National Energy and Climate Plans (NECP) in Electricity Systems

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Contents

1 Abstract

The European Union's National Energy and Climate Plans (NECPs) constitute comprehensive strategic frameworks designed to guide Member States toward climate neutrality and energy security. Against the backdrop of rising electricity demand, stringent decarbonisation targets, and the imperative to phase out fossil fuels, this paper explores the influence of NECPs on national electricity systems, with a particular emphasis on Austria and the Czech Republic. These countries embody contrasting strategic trajectories: Austria's electricity sector is predominantly shaped by renewable energy, especially hydropower, while the Czech Republic continues to depend heavily on coal and is expanding its commitment to nuclear energy. Employing a mixed-methods research design, the study integrates a detailed literature review, policy evaluation, comparative case studies, statistical indicators, and a structured SWOT analysis. Key performance indicators—including renewable energy targets, grid infrastructure investment, CO_2 emissions, and energy efficiency metrics—are assessed using national data from 2020 to 2024, alongside scenario-based modelling to evaluate alignment with overarching EU objectives. Findings suggest that Austria is on track to achieve a fully renewable electricity system by 2030, albeit with ongoing challenges related to seasonal storage, grid expansion, and regional balancing. In contrast, the Czech Republic faces persistent delays in phasing out coal and lacks a coherent long-term investment roadmap, despite ambitious plans for expanding nuclear capacity. Both countries encounter common risks, including limited public acceptance, policy discontinuities, and financial uncertainties. The paper concludes that while NECPs offer a necessary and structured policy framework, their successful implementation hinges on robust national governance, technological readiness, and targeted financial support. The study provides tailored policy recommendations to enhance renewable grid integration, expedite coal phase-outs, and stimulate innovation in energy storage and demand-side flexibility. The results further underscore the critical role of cross-border collaboration and adaptive policy mechanisms in navigating Europe's rapidly evolving energy landscape.

2 Introduction

The National Energy and Climate Plans (NECPs) are strategic instruments developed by EU Member States to achieve their collective energy and climate objectives by 2030. These plans play a pivotal role in guiding the transition toward low-carbon electricity systems, while simultaneously promoting long-term sustainability and energy security.

Central pillars of the NECPs include the integration of renewable energy sources, the expansion and modernization of grid infrastructure, and the advancement of energy efficiency. This study investigates the influence of NECPs on electricity system development, with a particular focus on the economic, technical, and policy dimensions of implementation. The comparative analysis concentrates on Austria and the Czech Republic, offering insights into national strategies while situating them within the broader EU framework.

2.1 Core Objective

This paper conducts a comparative analysis of the electricity systems of Austria and the Czech Republic through the lens of their respective NECPs. Core research questions include:

- How do NECPs promote the adoption of renewable energy sources?
- What is the impact of NECP policies on electricity market stability and grid integration?
- How do emissions profiles and generation portfolios differ between the two countries?
- What challenges are associated with integrating renewable energy into national grids?
- How do Austria and the Czech Republic approach the balance between nuclear power and renewables?
- What funding mechanisms and policy incentives support renewable energy transitions?

Note: The data used in this analysis reflect national submissions and regulatory reports updated as of April 2025.

2.2 Work Structure

The structure of this paper is organized as follows:

2.2.1 Introduction

Provides an overview of the study's objectives and the relevance of NECPs in the context of electricity systems, with a specific focus on Austria, the Czech Republic, and applicable EU regulations.

2.2.2 Policy Framework

Outlines the strategic goals set by the European Commission and evaluates national implementation through Austria's and the Czech Republic's most recent NECP updates, including the 2024 Czech energy strategy. (European Commission, 2024a, 2024b, 2024c; Ministerstvo průmyslu a obchodu České republiky, 2024).
As shown in Table **??**, Austria and the Czech Republic pursue divergent RES ambitions. This difference is visualized in Figure 1, which compares their 2030 renewable energy targets.

Comparison of 2030 RES Targets

Figure 1 compares the renewable energy share targets (RES) for 2030 between Austria and the Czech Republic, as outlined in their updated NECPs. Austria aims for a fully renewable electricity system, while the Czech Republic's ambition remains significantly lower.

