EU Energy Trends and the German Market

Introduction

Energy plays a fundamental role in a functional society. The process of a civilization is even measured in energy consumption (Kardashev scale). The climate crisis forces us to rethink our energy consumption and generation. The green transition has become a top priority under the European Green Deal and the REPowerEU plan, which aim to achieve climate neutrality by 2050 and reduce dependence on imports. Furthermore the aggression war from Russia has shown us how dangerous it can be for our industry to depend on foreign energy. The aim of this project is to analyze the trends and patterns in Europe's energy consumption and generation, with focus on the market stability, influence of renewable energy on electricity prices, how the Russia's invasion of Ukraine caused gas prices to increase dramatically ,which also influenced the electricity prices. We also build regression model where our independent variable was electricity prices.

Summary of relevant prior info

The European Green Deal (2019) is the growth strategy to make the EU clima neutral. The Russian's Invasion of Ukraine caused the 2021-2023 energy crisis in which record gas and electricity prices placed pressure on companies that rely on energy as a production input. The REPowerEU Plan (2022) was a direct response to the energy crisis, focusing on energy independence and acceleration of the renewable development. Europe imports liquefied natural gas (LNG) and oil. Germany's early feed-in tariffs, introduced in 2000 with the Renewable Energy Sources Act (EEG), guaranteed a fixed, long-term payment for renewable energy fed into the grid

Purpose

The purpose of this project is to analyze trends and relationships in Europe's energy system to understand how policy changes, market shocks, and renewable growth interact.

Preparation

We conducted thorough research to identify credible academic and official data sources. This included reviewing relevant literature and assessing the expertise of the authors. To ensure data reliability, we focused on official market platforms such as SMARD and ENTSO-E, studying their documentation in detail. Once we identified suitable and downloadable datasets, we considered how best to integrate them into our narrative and analysis

Data Preparation

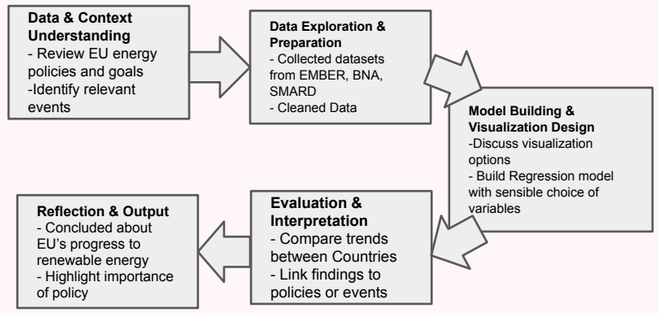
The European energy dataset was compiled from ember-energy.com (EMBER), a global energy think tank that aims to accelerate the clean energy transition with data and policy. It contained the data for all the European countries, with category, subcategory and variables of the energy type, the unit, in which the energy was measured (TWh, % etc.) and the value of the measured energy.

The Germany energy datasets were compiled from SMARD.de, the official transparency platform of the German electricity market, which provides detailed time-series data on electricity generation, consumption, and cross-border physical flows. Multiple CSV files over the years of 2015-2025 were downloaded to capture Germany's actual generation, installed generation capacity, forecasted and actual consumption, and cross-border imports and exports with neighboring countries over time. Each file contained a consistent temporal structure, allowing them to be cleaned and merged into a single analytical dataset for each relevant category.

Data preparation involved aligning column formats, harmonizing date fields, and ensuring numerical consistency across all categories. For generation, the datasets on actual and installed capacity were merged chronologically and cleaned for empty or inactive energy sources. For consumption, actual and forecasted electricity demand files were combined and standardized to a daily resolution. For cross-border physical flows, yearly datasets were merged to form a continuous multi-year series, retaining all records to reflect the evolution of trade intensity with neighboring countries.

Data preparation in this project also involved manually writing the gas market data down from the BNA since it was not downloadable.

Methodology



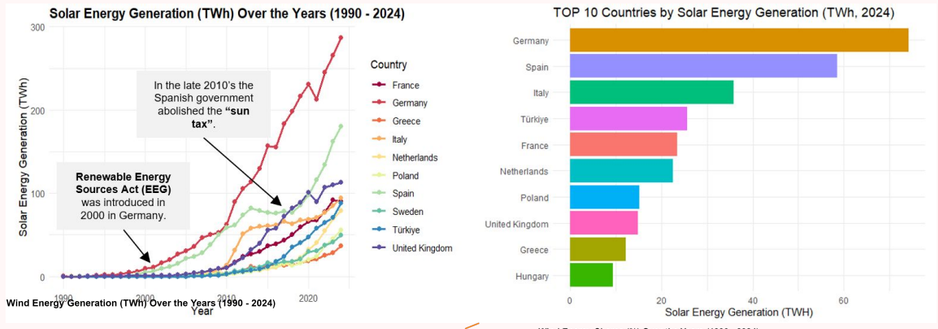
OLS: Use of sensible variables very important

