Navigating the Energy Landscape: Production, Consumption and Environmental Impact

Course Name: Visual Analytics (MGMT 59000 Fall 2024)

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Introduction and Background

Energy consumption is a critical factor driving economic growth, technological advancements, and environmental sustainability. As industries and households across the globe continue to demand more energy, the need to explore both traditional and renewable energy sources have never been more pressing. The shift from fossil fuels such as coal and petroleum towards cleaner, renewable energy sources like solar and wind energy is essential for reducing carbon emissions and ensuring long-term sustainability.

This project aims to analyze the trends in energy consumption across various sectors in the U.S., with a particular focus on the growing importance of renewable energy sources. By leveraging datasets provided by the U.S. Energy Information Administration (EIA), we will examine the shift from fossil fuels to renewables, regional disparities in energy production and consumption, and the corresponding impact on CO2 emissions.

The energy sector is experiencing a global transition, motivated by climate change concerns, government policies, and technological advancements. As highlighted by Lo and Zhao (2023), policy-driven transitions have greatly influenced energy consumption patterns and carbon footprints. This project seeks to dive deeper into these trends by identifying regions in the U.S. that have high fossil fuel consumption and exploring opportunities for adopting alternative, cleaner energy sources.

Objectives and Goals

The primary objective of this project is to explore the changing trends in energy production and consumption, particularly the shift from fossil fuels to renewable energy. Our specific goals are to:

- Identify the current trends in renewable energy consumption.
- Examine how these trends impact CO2 emissions.
- Highlight regions with high fossil fuel consumption where a transition to renewables could be beneficial.
- Explore possible strategies for optimizing energy efficiency across the U.S.

Our project will answer these key questions and provide insights that will help identify areas for improvement in energy production and consumption efficiency.

Datasets

This analysis utilizes several datasets from the U.S. Energy Information Administration (EIA), which provide a comprehensive view of energy trends across various sectors, including fossil fuels and renewables. The data covers a wide range of variables such as production, consumption, pricing, imports, and exports for different energy sources across U.S. states over multiple decades.

1. Total Energy Overview Dataset:

- **Purpose**: To track the production and consumption of various fuels, including fossil fuels, renewables, and nuclear energy, across different sectors and states.
- **Variables**: Energy source (coal, petroleum, natural gas, renewables), consumption, production, end-users, and state.
- **Size**: Several thousand records detailing annual energy production and consumption across U.S. states.
- **Limitations**: Some states may have missing data for certain years, especially for newer renewable energy sources like solar and wind.

2. Stagewise Renewable Energy Consumption Dataset:

- **Purpose**: To provide state-level data on the production and consumption of renewable energy sources such as wind, solar, and hydropower.
- **Variables**: State, energy source (renewable), production capacity, state rankings for energy consumption.
- **Size**: Data from 50 U.S. states, including total renewable energy production and consumption figures.
- **Limitations**: Some states with smaller renewable energy production may have limited data availability or estimates rather than direct measurements.

3. CO2 Emissions by Source Dataset:

- **Purpose**: To track state-level CO2 emissions from different energy sources, including coal, natural gas, and petroleum.
- **Variables**: Year, state, CO2 emissions (in thousand metric tons), energy source (coal, petroleum, natural gas).
- **Size**: Historical data from 1950 to 2023.
- **Limitations**: Some emission values may be interpolated or estimated, especially for older data.

4. Renewable Energy Production and Consumption by Source Dataset:

- **Purpose**: To track renewable energy production and consumption for different sources (wind, solar, hydropower) from 1949 to 2024.
- **Variables**: Year, renewable energy source, production and consumption figures (in kilowatt-hours), state.
- **Size**: Data spanning several decades, with thousands of records detailing the growth of renewable energy across the U.S.

- **Limitations**: Earlier data for renewables may be incomplete, especially for newer technologies like wind and solar.

These datasets enable a detailed analysis of both the production and consumption trends of energy sources and their environmental impacts, providing insights for businesses, policymakers, and analysts involved in energy capacity planning.