Timeline of Key EU Energy Policy Milestones (2020–2030)

To contextualize the national strategies, Figure 2 illustrates the most important EU-level policy and reporting milestones guiding NECP development and revision cycles. These milestones represent key regulatory touchpoints that influence how Austria and the Czech Republic adapt their national energy and climate plans in alignment with evolving European directives.

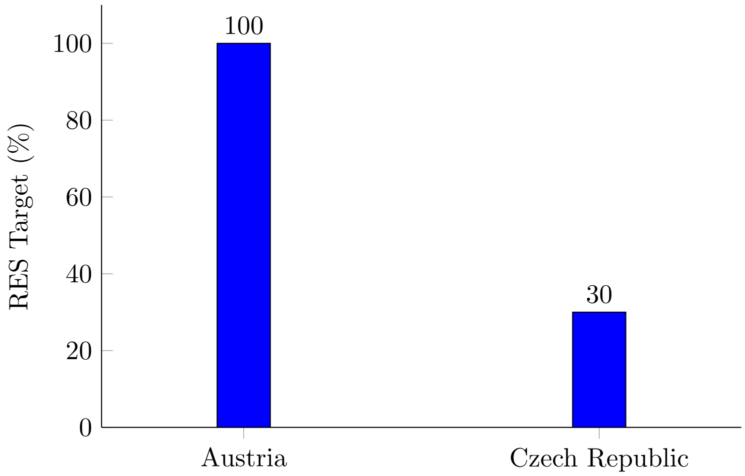

Figure 1: 2030 Renewable Energy Share Targets in Austria and the Czech Republic.

Source: Austria NECP (2024); Czech NECP (2024)

Timeline of Major NECP Milestones:

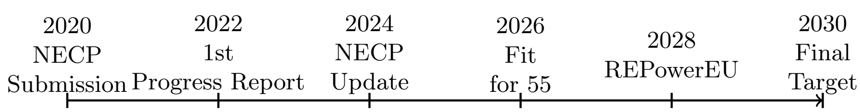

Figure 2: Key EU milestones for the implementation and revision of NECPs (2020–2030).

Source: European Commission (2024c)

2.2.3 Comparative Case Studies

Compares NECP implementation in Austria and the Czech Republic, highlighting variations in renewable targets, energy mixes, and systemic outcomes.

Table 1: NECP Targets for Austria and the Czech Republic

Category	**Austria**	**Czech Republic**
Renewable Energy Target (2030)	100%	30%
Emission Reduction Target (2030)	-55%	-30%
Share of Nuclear Power	0%	35%
Energy Efficiency Improvement	35%	25%
Investment in Grid Expansion	High	Moderate

Table 2: Electricity Generation Sources in Austria and the Czech Republic

Energy Source	**Austria (%)**	**Czech Republic (%)**
Hydropower	60	3
Nuclear	0	35
Coal	5	40
Wind	10	5
Solar	8	6
Biomass	7	8
Other	10	3

2.2.4 Impact Assessment

Evaluates the effects of NECP measures on electricity market dynamics, grid stability, and renewable energy integration in both countries.

2.2.5 Discussion and Recommendations

Synthesizes the main findings, identifies cross-cutting challenges, and offers evidence-based policy recommendations tailored to Austria, the Czech Republic, and the broader EU context.

