization of projects and the equitable distribution of funds (Groba, Breitschopf, 2013). Research indicates that ensuring transparency in fund allocation is critical to maintaining public trust and mitigating perceptions of political favouritism (Hager, Stefes, 2016). In Poland, similar concerns exist regarding the implementation of the Silesia Transformation Fund and the extent to which financial support will effectively reach the most affected communities. While the agreement provides a structured framework for transition, the dependency on European Union negotiations to finalize support mechanisms presents an additional layer of complexity and potential delays. Moreover, while public awareness campaigns in Germany have successfully increased support for renewable energy, Poland's engagement strategies have been more reactive, addressing stakeholder concerns primarily through legal consultation requirements and negotiated agreements. This discrepancy highlights the varying political and economic factors influencing each country's energy transition strategy (UNECE, 2023).

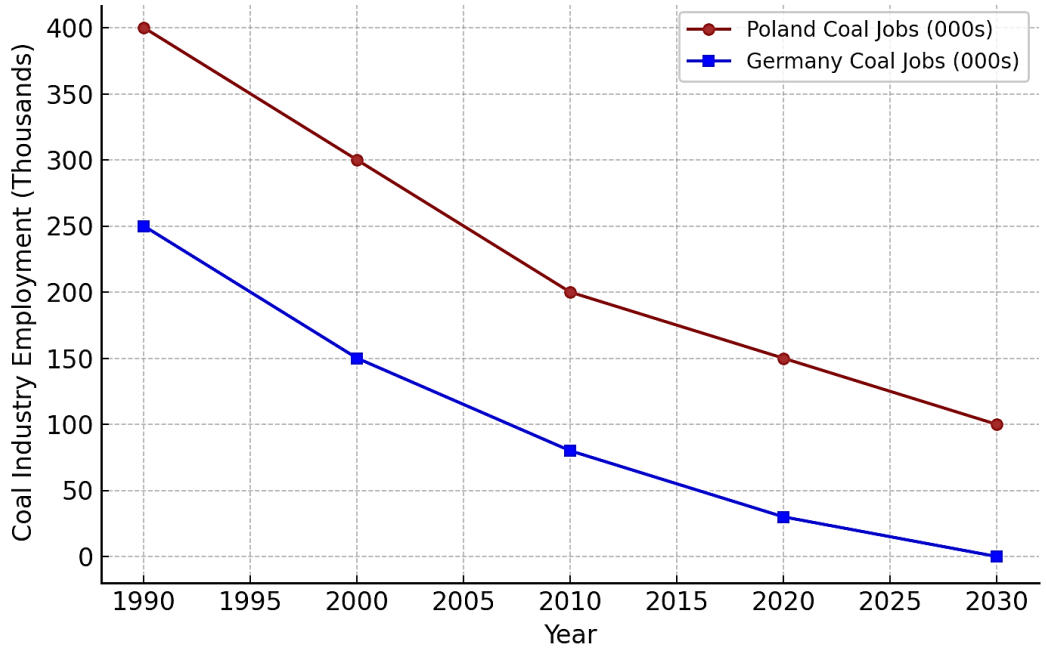

Figure 3. Decline in coal Employment in Poland and Germany.
Source: (European Commission, 2021).

6. Transition governance models in Poland and Germany

Germany and Poland are both undergoing significant energy transitions, moving away from coal toward renewable and low-emission energy sources. However, their approaches differ due to governance structures, economic strategies, and regional socio-political considerations. Germany's coal phase-out governance follows a multi-level approach, involving federal, state, and municipal authorities. The Federal Government sets overarching policies, while state and local governments implement region-specific strategies to mitigate socio-economic impacts. Key legislation, such as the Federal Climate Protection Act (2019), Coal Exit Act (2020), Renewable Energy Sources Act (EEG, 2023), provides a legal framework for this transition. Additionally, the Coal Exit Act (2020) allocates substantial financial aid for economic restructuring and workforce reskilling. In contrast, Poland's transition is guided by a combination of regulatory and market-based mechanisms. The Energy Policy of Poland until 2040 (PEP2040) outlines a long-term vision based on three pillars:

- Just Transition – ensuring that affected regions and communities receive financial and developmental support.
- Zero-Emission Energy System – transitioning through nuclear power, offshore wind energy, and increased distributed energy production.
- Good Air Quality – investing in district heating, electrification of transport, and zero-emission housing.