Data Story: Energy Transition in the U.S. (1990-2022)

Through the analysis and visualization of the U.S. energy data, clear trends emerge that highlight a significant shift in energy production and consumption. The following charts illustrate the gradual transition from traditional fossil fuels to renewable energy sources, along with the regional and temporal differences in production, consumption, and environmental impacts. This data story provides insights into the current state of energy use in the U.S. and sheds light on the opportunities and challenges of a sustainable energy future.

Chart 1: Trend of Energy Production by Source (1990-2022)
(Dataset - State_production_data.xlsx)

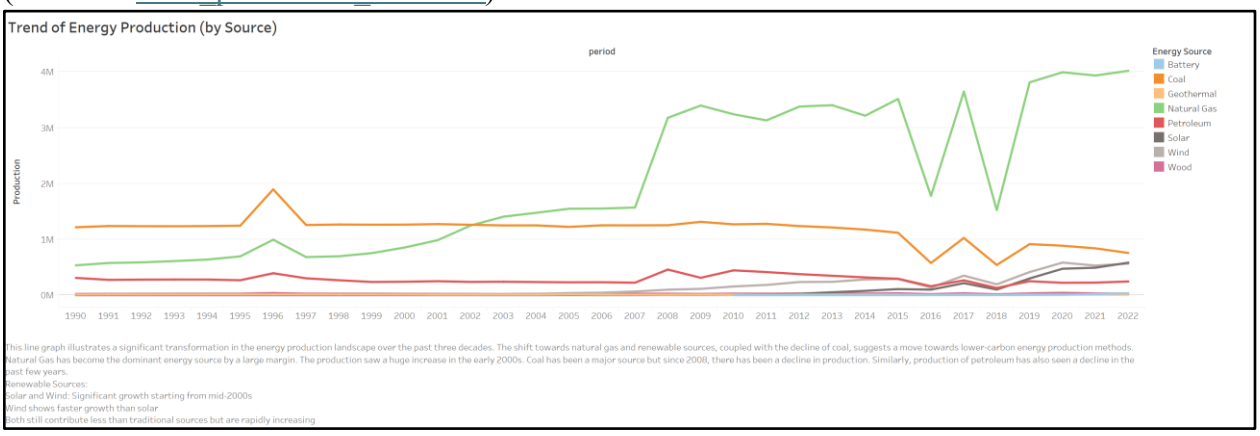

Figure 1: Trend of Energy Production

The first line graph reveals the transformation in energy production in the U.S. over the past three decades. Notably, **natural gas** has emerged as the dominant energy source since the early 2000s, overtaking coal and petroleum. Natural gas production surged in the 2000s due to technological advancements in fracking and horizontal drilling, which made shale gas extraction more cost-effective.

Simultaneously, **coal production** has steadily declined, reflecting the shift away from high-carbon energy sources toward cleaner options. **Petroleum** has maintained relatively stable production levels, but its share of the energy mix is declining as renewables and natural gas rise.

Renewable energy, particularly **wind** and **solar**, has experienced exponential growth, especially since 2010. This surge underscores the growing commitment to reducing carbon emissions and addressing climate change.

Chart 2: State-Level Energy Production by Source (Map Visualization)
(*Dataset* - State_production_data.xlsx)