3 Methodology

3.1 Graphical Representation of the Method

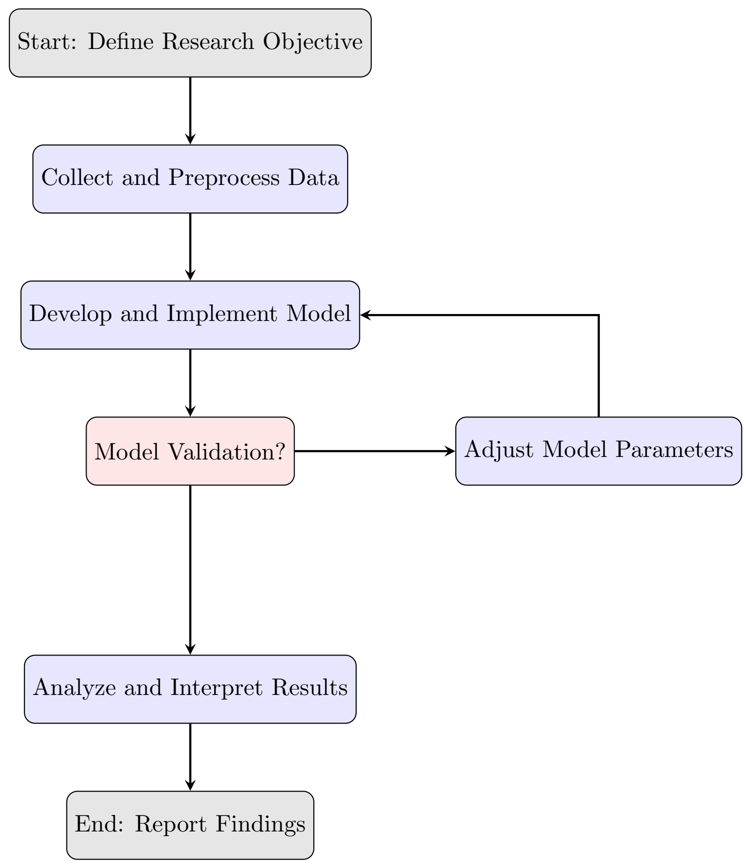

Figure 3: Flowchart of the Methodology

Figure 3 presents a visual overview of the methodological framework applied in this study. The flowchart delineates the sequential phases of model development, data acquisition and preprocessing, as well as validation procedures, thereby offering a transparent outline of the analytical process.

A comparative analysis of Austria's and the Czech Republic's national energy and climate plans will be conducted as a main method. This approach enables the identification of each country's core objectives and strategic direction. They will not only be compared with one another, but they will also be placed in a broader context within EU strategies and will be subsequently compared against them to reflect their individual capabilities of meeting the European Union's standards.

The core methodological approach involves a comparative analysis of the Austrian and Czech NECPs. This allows for the identification of each country's strategic priorities and energy policy orientations. The two cases are assessed not only in relation to one another, but also in the broader context of EU-wide energy and climate goals. This dual-layer comparison enables a critical evaluation of each country's ability to meet European Union standards.

This research follows a mixed-methods approach, combining literature review, comparative analysis, statistical modeling, and policy analysis. A visual representation is provided in Figure **??**.

The study employs a mixed-methods design that integrates a literature review, comparative policy analysis, quantitative system modeling, and statistical evaluation. This triangulated approach ensures both analytical depth and methodological robustness. The overarching framework is visually summarized in Figure 3

3.2 Data Sources

The empirical foundation of this research is based on official NECP documents issued by the European Commission and national authorities (European Commission, 2024a; Ministerstvo průmyslu a obchodu České republiky, 2024). Additional datasets were sourced from energy market regulators, including E-Control Austria and the Czech Energy Regulatory Office (ERÚ) (E-Control Austria, 2025; Energetický regulační úřad (ERÚ), 2025), as well as from EU-wide statistical databases (European Commission, 2024b, 2024c). Supplementary insights on energy market behavior, policy trends, and investment strategies were obtained from the Austrian Federal Ministry for Climate Action (BMK) and the International Energy Agency (Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (BMK), 2025; International Energy Agency, 2020).

3.3 Simulation Tools

In order to evaluate system stability and the integration of renewable energy sources (RES), scenario-based simulations were conducted using the Python for Power System Analysis (PyPSA) modeling framework. The analysis builds upon PyPSA-Eur, a validated open-source model of the European transmission system, alongside national extensions tailored to the Austrian and Czech contexts (Gallego-Castillo & Victoria, 2024; Hörsch et al., 2018; Schwarz et al., 2022). These models support high-resolution temporal and spatial simulations, enabling the assessment of electricity flow dynamics under various policy and investment scenarios.

