Renewable Energy Data Analysis

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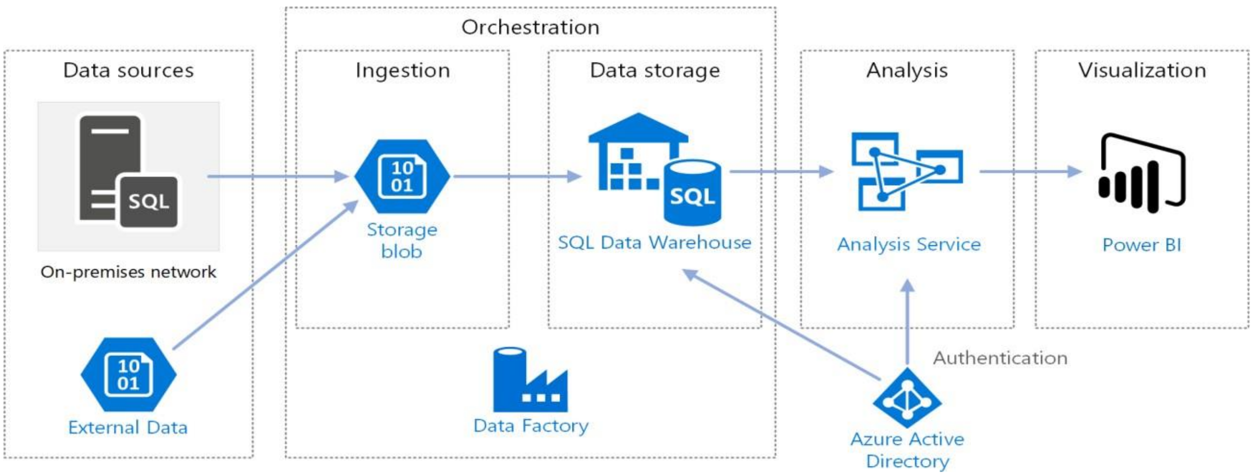
Data Architecture:



Data Centralization:

1. Data is stored in Azure Data Lake or a Data Warehouse, ensuring consistency and accessibility.
2. Azure services like Azure Data Lake Storage Gen2 and Azure SQL Data Warehouse are used for this purpose.

Data Transformation (ETL):

1. ETL processes extract and transform data from source files using tools like Azure Data Factory and Azure Databricks.
2. Automation is key to systematically processing raw data from Excel spreadsheets.

Visualization:

1. Power BI creates interactive dashboards and reports for analyzing power market forecasts.

2. Reports are designed for customization, allowing users to adjust parameters like currency, quarters, and years.

Automation:

1. Automation streamlines data loading and transformation, reducing manual effort.
2. Azure services such as Azure Data Factory and Azure Logic Apps are scheduled to automate data tasks, ensuring consistency.

User-Friendly Power BI:

1. Power BI's user-friendly interface enables users to interact with data through slicers, filters, and other features.
2. Users can explore and analyze power market data, answering specific questions easily.

Data Cleaning and transformation:

Python played a vital role in the ETL (Extract, Transform, Load) process in this use case:

1. Data Extraction: Python libraries like Pandas and openpyxl were used to extract data from the Excel spreadsheets provided by Aaron and Brian. This step involved reading the data from the Excel files into Pandas DataFrames.
2. Data Cleaning: Raw data often contains inconsistencies, missing values, or errors. Python allowed for the identification and handling of such issues. Data cleaning involved tasks like removing duplicates, filling missing values, and handling outliers.
3. Data Transformation: Python's extensive ecosystem of libraries provided the capability to transform data effectively. For example, Pandas allowed for data aggregation, merging, and reshaping to prepare it for analysis. Additionally, calculations like currency conversion and inflation adjustment could be performed programmatically.
4. Data Validation: Python scripts could be written to validate the data, ensuring that it met specific criteria or business rules. This validation step helps maintain data quality.

Data Cleaning and Transformation in Power BI:

Power BI is a powerful business intelligence tool that excels in data visualization and reporting. In this use case, Power BI complemented Python in the following ways:

1. Data Integration: Power BI can connect to various data sources, including Azure Data Lake or Data Warehouse, where the cleaned and transformed data from Python is stored. This integration ensures that up-to-date data is available for reporting.
2. Data Modeling: Power BI's data modeling capabilities allow users to define relationships between different datasets and create calculated columns and measures. This is especially useful for creating complex calculations and aggregations.