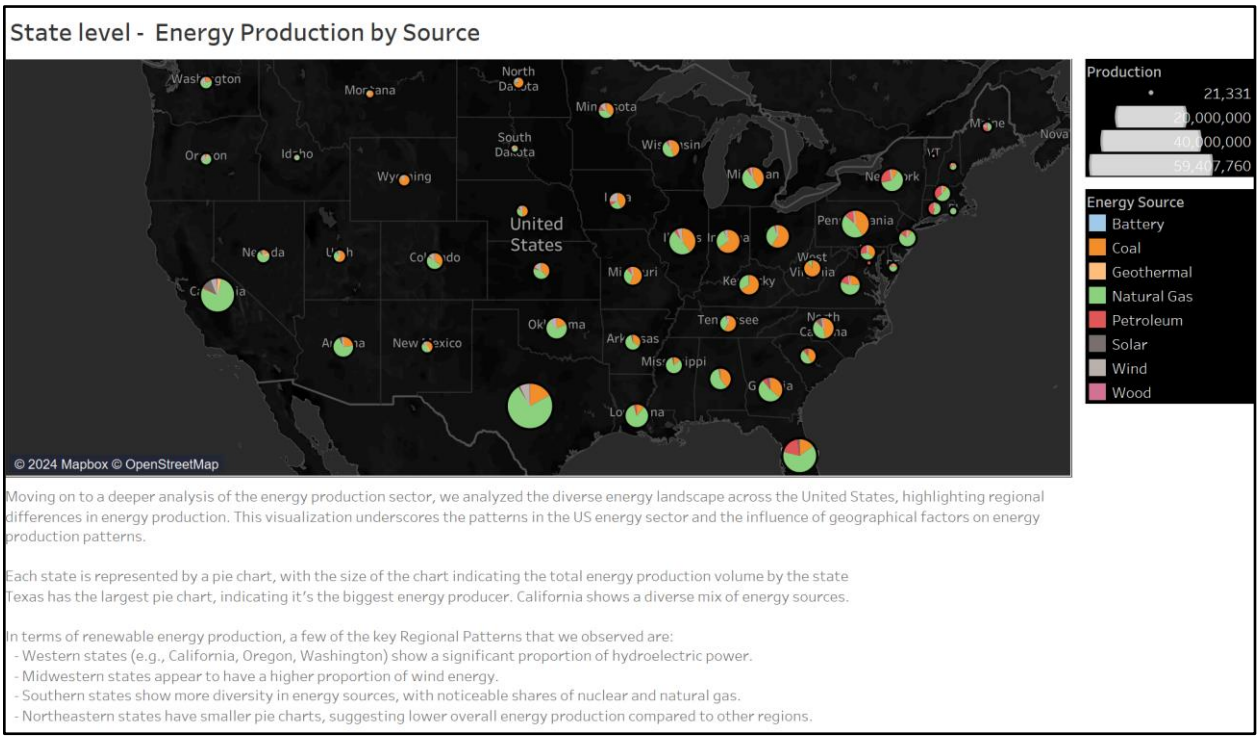

Figure 2: Trend of Energy Production – by State

The second chart maps the energy production landscape across the U.S., highlighting state-level differences in energy sources. **Texas** leads the nation in total energy production, with natural gas dominating its output. This is primarily due to Texas' vast natural gas reserves and its strategic focus on energy production.

Western states like **California**, **Oregon**, and **Washington** are pioneers in renewable energy, particularly solar, wind, and hydroelectric power. This reflects the states' ambitious energy policies and abundant renewable resources.

In the **Midwest**, states like **Iowa** and **Kansas** have taken advantage of the region's wind resources, emerging as significant wind energy producers. The geographic diversity in energy production highlights the varying natural resources available to states and their policy-driven efforts to transition to cleaner energy.

Chart 3: Top 10 Energy-Producing States

(Dataset - State_production_data.xlsx)