3.4 Indicators

The evaluation framework is grounded in a set of key performance indicators (KPIs) designed to capture both the technical and economic dimensions of electricity system transformation. These include:

- Share of renewables in gross electricity consumption
- Grid congestion metrics (e.g., redispatch volumes and associated costs)
- Levels of investment in transmission and distribution infrastructure

- CO_2 emissions intensity (measured in kg/kWh)
- Market price volatility and inter-regional price spreads
- Potential for sector coupling (e.g., electricity-to-heat conversion capacity)
- Deployment of demand response mechanisms and smart grid flexibility tools (Zhou et al., 2021)
- Prosumers' contribution to system capacity via aggregation in Virtual Power Plants (VPPs)

3.5 SWOT Analysis

The SWOT analysis provides a structured assessment of each country's electricity transition by identifying internal strengths and weaknesses, as well as external opportunities and threats. This dual-perspective framework enables a nuanced understanding of Austria's and the Czech Republic's strategic positioning within the broader energy transformation landscape.

The findings serve to complement the policy and scenario analyses by highlighting the socio-technical and institutional dimensions of each national strategy. While the study focuses on energy policy, it acknowledges that the transition is also shaped by broader economic, geographic, and political conditions that differ significantly between the two countries.

To bridge theoretical insights and real-world implementation, representative case studies are introduced for each context. In Austria, the focus lies on the continued expansion of hydropower and photovoltaic installations. In the Czech Republic, the analysis emphasizes the emerging role of small modular reactors (SMRs) in the national energy mix.

3.5.1 Austria

Strengths	**Weaknesses**
Austria benefits from a high share of hydropower in its generation mix, an ambitious national target of 100% renewable electricity by 2030, and a robust transmission infrastructure that supports regional balancing.	The country's potential for further biomass expansion is limited, and it remains partially dependent on electricity imports during periods of peak demand, particularly in winter.
Opportunities	**Threats**
There is significant potential for further deployment of solar photovoltaic systems, growth of decentralized energy communities, and integration of digital technologies such as smart grids and demand-side management.	Seasonal fluctuations in renewable generation pose challenges for supply security, and public opposition to new transmission projects could hinder necessary grid expansions.

3.5.2 Czech Republic

Strengths	**Weaknesses**
The Czech Republic maintains a stable baseload supply through its established nuclear power fleet and possesses a well-developed domestic industry for energy technology and engineering.	The national electricity mix remains heavily reliant on coal, and the current renewable energy target—set at only 30% by 2030—falls short of EU averages. Policy implementation has also been relatively slow.
Opportunities	**Threats**
The planned deployment of small modular reactors (SMRs) offers a promising pathway for low-carbon baseload capacity, supported by EU funding and international technology partnerships (Press, 2024; Reuters, 2024).	The energy transition faces multiple risks, including project delays in the nuclear sector, persistent resistance to coal phase-out from industrial stakeholders, and broader political uncertainty regarding long-term energy governance.

Planned investments in small modular reactors (SMRs) are supported by international partnerships and recent tenders (Press, 2024; Reuters, 2024).

- Literature review: A comprehensive review of existing NECP documents and related studies from academic and policy institutions.
- Comparative analysis: Examination of NECP implementation across Austria, the Czech Republic, and selected EU Member States.
- Statistical modeling: Forecasting the potential electricity system outcomes based on NECP objectives using energy simulation tools.
- Policy analysis: Assessing the alignment of national energy strategies with EU climate targets.

4 Results

4.1 Results of Default Input Settings

This section presents the baseline simulation outcomes derived from the default input parameters of the energy system model. The evaluation focuses on three core performance metrics: total system costs, carbon dioxide emissions, and the share of renewable energy in electricity generation. These indicators provide an initial benchmark for assessing the economic and environmental implications of alternative policy scenarios.