While Germany emphasizes direct government intervention and public-private collaboration, Poland relies on market-driven solutions, including the Polish Power Exchange for renewable energy trading. Germany's transition has been supported by significant public and private investments in renewable energy, digital industries, and workforce retraining. The Ruhr region serves as a prime example of economic diversification through business incentives, infrastructure modernization, and research investments. Germany also promotes public-private partnerships to create innovation hubs and green business incubators that stimulate entrepreneurship and job creation. Poland, on the other hand, integrates economic modernization within its broader energy policy goals. The Energy Policy of Poland until 2040 (PEP2040) aims to create up to 300,000 new jobs in sectors such as renewable energy, nuclear power, electromobility, and digital infrastructure. Unlike Germany, where workers transition into green energy sectors, Poland's model includes support for individual energy consumers, shielding them from rising energy costs while encouraging participation in the energy market. Germany's transition heavily involves major energy companies, such as RWE and Uniper, which have committed to early coal plant closures and investments in wind, solar, and hydrogen-based energy solutions. Research institutions like the Fraunhofer Institute (Fraunhofer ISE, 2023) and Agora Energiewende (Agora Energiewende, 2015) contribute policy recommendations and technological insights to guide the transition. Environmental NGOs, including WWF Germany (WWF Germany, 2023), advocate for stronger climate policies and social justice in the transition process. In Poland, private sector engagement is growing, driven by tax incentives, subsidies, and feed-in tariffs. The government promotes energy efficiency through public-private collaborations and energy trading platforms. While Germany's transition model integrates environmental NGOs in policy discussions, Poland's transition places greater emphasis on ensuring energy security and modernizing industrial energy. Germany's coal phase-out has resulted in substantial reductions in greenhouse gas emissions, improved air quality, and land restoration. Former coal mining sites have been repurposed into green spaces, cultural centres, and renewable energy farms, contributing to biodiversity conservation and sustainable urban development. Poland's transition also prioritizes air quality improvements, particularly through investments in district heating, transport electrification, and energy-efficient housing. Unlike Germany, which has already made significant progress in reducing coal dependency, Poland still relies on coal but aims for long-term decarbonization with the implementation of nuclear energy and offshore wind projects.

Germany's main challenge is maintaining energy supply stability while rapidly transitioning to renewables. Ensuring continued economic growth and job security in former coal-dependent regions remains a priority. Poland, meanwhile, faces the challenge of balancing energy security with climate commitments. The gradual approach in PEP2040 (Ministry of Climate and Environment, 2021) allows Poland to transition while maintaining stable electricity production. However, reliance on gas as a transitional fuel poses long-term sustainability concerns.

7. Discussion

The historical trajectory of coal mining in both Germany and Poland reveals its foundational role in national industrialization, economic stability, and regional development. For decades, coal was not only a dominant energy source but also a key pillar of employment and economic activity—particularly in the Ruhr Valley of Germany and the Silesian region of Poland. However, the contemporary global shift toward low-carbon development has necessitated a reassessment of coal's long-standing centrality in energy systems. The divergent approaches taken by Germany and Poland in phasing out coal offer valuable insights into the complex, multidimensional nature of energy transitions and provide transferable lessons for other fossil fuel–dependent economies. Germany embarked on a relatively early and structured transition away from coal, underpinned by a robust legal and institutional framework. The adoption of the political regulations provided clear timelines and targets, including a legally binding commitment to cease coal-fired energy production by. This legal certainty has been instrumental in attracting investment in renewable energy and facilitating the gradual transformation of the energy sector. Central to Germany's approach was the establishment of the Commission on Growth, Structural Change and Employment (Kohlekommission), which brought together diverse stakeholders, including government bodies, industry representatives, trade unions, environmental NGOs, and civil society (Kohlekommission, 2019). This participatory mechanism ensured that the transition strategy was informed by a broad consensus and reflected a balanced integration of economic, environmental, and social priorities. Significant financial allocations have accompanied Germany's coal exit strategy, with federal and regional governments pledging billions of euros to support structural transformation, workforce retraining, and environmental rehabilitation in former coal regions. However, despite this comprehensive approach, Germany has encountered notable challenges. Critics have pointed to disparities in the distribution of transition funds, with concerns that large energy corporations have disproportionately benefited, while local communities have seen comparatively fewer direct gains (Agora Energiewende, 2015). Furthermore, the accelerated pace of the coal phase-out, while aligned with international climate commitments, has raised concerns about energy supply stability and overreliance on natural gas as a transitional fuel—issues that have become more pronounced in the context of recent geopolitical uncertainties and volatile energy markets.