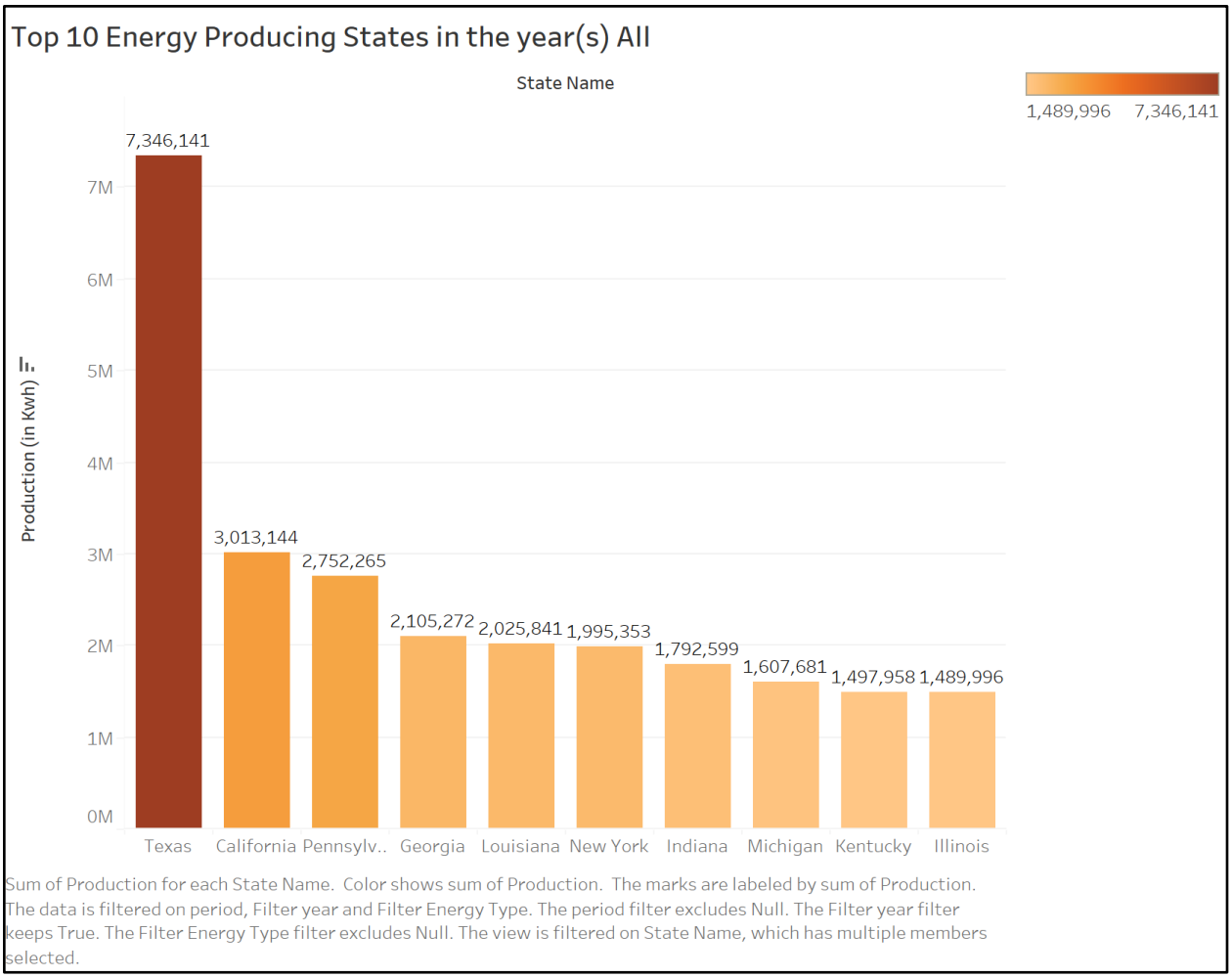

Figure 3: Top 10 Energy Producing States

This bar chart further emphasizes **Texas**' dominance in energy production, driven by its rich natural gas and petroleum resources. Texas' production is nearly double that of the second-highest producer, **California**.

Other states in the top 10 include **Pennsylvania** and **Georgia**, both of which have made significant strides in energy production. Pennsylvania's growth in natural gas production, driven by the Marcellus Shale, is particularly noteworthy.

Chart 4: Top 10 Energy-Consuming States

(*Dataset* - State_production_data.xlsx, Consumption_Data.xlsx)