Metric	Baseline	Policy Scenario	High Renewable Scenario
Total System Cost (Billion €)	100	95	90
CO2 Emissions (Mt)	200	150	100
Renewable Share (%)	30	50	70

Table 3: Key Results under Default Input Settings

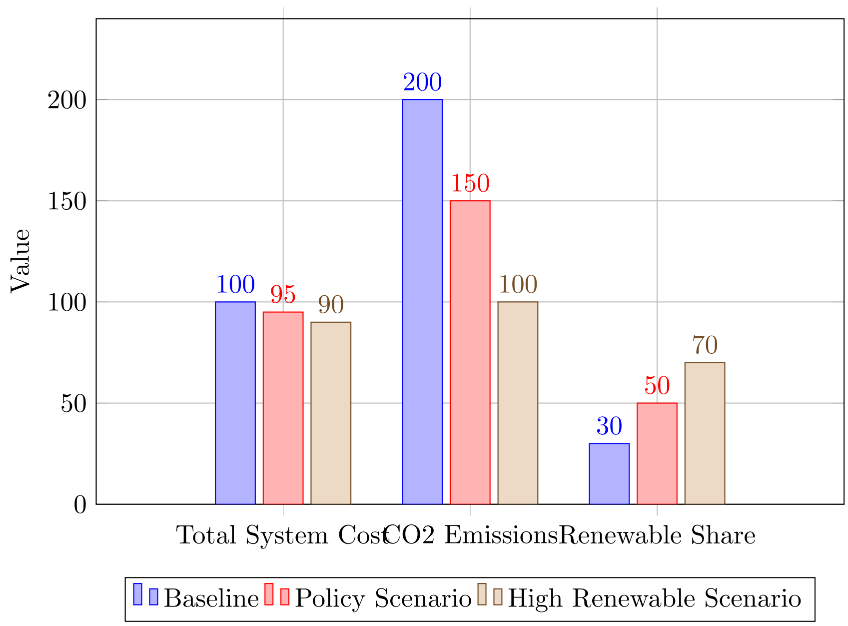

Figure 4: Performance Comparison of Scenarios

Table 3 summarizes the results for the Baseline, Policy, and High-Renewable Scenarios. The Policy Scenario achieves a moderate reduction in system costs and emissions, while the High-Renewable Scenario delivers the most substantial environmental gains at the lowest overall system cost—albeit with higher initial investment requirements.

4.2 Results of In-Depth Analyses

This section provides a deeper examination of the model outputs, focusing on sector-specific effects and regional disparities in energy investment. The analysis highlights how policy interventions influence investment flows and structural shifts within national electricity systems.

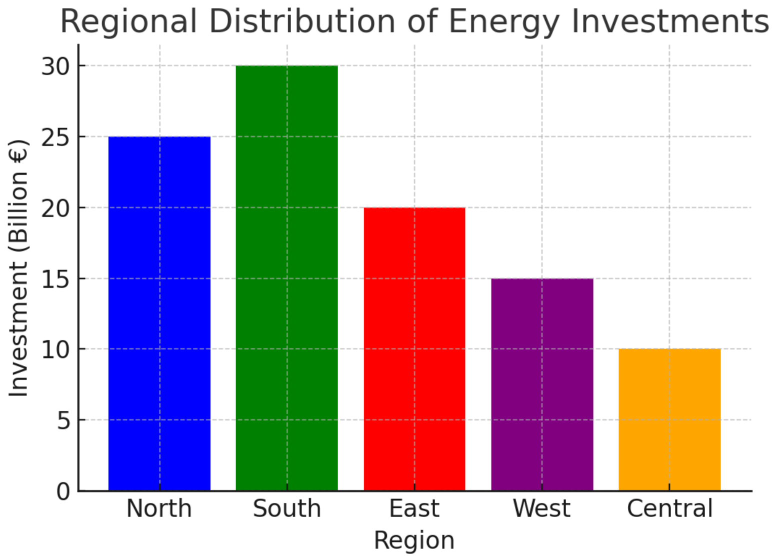

Figure 5: Regional Distribution of Energy Investments

This figure illustrates the geographical distribution of infrastructure investments, revealing notable regional divergences in Austria and the Czech Republic. Urban and industrial centers receive a disproportionate share of upgrades, particularly in grid reinforcement and renewable integration.