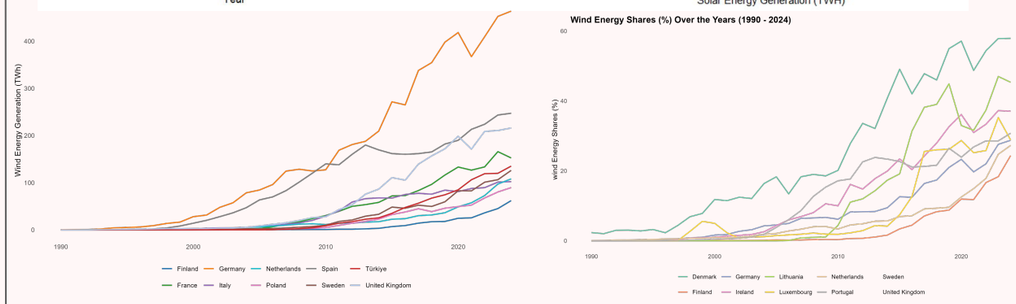
OLS only possible with forecasted Data since other Data is not publicly available (or very expensive)

OLS was done in R, where we used the lm() function

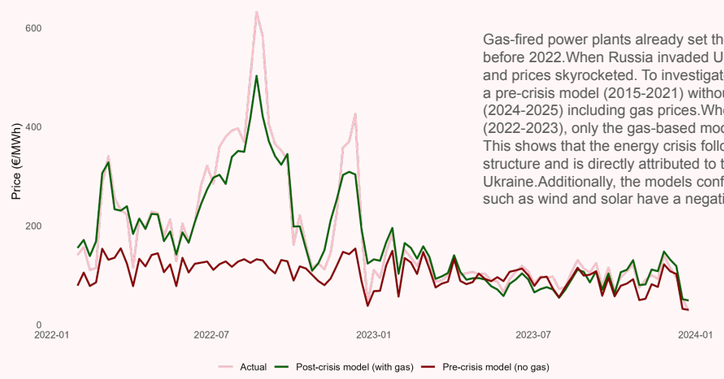
Results & Discussion

How has the EU Energy Sector developed over the years





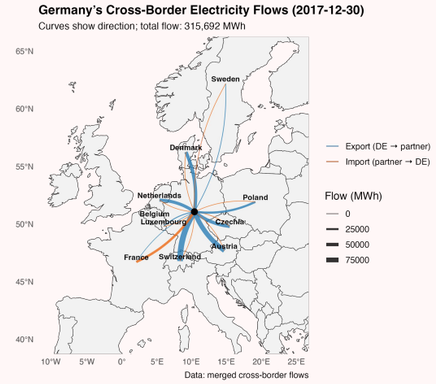
Influence of the Russian Invasion on the German Market



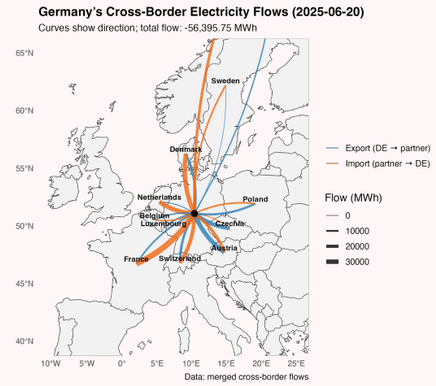
Gas-fired power plants already set the marginal electricity price in Europe before 2022.When Russia invaded Ukraine, gas supplies were disrupted and prices skyrocketed. To investigate this, two models were built:
a pre-crisis model (2015-2021) without gas data, and a post-crisis model (2024-2025) including gas prices.When both predicted the crisis years (2022-2023), only the gas-based model captured the price surge.
This shows that the energy crisis followed the merit order market structure and is directly attributed to the Russian invasion of Ukraine.Additionally, the models confirm, that renewable energy sources such as wind and solar have a negative correlation with the energy price.

Germany's import/ export market

The map from a specific day in 2017 shows Germany as a major exporter, with dominant outflows to Netherlands, Austria Denmark, and Switzerland → reflects period of periods of high renewable generation, likely from a cold, strong onshore and offshore wind generation that drives Germany to export excess electricity north and south-east.



In contrast, the map from a specific day in 2025 reveals massive net imports, especially from France Denmark, Netherlands and Switzerland, indicating times of lower domestic renewable output and higher reliance on cross-border supply → solar peaks may have passed or demand exceeded local supply; France's nuclear and Switzerland's hydro resources offset temporary German shortfalls.