Poland, by contrast, has adopted a more gradual and adaptive approach, shaped by its substantial socio-economic dependence on coal. Coal continues to account for a significant share of Poland's electricity generation, and the sector remains a critical source of employment in certain regions. The absence of a legislated coal exit date has provided policymakers with greater flexibility but has also introduced uncertainty for investors and stakeholders. The country's primary strategic document, the **Energy Policy of Poland until 2040 (PEP2040)**, sets out broad decarbonization goals, including a reduction in the share of coal in the energy mix and a planned increase in renewables. However, natural gas remains central to

Poland's transition plans, reflecting both infrastructural realities and political preferences for a fuel perceived as more controllable and secure in the short term. While Poland has initiated social dialogue processes—most notably the 2021 Social Agreement on the Transformation of the Coal Mining Sector—these efforts have often been reactive rather than anticipatory. The agreement includes provisions for employment guarantees, compensation, and retraining programs, but its long-term impact remains uncertain due to limited institutional capacity and persistent mistrust among affected communities (European Commission, 2021). Moreover, environmental degradation, particularly air pollution in coal-intensive regions such as Silesia, continues to pose serious public health and sustainability concerns, undermining efforts to attract green investment and stimulate broader economic diversification. The comparative experiences of Germany and Poland in transitioning away from coal offer several critical bilateral lessons for managing energy transitions in fossil fuel-dependent contexts:

Table 2.
Bilateral Lessons for Poland and Germany in energy transformation context

Institutional and Legal Clarity Facilitates Predictability	Germany's structured, legally binding roadmap has provided a clear framework for both public and private actors. This contrasts with Poland's more flexible, but less predictable, strategy. Legal certainty can enhance investor confidence, reduce market risk, and promote sustained policy implementation over time.
Socio-Economic Realities Must Shape Transition Pathways	Poland's slower approach reflects the embeddedness of coal in local economies and the potential social fallout from rapid disengagement. A key takeaway is that energy transitions must be context-sensitive and calibrated to avoid socio-economic disruption. Gradualism, while slower, may be necessary where coal underpins regional livelihoods.
Stakeholder Participation Enhances Legitimacy and Consensus	Germany's stakeholder engagement mechanisms, particularly the Kohlekommission, highlight the value of inclusive policy processes. Broad-based participation can improve policy legitimacy, enhance public trust, and reduce resistance.Poland's experience points to the need for more proactive and meaningful community engagement to ensure local buy-in.
Financial Support Must Be Equitable and Targeted	Transition-related funding must be distributed transparently and fairly. While Germany has mobilized substantial financial resources, concerns about corporate capture highlight the importance of designing compensation schemes that prioritize affected workers and communities.
Public Awareness and Communication Are Critical	Germany's investment in public education campaigns has helped normalize the transition and increase support for renewables. Poland's more limited communication efforts have contributed to persistent scepticism, suggesting that effective transitions must include sustained efforts to inform, educate, and empower the public.
Balancing Energy Security with Climate Goals Remains Challenging	Both countries illustrate the tension between decarbonization and energy security. Germany's pivot to natural gas and Poland's continued reliance on coal and gas raise important questions about the sustainability of transitional fuels. Diversification of energy sources and accelerated investment in renewables are essential to reduce dependency on fossil-based energy and ensure long-term stability.

Source: Own Study.

8. Conclusion

The comparative analysis of energy transition governance in Poland and Germany reveals two distinct yet instructive models shaped by historical legacies, socio-political dynamics, and economic priorities. Germany exemplifies a structured, legally codified approach rooted in multi-level governance, stakeholder inclusivity, and long-term planning. This model emphasizes legal certainty, stakeholder consensus, and integrated regional development, offering a replicable framework for managing energy transition in post-industrial economies. In contrast, Poland's transition reflects a more cautious, adaptive strategy shaped by continued dependence on coal for energy security and economic stability—particularly in regions like Silesia with long-term decarbonization goals, the absence of a legally binding coal exit date, reliance on transitional fuels like natural gas. While Poland has initiated efforts toward just transition—such as the 2021 Social Agreement—public trust and policy coherence remain challenges due to delays in funding, inconsistent stakeholder influence, and uneven regional development. Despite their differences, both countries face common challenges: ensuring social justice, economic resilience, and environmental sustainability during the energy transition. Germany and Poland exemplify two distinct yet instructive models of energy transition in coal-reliant economies. Germany's legally anchored, consensus-driven approach offers a potential blueprint for structured decarbonization, while Poland's gradualism underscores the importance of aligning climate ambitions with socio-economic realities. Both experiences affirm that successful energy transitions require a holistic strategy—balancing environmental imperatives, economic resilience, and social justice. As the European Union moves toward deeper decarbonization, mutual learning between member states will be essential. By drawing on each other's strengths and addressing shared challenges collaboratively, countries like Germany and Poland can pave the way for a more just and sustainable energy future.

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