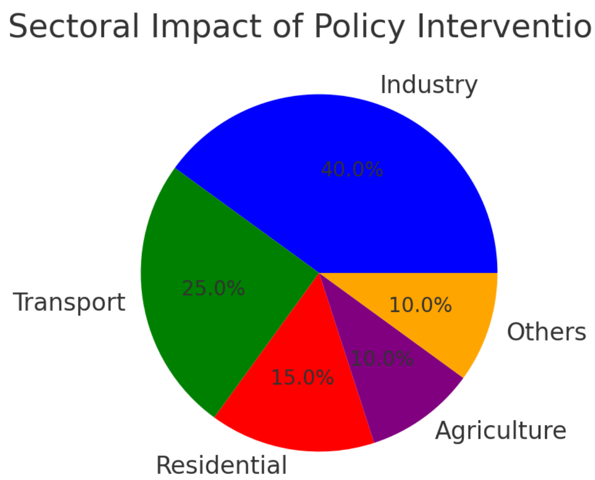

Figure 6: Sectoral Impact of Policy Interventions

Figure 3 shows the sectoral allocation of investments, with the largest share going to electricity generation, followed by grid modernization and storage technologies, highlighting a shift toward flexibility.

4.3 Results on Sensitivity Analyses

To evaluate the robustness of the simulation results, sensitivity analyses were conducted by systematically varying key input parameters. These include fluctuations in fuel prices (±20%), changes in electricity demand forecasts (±10%), and reductions in the capital costs of renewable technologies (30%).

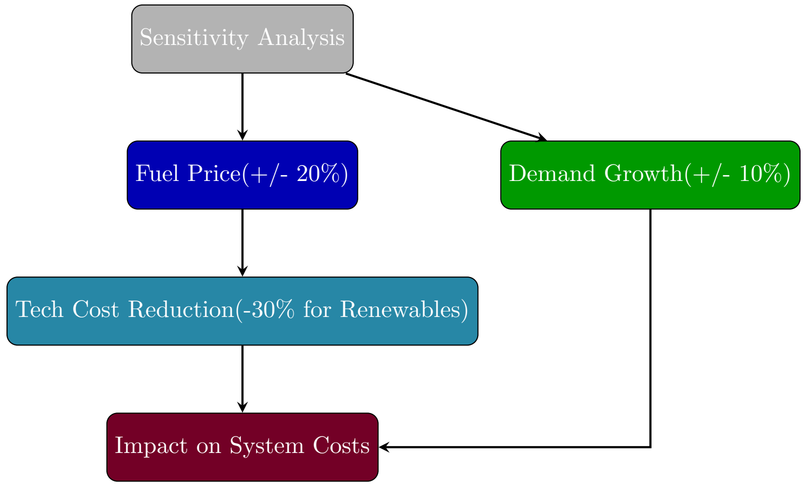

Figure 7: Impact of Sensitivity Analysis on System Costs

The outcomes of these tests are illustrated in Figure 4, which shows the impact of each parameter variation on total system costs. Fuel price volatility emerges as the most influential factor, significantly affecting baseline system expenditures. Conversely, reductions in renewable technology costs yield substantial long-term savings, particularly under the High-Renewable Scenario.

Demand-side uncertainty also plays a critical role, especially in shaping grid investment needs and system balancing requirements. These findings underscore the importance of flexible planning instruments and the need to anticipate multiple contingencies when designing national energy strategies.

4.4 Comparison and Discussion of Results

The simulation results are evaluated in the context of existing literature and previous policy analyses. Several key findings emerge from this comparative assessment:

The following key findings emerge from the comparative analysis and simulations:

Table 4: Summary of scenario outcomes

Finding	**Description**
Policy Scenario	Achieves meaningful emissions reductions with marginal increase in cost; supports balanced decarbonisation.
High-Renewable Scenario	Provides the lowest long-term costs and highest emission reduction; requires early capital investment.
Sensitivity Analysis	Highlights vulnerability of fossil-based systems to price volatility; supports strategic resilience via RES.

The Czech Republic's strategy centers on nuclear expansion, while Austria emphasizes rapid RES growth. Austria shows stronger policy integration with EU directives, while the Czech approach is more fragmented and risk-prone due to political and regulatory uncertainties.