The changing trade balance underlines how Germany acts as both a supplier and consumer in Europe's integrated market, depending on renewable conditions and demand peaks.

Critique & conclusion

During the project, we learned the importance of verifying data availability and accessibility before starting a large-scale analysis. Ensuring that a sufficiently large and freely accessible dataset exists is crucial for defining a realistic research scope early in the process. One challenge we encountered was time management, as starting earlier would have allowed us to explore additional data sources and develop our analysis further. We do not believe that any significant sources of bias affected our results, since we relied on official and transparent data from SMARD and ENTSO-E. Our main advice for future students is to begin early, establish a clear research story from the beginning, and set aside extra time for data cleaning and integration, as these steps often take longer than expected

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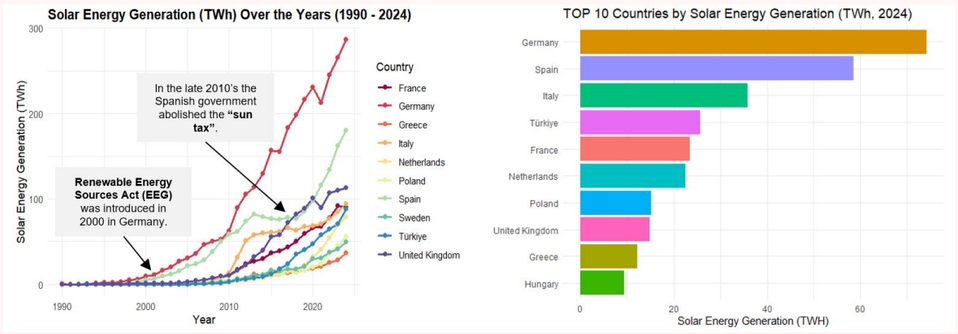
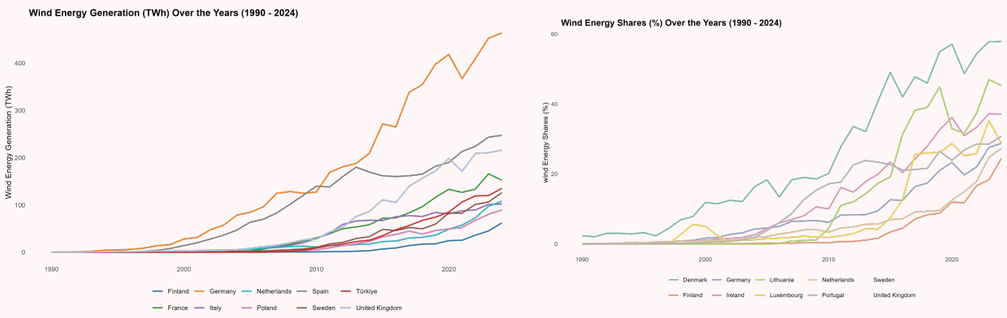
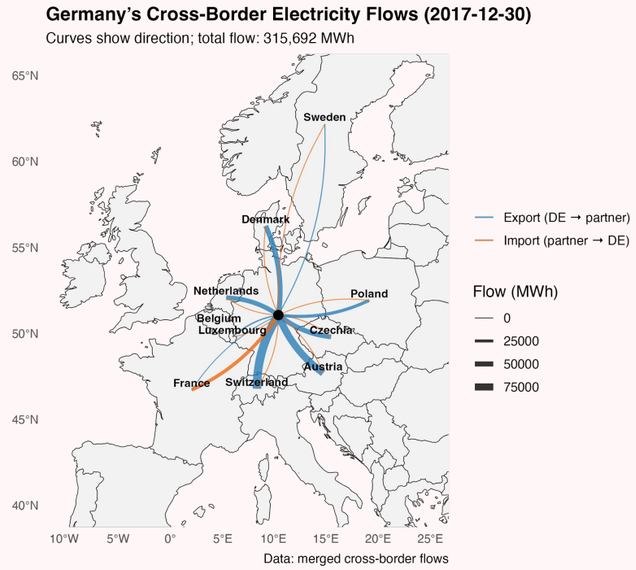
How has the EU Renewable Energy Sector developed over the years?





Is Germany an Electricity Importer/Exporter?