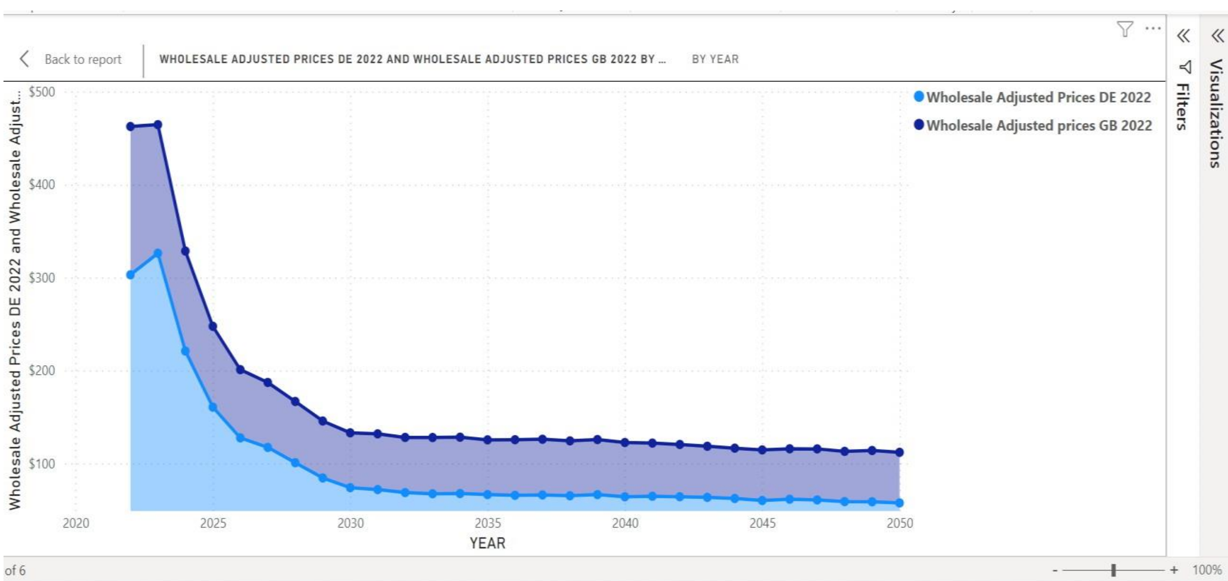
3. Interactive Reports: Power BI is renowned for its ability to create interactive and visually appealing reports and dashboards. Users can explore data by filtering, slicing, and drilling down, making it easy to gain insights.

4. Parameterization: Power BI enables the creation of user-friendly interfaces, like slicers and filters, that allow users to change parameters such as currency, quarters, and years. This flexibility empowers users to customize their analyses.

In summary, data cleaning and transformation (ETL) in this use case were performed efficiently using Python for data manipulation, including extraction, cleaning, and transformation, and Power BI for data visualization, reporting, and interactive features. Together, they provided a comprehensive solution to prepare and analyze power market data effectively, facilitating data-driven decision-making.

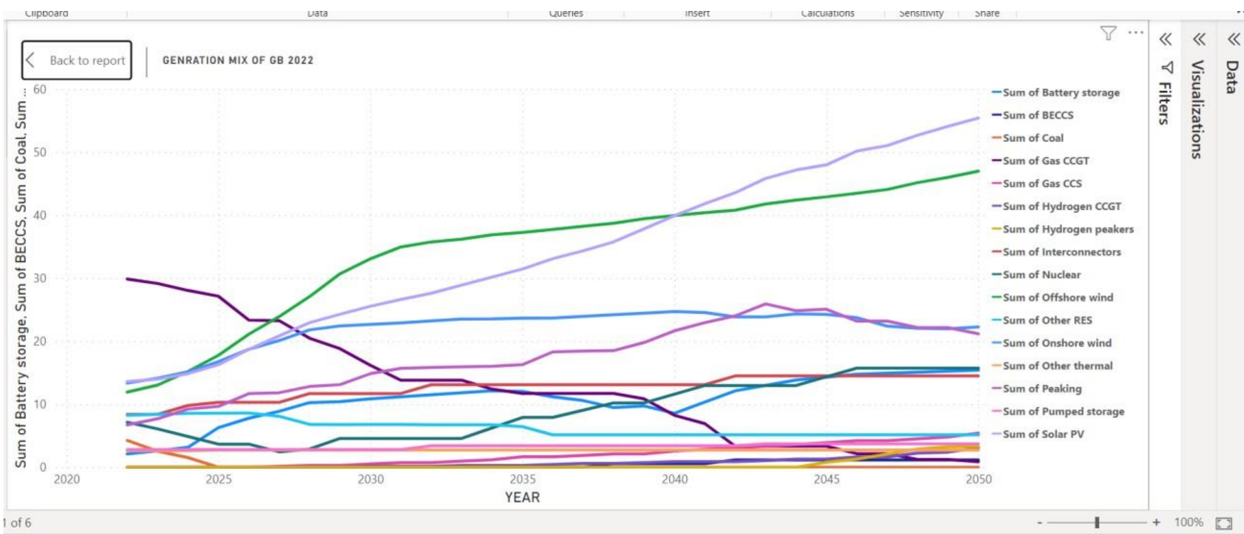
Data Visualization and Analysis:

How do wholesale power prices (baseload) compare between GB and DE and whether their respective power generation mix could explain the difference?



1. **Comparing Wholesale Power Prices (Baseload) between GB and DE**:
   - GB generally has higher wholesale power prices than DE throughout the entire period.
   - The difference in prices becomes more pronounced as time progresses, with GB prices consistently higher.
2. **Possible Explanations for Price Differences**:

- The difference in wholesale power prices between GB and DE could be influenced by various factors, including differences in energy policy, supply and demand dynamics, infrastructure, and the energy generation mix in each country.
- Investigating the power generation mix in both countries may help explain the price differential.