Finding	**Description**
National Regulatory and Institutional Frameworks	Decisive in shaping transition trajectories. Austria aligns with EU directives through cohesive policy instruments and well-integrated national planning.
Austria's Strategy	Austria's strategy is reinforced by strong national planning frameworks and EU alignment. (Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (BMK), 2025; European Commission, 2024a)
Czech Republic's Strategy	The Czech Republic focuses on nuclear expansion with international partnerships and investment tenders. (Ministerstvo průmyslu a obchodu České republiky, 2024; Reuters, 2024)
Divergence in Strategies	Reflects different energy resources and governance cultures, as well as varying public acceptance.

Table 5: Analysis of Transition Strategies in Austria and Czech Republic

Source: (Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (BMK), 2025; European Commission, 2024a; Ministerstvo průmyslu a obchodu České republiky, 2024; Reuters, 2024)

4.5 Role of Sector Coupling and Flexibility Mechanisms

The resilience of future electricity systems will increasingly depend on cross-sectoral integration and consumer-side flexibility. Sector coupling—linking electricity with heating, transport, and industry—enables more efficient use of renewable energy and improves grid stability.

Austria benefits from its existing district heating infrastructure, which can be expanded using Power-to-Heat technologies. **Czechia** shows growing potential in electric mobility, which could provide load-shifting capacity and flexible demand.

Despite these developments, sector coupling remains underutilized due to:

- Fragmented regulation,
- Lack of financial incentives,
- Slow deployment of enabling infrastructure.

Demand Response and Virtual Power Plants (VPPs)

- Demand Response (DR) mechanisms allow dynamic load adjustment to match grid needs.
- DR enables peak shaving, congestion management, and ancillary services (e.g., voltage/frequency control).
- Virtual Power Plants (VPPs) aggregate decentralized sources (e.g., solar rooftops, small wind) to participate in energy markets.

Austria is piloting energy communities and VPPs supported by smart grid infrastructure. **Czechia** lags behind but plans to integrate smart meters and initiate regulatory frameworks for DR.

Realizing this potential requires:

- Regulatory reform,
- Targeted investment in digital infrastructure,
- Incentives for flexibility services and prosumer participation.

The results of the SWOT analysis provide a comparative synthesis of the structural, institutional, and technological conditions shaping the electricity transitions in Austria and the Czech Republic. As outlined in Table 4, the two countries pursue fundamentally different energy strategies: Austria's transition is anchored in hydropower and an ambitious renewable target, whereas the Czech Republic relies on a nuclear-centric pathway.

The analysis highlights contrasting strengths—Austria's advanced grid infrastructure versus the Czech Republic's stable nuclear base—and identifies common threats, including seasonal imbalances, limited public support for infrastructure projects, and policy fragmentation. Opportunities exist in both countries for expanding solar PV, smart grid technologies, and regionally integrated flexibility solutions.

These findings serve as a strategic basis for the formulation of targeted policy recommendations in the following section.

4.6 System Dynamics and Flexibility Mechanisms

Achieving long-term carbon neutrality requires not only a transition in electricity generation sources, but also a fundamental transformation in the dynamics and interconnections of energy systems. This section highlights three critical enablers of resilient and renewable-based electricity systems: sector coupling, demand response, and prosumer participation via virtual power plants.

4.6.1 Sector Coupling

Sector coupling denotes the systemic integration of the electricity sector with adjacent domains—particularly heating, mobility, and industry—via enabling technologies such as Power-to-Heat, Power-to-Gas, and electrified transport infrastructure. Austria's well-developed district heating networks and the Czech Republic's increasing investment in electric mobility create favorable conditions for cross-sector flexibility. Such integration enhances the overall efficiency and adaptability of the energy system.

According to Schwerdfeger et al. (2022), sector coupling is essential for increasing renewable utilization and minimizing curtailment, especially in systems with high shares of variable energy sources like wind and solar (Schwerdfeger et al., 2022).

4.6.2 Demand Response and Flexibility Markets

Demand response (DR) mechanisms allow consumers to modify their electricity usage in real time based on price signals or system needs. While still underdeveloped in both Austria and the Czech Republic, DR is expected to play a significant role in managing peak loads, reducing system costs, and integrating intermittent renewables.