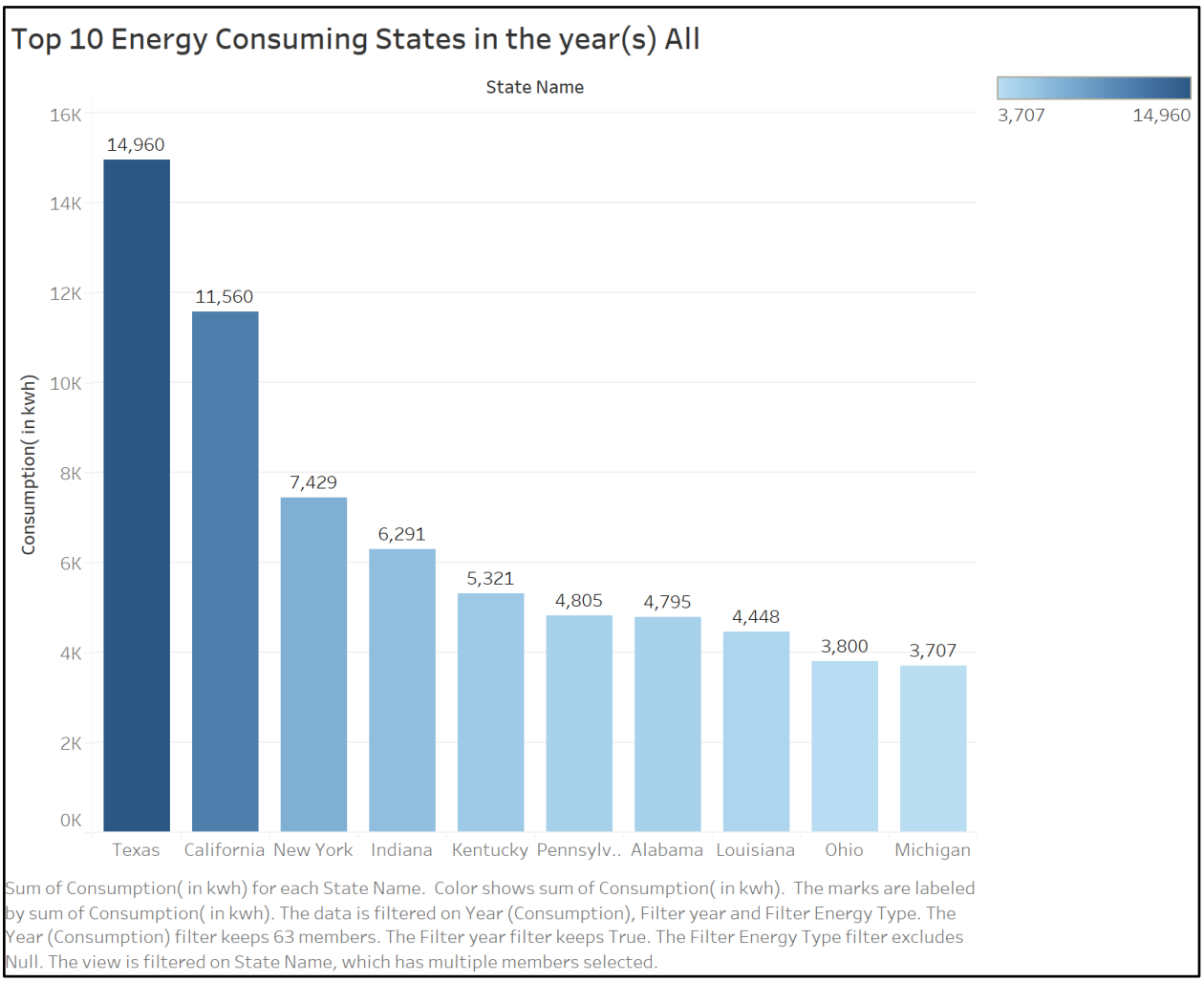

Figure 4: Top 10 Energy Consuming States

While Texas leads in energy production, it is also the largest consumer of energy. This is driven by its large population, industrial base, and energy-intensive sectors like manufacturing and petrochemicals. **California** and **New York**, two other populous states, follow in consumption.

Interestingly, states like **Indiana** and **Kentucky** consume more energy than some of their larger counterparts, driven by their industrial economies.