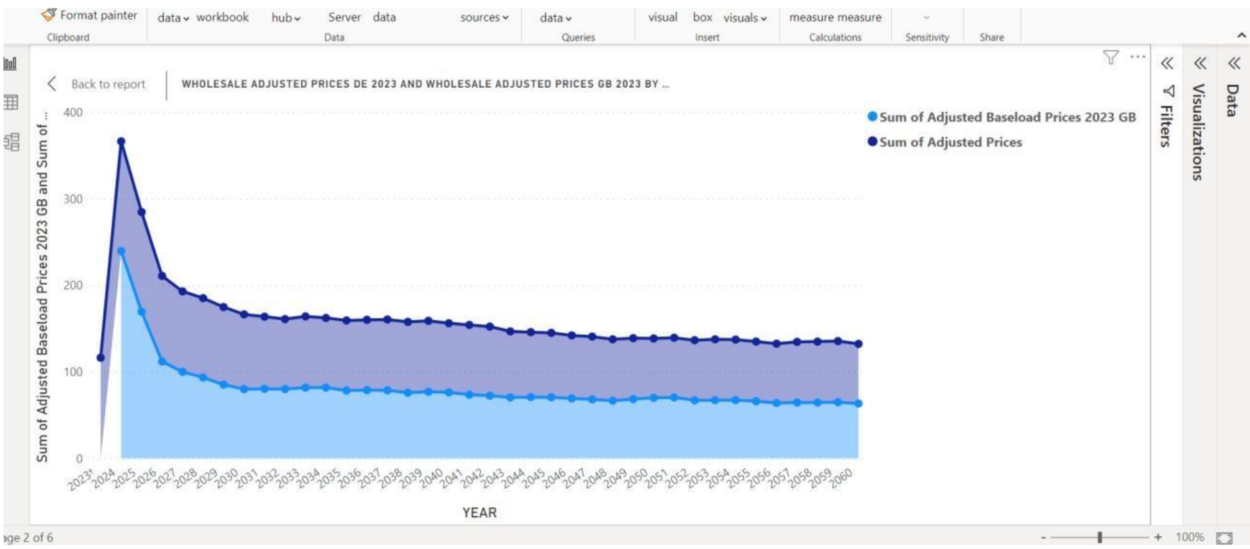


1. **Trends in Power Generation Mix**:
   - The power generation mix has significantly changed over the years, with a clear transition towards renewable energy sources and away from fossil fuels.
   - Solar PV and onshore wind have seen substantial growth, becoming the dominant sources of energy by 2050.
2. **Renewable Energy Dominance**:
   - Solar PV and onshore wind have become the primary sources of electricity generation by 2050, indicating a strong shift towards renewables in both GB and DE.
   - The decline of coal and gas-based generation is evident, suggesting a reduction in carbon-intensive energy sources.
3. **Emerging Technologies**:
   - Technologies like battery storage and hydrogen-based generation (e.g., Hydrogen CCGT and Hydrogen peakers) have gained importance in the energy mix, especially in the later years.
4. **Impact on Wholesale Prices**:

- The shift towards renewable energy sources (solar PV and onshore wind) is likely to have contributed to the lower wholesale power prices in the later years. Renewable energy sources often have lower operating costs.

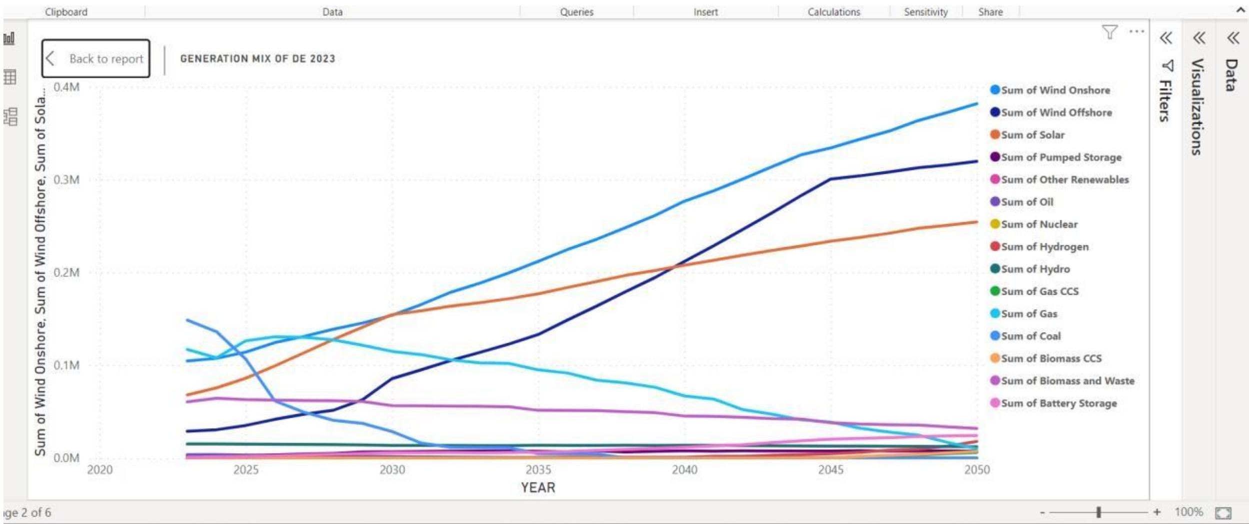
5. **Future Considerations**:

    - This data suggests that both GB and DE are making significant strides towards a cleaner and more sustainable energy mix, which can have positive implications for reducing greenhouse gas emissions.