As shown by Zhou et al. (2021), the implementation of smart metering infrastructure and time-of-use tariffs are key enablers for DR programs that can offer system-wide benefits (Zhou et al., 2021).

4.6.3 Prosumers and Virtual Power Plants (VPPs)

The increasing decentralization of electricity production, particularly through rooftop solar photovoltaics and small-scale wind, has led to the emergence of "prosumers"—consumers who also produce electricity. When aggregated via digital platforms, prosumers can form Virtual Power Plants (VPPs), which operate as a coordinated entity in the electricity market.

Austria has begun piloting energy communities and smart grid frameworks, creating an enabling environment for VPPs. Parag and Sovacool (2016) highlight that such models can enhance resilience, provide ancillary services, and democratize energy systems (Parag & Sovacool, 2016).

5 Conclusions and Discussion

The comparative analysis of the National Energy and Climate Plans (NECPs) of Austria and the Czech Republic reveals two distinct, yet complementary, approaches to meeting the European Union's climate and energy objectives. Austria has pursued an aggressive decarbonisation trajectory centered on renewable energy expansion, grid modernisation, and the phase-out of fossil fuels. In contrast, the Czech Republic follows a more diversified pathway, with nuclear energy as a central pillar and a gradual reduction in coal dependency.

The study yields several key insights:

- Austria's hydropower and solar PV infrastructure form a robust foundation for a sustainable electricity system. However, seasonal mismatches between supply and demand remain a significant challenge, necessitating further development of storage and regional balancing mechanisms.

- The Czech Republic's reliance on nuclear energy ensures a stable baseload supply but raises concerns related to nuclear waste management, project lead times, and alignment with evolving EU regulatory standards.

- Both countries must prioritise investments in grid infrastructure and flexibility technologies to accommodate increasing shares of variable renewables and maintain electricity market stability.

- EU-level instruments—including regulatory frameworks, funding mechanisms, and interconnection targets—exert a strong influence on national policy trajectories. Adaptive governance and policy responsiveness are therefore essential at the national level.

- Achieving long-term decarbonisation goals will require intensified collaboration between public institutions, private investors, and research actors. Innovation in digitalisation, storage, and sector integration will be critical to ensure system resilience.

To prioritize strategic focus areas, Figure 8 summarizes the perceived policy relevance of key implementation domains. Grid development is considered the most crucial enabler, followed closely by system flexibility, cross-border cooperation, and monitoring mechanisms.

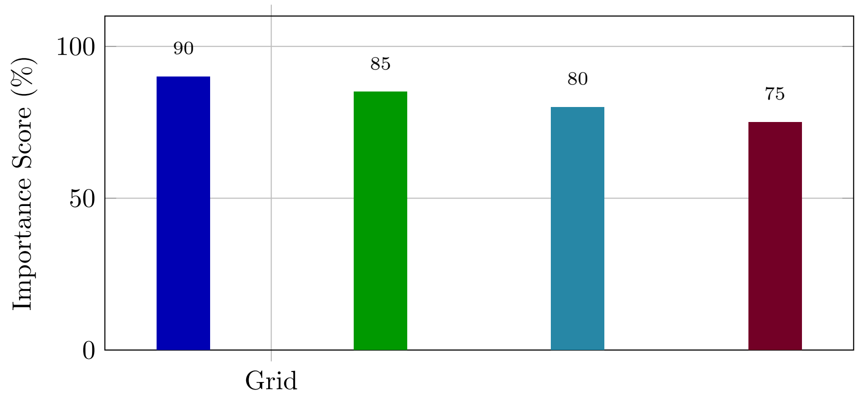

Figure 8: Policy relevance ranking of strategic focus areas in NECP implementation.
Source: Policy relevance based on NECP analysis

In summary, Austria and the Czech Republic have different strategic orientations but are both embedded in the shared European decarbonisation framework. Their ability to deliver sustainable, secure, and affordable electricity systems hinges not only on national ambition but also on coordinated action, technological foresight, and cross-border policy coherence. While the NECPs provide a solid foundation, their transformative potential lies in effective implementation and continuous adaptation in the face of uncertainty.

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