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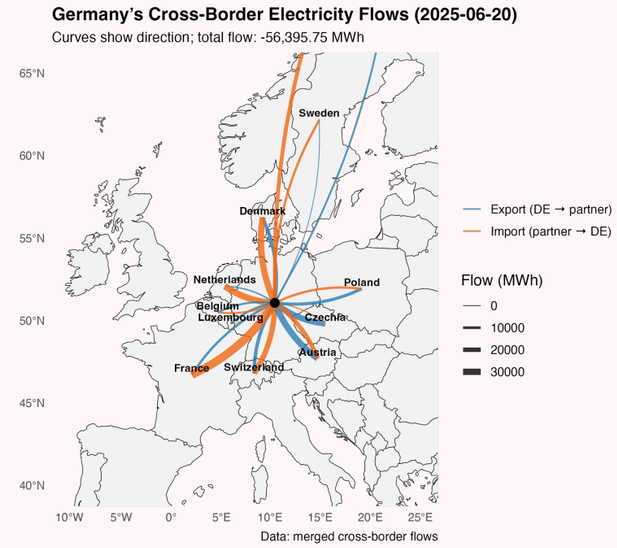

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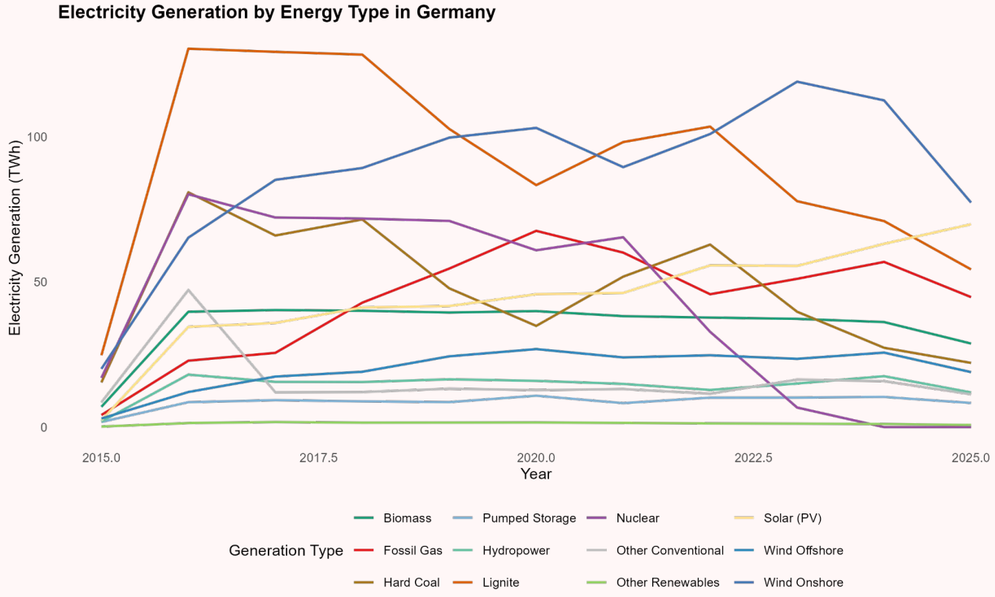
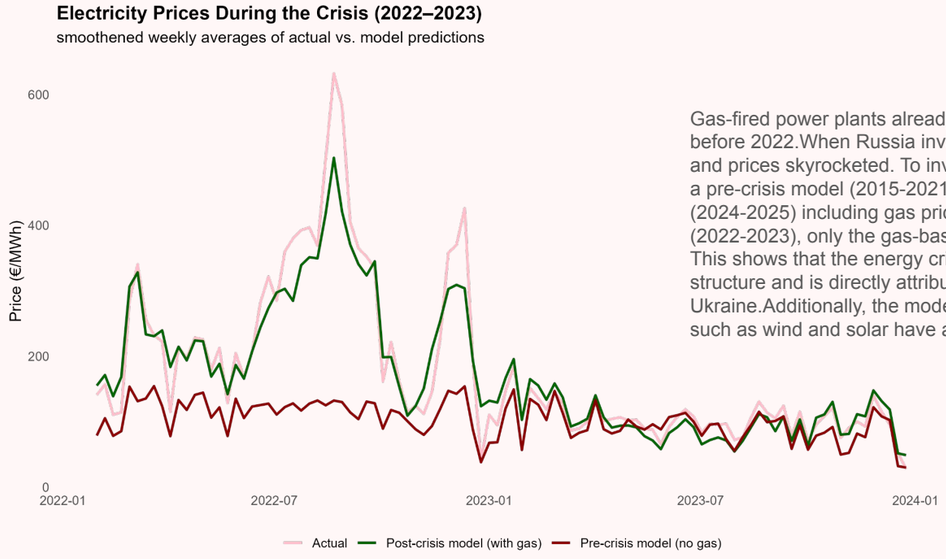
How did Germany's Electricity Generation Mix Change over the Years?



How did the Russian Invasion on Ukraine Impact the German Electricity Market?



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