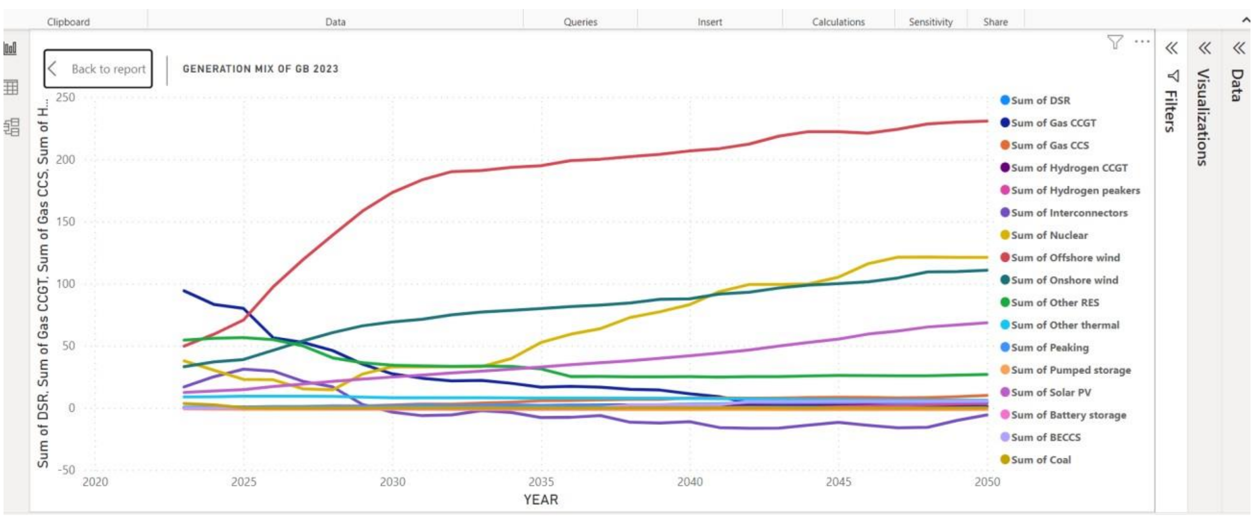


- In 2023, the wholesale power price in GB is $116.2808 per unit, while the wholesale power price in DE is $126.7727 per unit.

- GB has a lower wholesale power price compared to DE in 2023. This suggests that electricity is cheaper in GB for this specific year.

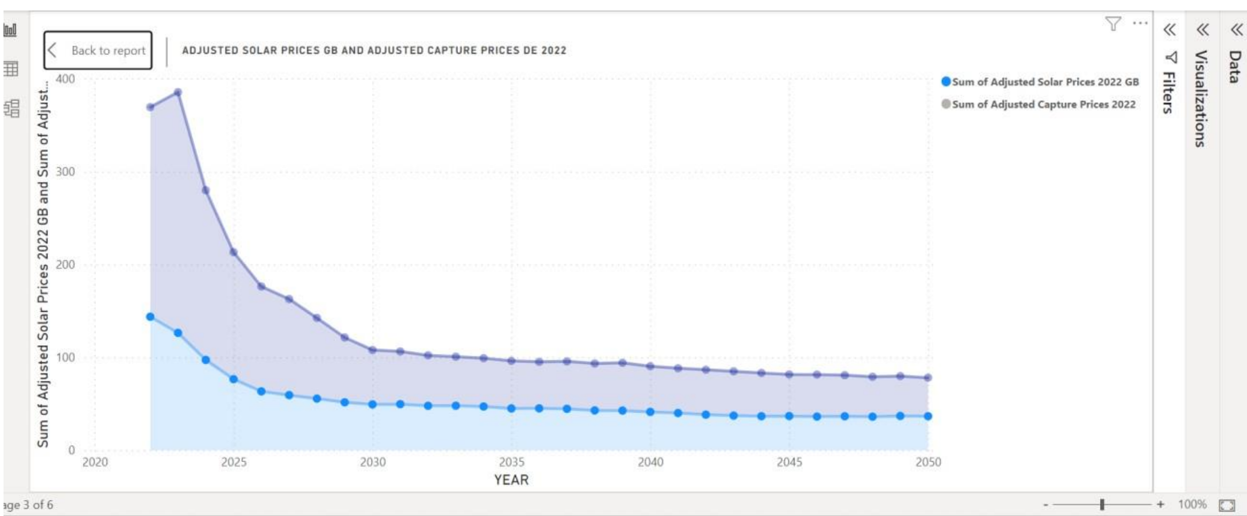


- In 2023, the generation mix in Germany (DE) consists of various energy sources, including onshore wind, offshore wind, solar, pumped storage, other renewables, oil, nuclear, hydrogen, hydro, gas CCS (Carbon Capture and Storage), gas, coal, biomass CCS, biomass and waste, and battery storage.
- Notably, renewable energy sources like onshore wind, offshore wind, solar, and other renewables make up a substantial portion of the generation mix, indicating a significant shift towards cleaner energy sources.
- The presence of nuclear and hydro in the mix also contributes to a low-carbon generation profile.
- Gas, gas CCS, and coal are present but seem to play a less prominent role in the generation mix.



- The generation mix in Great Britain (GB) in 2023 consists of various energy sources, including DSR (Demand Side Response), Gas CCGT (Combined Cycle Gas Turbines), Gas CCS (Carbon Capture and Storage), Hydrogen CCGT, Hydrogen peakers, Interconnectors, Nuclear, Offshore wind, Onshore wind, Other RES (Renewable Energy Sources), Other thermal, Peaking, Pumped storage, Solar PV, Battery storage, BECCS (Bioenergy with Carbon Capture and Storage), and Coal.
- Notably, renewable energy sources like Offshore wind, Onshore wind, Solar PV, and Other RES make up a substantial portion of the generation mix, indicating a significant shift towards cleaner energy sources.
- Gas CCGT and Gas CCS are also present in the mix, but their contributions appear to be lower compared to renewable sources.
- Coal seems to have a minimal presence in the generation mix, reflecting a decrease in coal-fired power generation.
- Demand Side Response (DSR) and Interconnectors are components of the generation mix, reflecting efforts to manage and integrate variable renewable energy sources efficiently.