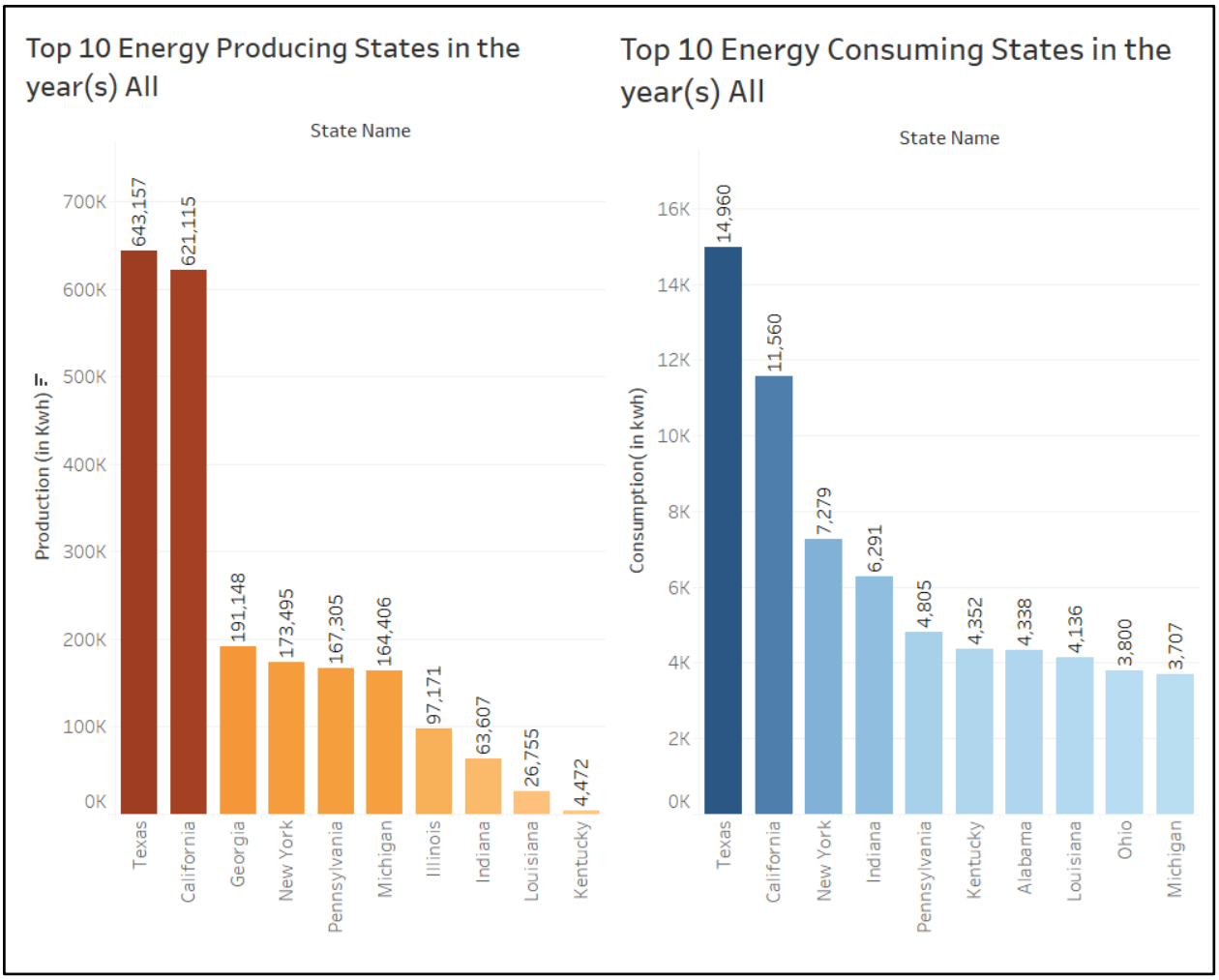

Figure 5: Top 10 Energy Producing vs Consuming States

Chart 5: Energy Production and Emissions Trends (1990-2022)

(*Dataset* - Emissions_Data.xlsx, State_production_data.xlsx)