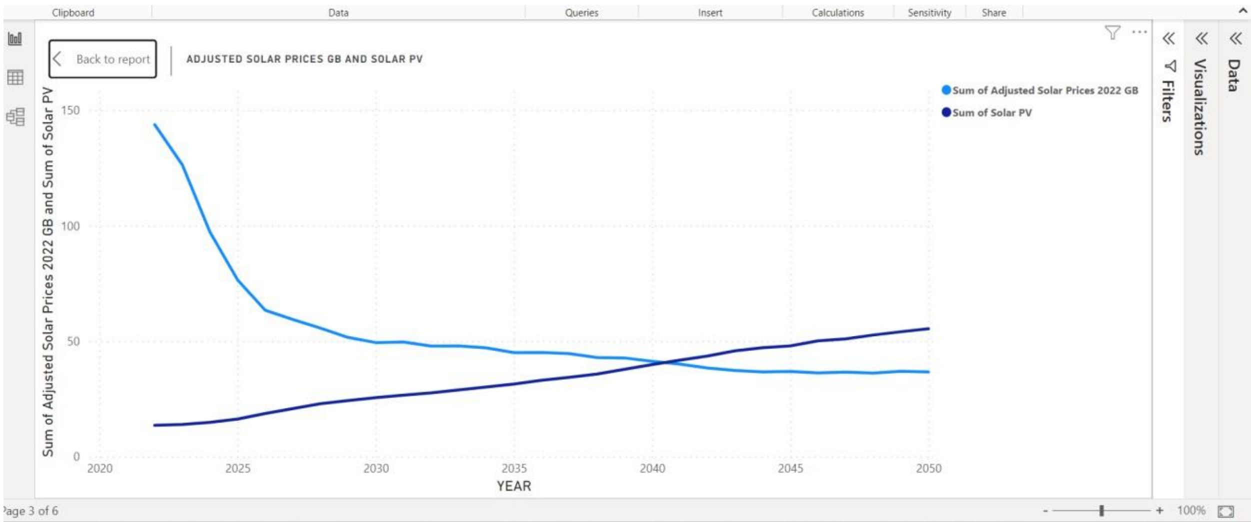
2. From a capture price perspective, which technology offers better potential between solar PV in GB and onshore wind in DE?



1. **Solar Prices Decline:** The data shows a significant decline in the Sum of Adjusted Solar Prices from 2022 to 2050. In 2022, the solar price was relatively high at 143.7606, but it steadily decreases over the years. By 2050, it reaches 36.7037, indicating a consistent downward trend.
2. **Capture Prices Pattern:** The Sum of Adjusted Capture Prices appears to have a different pattern. In 2022, it was 225.5877, significantly higher than the solar prices. However, it also experiences a general downward trend but with fluctuations. It reaches a low of 41.478 in 2050.

3. **Capture Prices vs. Solar Prices:** Initially, Capture Prices were considerably higher than Solar Prices, indicating that the cost of capturing solar energy might have been relatively high. However, over time, the Capture Prices decrease and start to align more closely with Solar Prices.

4. **Capture Prices in 2030s:** A notable drop in Capture Prices occurs in the 2030s, indicating a potential technological breakthrough or a significant shift in the energy landscape during that period.

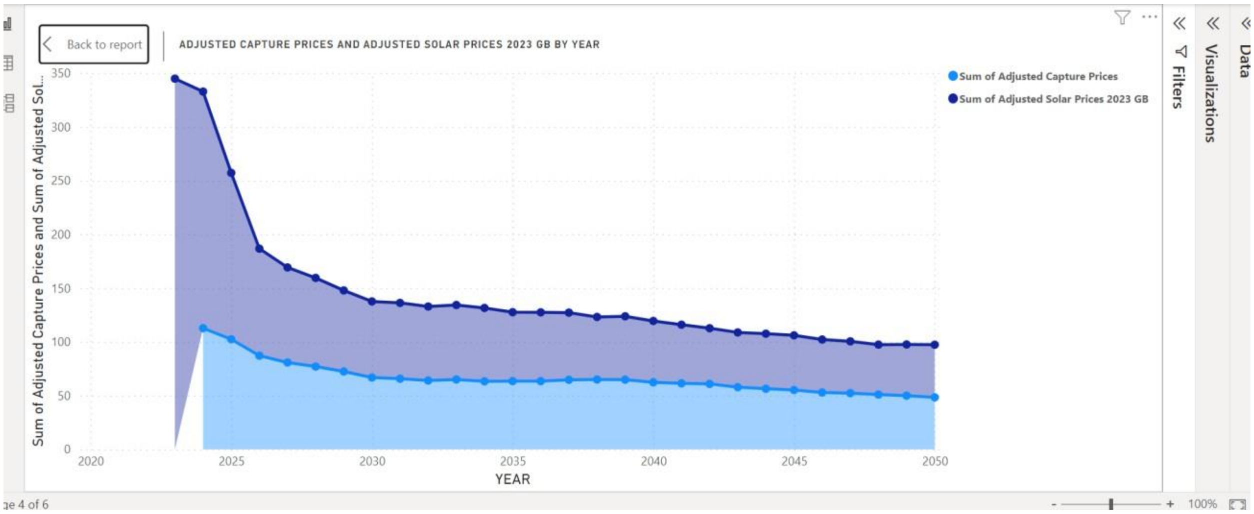


1. **Solar PV Generation:** In 2022, the Sum of Solar PV generation was relatively high at 601.85. This indicates that solar photovoltaic systems contributed significantly to the electricity generation in GB during that year.

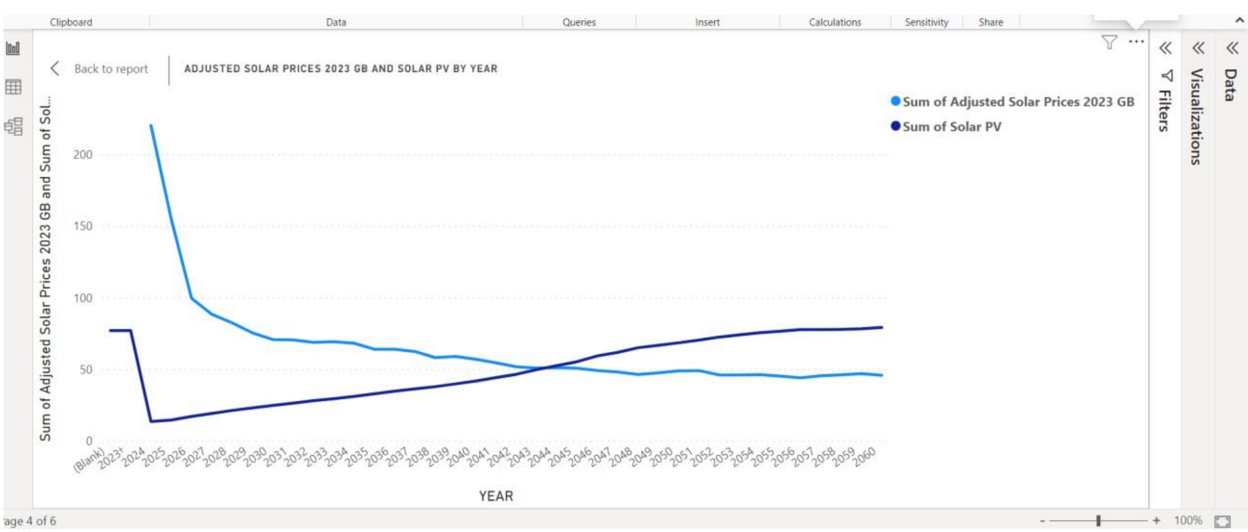
2. **Solar Price vs. Solar PV Generation:** The Sum of Adjusted Solar Prices for 2022 in GB was 353.6822, which is relatively high compared to the subsequent years. Despite the high solar prices, the solar PV generation was substantial, suggesting that solar energy was already a significant part of the energy mix, possibly due to favorable policies and incentives.

3. **Price Decline:** Starting from 2023, the Sum of Adjusted Solar Prices shows a consistent downward trend. This indicates a positive shift towards more competitive solar energy pricing, making it an attractive option for both consumers and the energy industry.

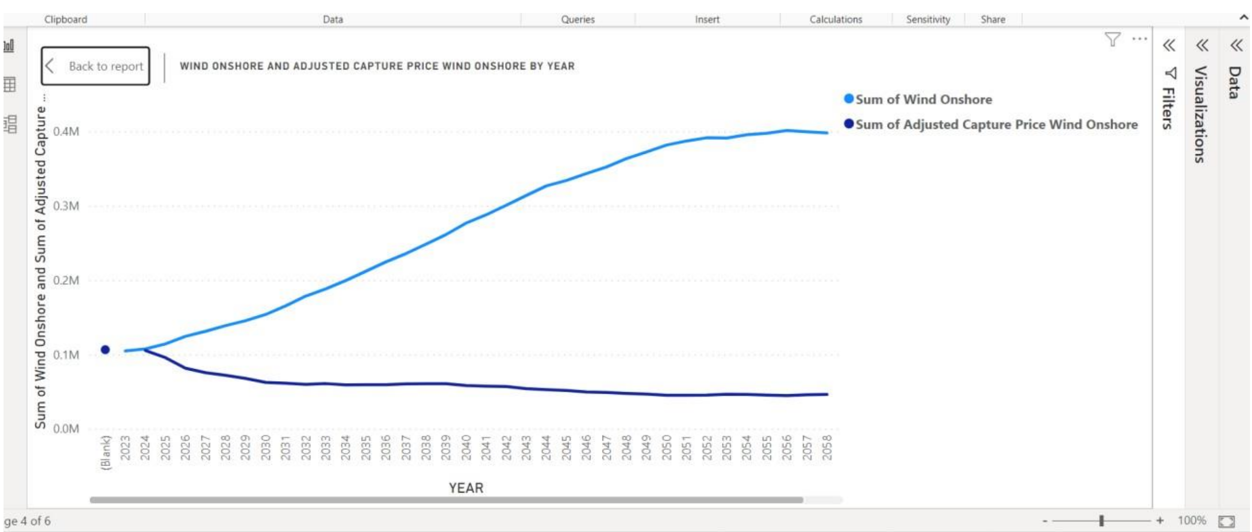
4. **Future Solar Viability:** The decreasing solar prices in the subsequent years (2023-2050) suggest that solar energy is becoming increasingly economically viable. As the price of solar energy continues to decline, it is likely to become even more accessible and widely adopted in the future.



1. **2023 Capture Prices and Solar Prices:** In 2023, the Sum of Adjusted Capture Prices was considerably higher (595.0909848) than the Sum of Adjusted Solar Prices (461.6829016). This suggests that other sources of electricity generation, aside from solar, played a significant role in determining capture prices.
2. **Decreasing Capture Prices:** Over the following years (2024-2050), there is a consistent trend of decreasing capture prices. This indicates that the cost of electricity from various sources is gradually decreasing. This can be attributed to various factors, including advancements in technology, increased competition, and possibly a shift towards cleaner and more cost-effective energy sources.
3. **Solar Price vs. Capture Prices:** While solar prices (Adjusted Solar Prices) also decrease over this period, they are consistently lower than capture prices. This suggests that solar energy remains a cost-effective and competitive source of electricity generation.