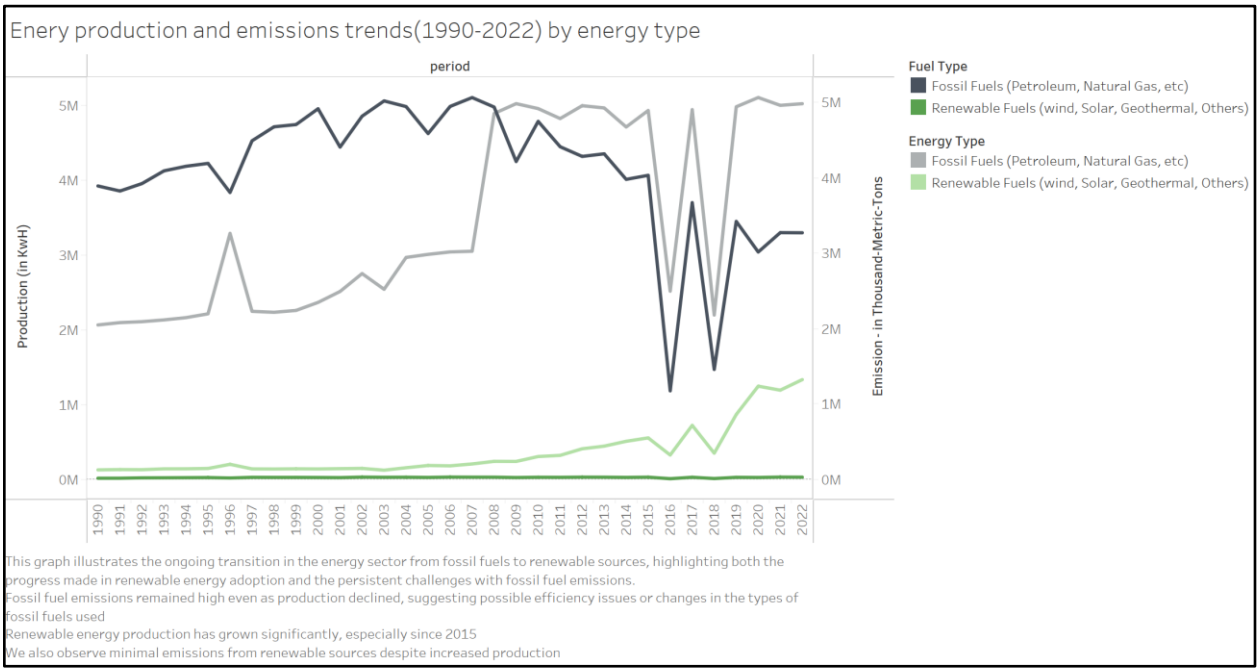

Figure 6: Energy Production vs Emission Trends

This chart provides a clear link between energy production and CO2 emissions. Fossil fuels such as coal, natural gas, and petroleum have historically been the largest contributors to emissions. However, while **fossil fuel emissions** have remained high, the decline in coal production and the rise of natural gas and renewables have helped slow the growth of emissions.

Renewable energy sources, on the other hand, have seen significant growth, particularly since 2015. While renewables still produce relatively low emissions compared to fossil fuels, their increasing share of the energy mix is a positive step toward reducing the U.S.'s overall carbon footprint.

Chart 6: Rankings- Total Renewable Energy Consumed Per Capita

(*Dataset* - Consumption_Data.xlsx)

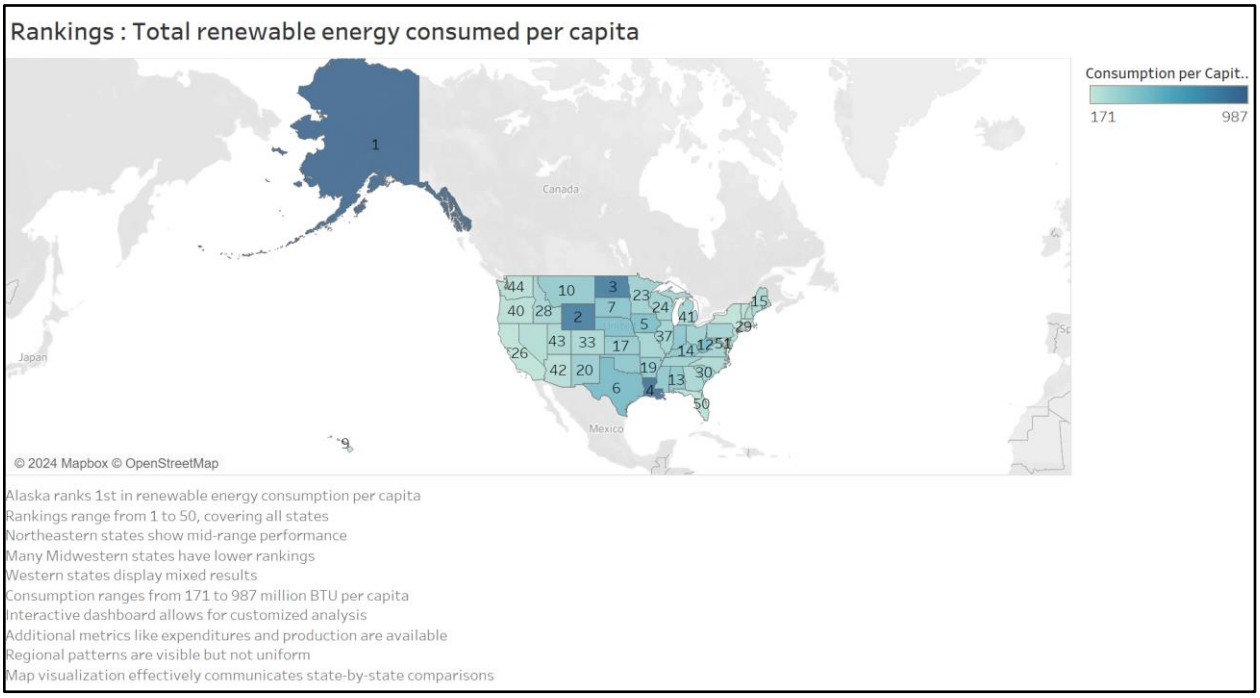

Figure 7: Top Renewable energy consuming states per capita (ranked)

This map visualization ranks states based on their renewable energy consumption per capita. **Alaska** emerges as the top state for renewable energy consumption, likely due to its reliance on hydroelectric power and geothermal energy. **Western states** like **California** and **Oregon** also rank highly, reflecting their leadership in renewable energy policies.

States in the **Midwest** and **South** tend to rank lower, highlighting the continued reliance on fossil fuels in these regions. However, the growing adoption of wind energy in the Midwest is a positive sign for the future.

Summary and Conclusion

This analysis of U.S. energy production and consumption trends over the past three decades highlights several key takeaways:

1. **Natural gas** has become the dominant energy source, replacing **coal** as the primary fuel for electricity generation.
2. **Renewable energy** sources, particularly **wind** and **solar**, have experienced exponential growth, driven by government policies, technological advancements, and environmental concerns.
3. The geographic diversity in energy production reflects regional differences in natural resources and policy approaches, with **Texas** leading in overall production and **Western states** like **California** excelling in renewables.
4. **CO2 emissions** remain a concern, particularly for fossil fuels, but the growth of renewables offers a promising path toward reducing the U.S.'s carbon footprint.

As energy demands continue to rise, especially with advancements in technology, the need for a continued focus on renewable energy is evident. This analysis underscores the importance of transitioning to cleaner energy source.

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Contributions

Nandini Priya Devalla: Played a key role in the development of the project by contributing significantly to the initial dashboard creations. Worked on the Tableau workbook, ensuring data was visualized effectively and insights were presented clearly. In addition, collaborated on drafting the final research report, bringing together the analysis and findings from the project.

Muskan Aggarwal: Shaped the overall storyline of the project, ensuring the narrative aligned with the research and data insights. Worked on and delivered the final presentation. Helped in initial tableau development for the team's analysis.

Yash Kothari: Responsible for identifying the research topic and explored datasets to reach to final visualization story. Ensured that the datasets were structured appropriately for analysis. Worked on Tableau in developing the map-based dashboard, integrating visualizations, and refining the data story to convey meaningful insights.

Dhairya Dedhia: Led the data gathering and cleaning process, ensuring that the datasets used in the project were accurate, relevant, and ready for analysis. Ensured the data quality was high and worked on initial tableau workbook.

Kaushalya Naidu: Contributed to the project topic and by working on the initial dashboard creation, helping to establish a strong visual framework for presenting data insights. Also involved in the preparation of the final research report, working to ensure that the report provides a comprehensive overview of the research conducted.