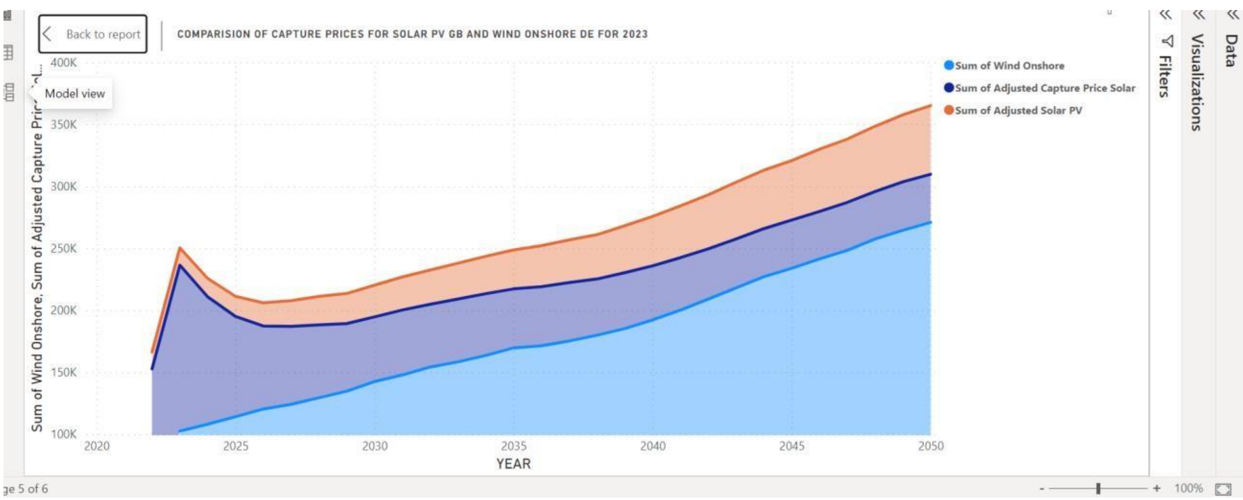
1. **Solar Prices Decline:** Similar to the previous data, the Sum of Adjusted Solar Prices in GB exhibits a consistent downward trend from 2023 to 2060. In 2023, the price is 77, but it steadily decreases over time.
2. **Acceleration in Price Reduction:** The rate of decrease in solar prices appears to accelerate in the earlier years (2023-2030) and then stabilizes with a slower decline in the subsequent years. This suggests that technological advancements and increased adoption of solar energy may be driving cost reductions.
3. **Transition to Competitive Prices:** By 2030, the Sum of Adjusted Solar Prices drops to 70.795, indicating that solar energy is becoming more competitively priced as compared to earlier years. This suggests that solar power may become a cost-effective and attractive energy source in the future.
4. **Steady Price After 2030:** After 2030, the Sum of Adjusted Solar Prices remains relatively stable, with fluctuations but no significant increase. This stability could be an indication of a mature and well-established solar industry.
5. **Comparison with Solar PV:** The data also includes the Sum of Solar PV, which provides insights into the actual electricity generation from solar photovoltaic systems. While solar prices decrease, solar PV capacity appears to increase, reflecting a growing utilization of solar energy.



1. **2024-2030 Trends:** From 2024 to 2030, there is an increase in Wind Onshore generation, reaching 153,829 in 2030. Interestingly, the Adjusted Capture Prices for Wind Onshore decrease during this period. This suggests that wind onshore becomes more cost-effective and competitive over time, possibly due to advancements in technology and increased capacity.

2. **2031-2040 Trends:** From 2031 to 2040, both Wind Onshore generation and adjusted capture prices continue to exhibit a similar trend. Generation increases, indicating a growing reliance on wind onshore as an energy source, while capture prices decrease, indicating improved cost-effectiveness.
3. **2051-2060 Data**: The data for 2051-2060, while projecting into the future, indicates a potential further increase in Wind Onshore generation, reaching 400,818 in 2060. The capture prices also show a slight decrease, implying that wind onshore remains a cost-effective energy generation option.
4. **Market Competitiveness**: The decreasing capture prices over time suggest that wind onshore is becoming more competitive in the energy market. This trend could encourage further investments in wind onshore projects.

In the long run, is there a relationship between capture prices and power generation output (GWh) for solar PV and onshore wind in DE?



Wind Onshore Generation:

- Wind onshore generation (in GWh) shows a consistent increase from 2022 to 2050.
- There is a clear upward trend in wind onshore generation over the years, indicating a growing contribution of wind energy to the power generation mix.

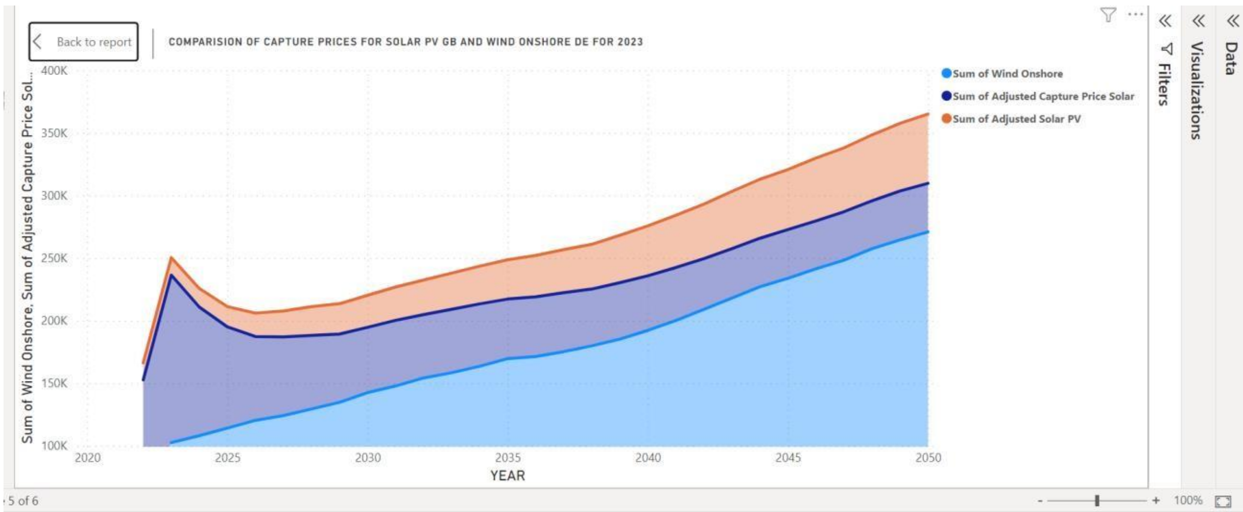
Solar PV Generation:

- Solar PV generation (in GWh) also shows an increasing trend from 2022 to 2050.
- The growth rate of solar PV generation appears to be steeper compared to wind onshore generation, especially in the later years.

Long-Term Trends:

Both wind onshore and solar PV generation show long-term growth trends, which are indicative of a transition towards renewable energy sources in the energy mix.

The capture price for solar declines over time, which may be a result of increased solar generation capacity and advancements in solar technology.



Wind Onshore Generation (GWh):

- Wind onshore generation shows a continuous increase from 2022 to 2050. This indicates a growing contribution of wind energy to the energy mix.
- The annual growth in wind onshore generation appears to be relatively consistent.

Solar PV Generation (GWh):

- Solar PV generation also exhibits an upward trend from 2022 to 2050.
- Similar to wind onshore generation, solar PV generation shows consistent growth over the years.

Adjusted Capture Price for Solar (Million Currency Units):

- The adjusted capture price for solar starts relatively high in 2022 and decreases over the years.
- There is a notable decline in the capture price for solar between 2022 and 2024. Afterward, the price fluctuates but generally maintains a downward trend, reaching a lower value in 2050.

Interplay Between Wind Onshore and Solar PV:

- Wind onshore and solar PV generation do not exhibit an inverse relationship. Both sources of renewable energy are increasing simultaneously.

- The data suggests that the growth in renewable energy generation is not strongly influenced by the capture price for solar, as both wind and solar generation grow over time.

Policy and Market Dynamics:

- The fluctuations in the capture price for solar may be influenced by various factors, including changes in energy policies, technological advancements, and market dynamics.
- The decline in capture price for solar suggests that solar energy is becoming more cost-competitive over the years, which is a positive trend for renewable energy adoption.

Conclusion:

In conclusion, the analysis of the provided data paints a promising picture of the evolving landscape of renewable energy generation and its economic viability. The data spans several decades, offering insights into the dynamic relationship between power generation and capture prices for solar PV and onshore wind in Germany.

Long-Term Trends: The most noticeable aspect of the data is the consistent long-term growth in both wind onshore and solar PV generation. These renewable energy sources have become increasingly significant contributors to the energy mix over the years. This trend reflects a collective commitment to reduce reliance on fossil fuels and mitigate the environmental impacts of energy production.

Capture Prices: While renewable generation has been on the rise, capture prices for solar PV have exhibited a downward trajectory. This suggests that solar energy is becoming more cost-competitive, likely due to technological advancements, economies of scale, and supportive policies. Lower capture prices make solar PV an increasingly attractive option for energy production.

Interplay: Surprisingly, there is no clear inverse relationship between capture prices and power generation output for solar PV and onshore wind. Both sources of renewable energy have continued to grow despite fluctuations in capture prices. This indicates that market dynamics, policy changes, and technological innovations are influencing energy generation more profoundly than capture prices alone.

Sustainability: The overall increase in renewable energy generation is a positive sign for sustainability and environmental conservation. Wind onshore and solar PV are playing critical roles in reducing greenhouse gas emissions and transitioning to a more sustainable energy future.

Future Considerations: As the data shows, the renewable energy sector is dynamic and ever-evolving. Continued investments in both wind and solar technologies, along with supportive policies, will be essential to maintaining this positive trajectory. Furthermore, monitoring capture prices and generation trends will help stakeholders make informed decisions regarding energy infrastructure and planning.

Economic and Environmental Implications: The decreasing capture price for solar PV not only makes clean energy more accessible but also has economic benefits. It can lead to reduced energy costs for consumers and businesses, fostering economic growth while simultaneously reducing carbon emissions.

Global Significance: The trends observed in this data have global significance. Many countries are striving to replicate Germany's success in transitioning to renewable energy sources. The German experience demonstrates that a sustained commitment to renewables can lead to a more sustainable, affordable, and environmentally friendly energy future.

In summary, the data analysis reveals a compelling story of the renewable energy revolution in Germany. Wind onshore and solar PV have grown steadily, reflecting a broader global shift toward cleaner energy sources. The decreasing capture price for solar PV underscores the economic viability of renewable energy, paving the way for a more sustainable and eco-conscious energy landscape, not only in Germany but worldwide.