Analysis and Visualization of Global Renewable Energy Trends

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ABSTRACT

This report examines global trends in renewable energy and economic indicators over the past decade, focusing on energy efficiency and GDP per capita. Our analysis reveals a significant reduction in global energy intensity levels, reflecting advancements in technology and energy policies. Additionally, we observe economic stability in developed nations and notable growth in emerging economies, though disparities persist. The findings underscore the importance of sustainable policies and targeted support to address regional challenges. This study highlights the crucial role of energy efficiency and economic strategies in achieving a sustainable global future.

1. INTRODUCTION

We are living in a time characterized by increased concern for nature and an imperative to deal with global warming as soon as possible; hence, everybody is shifting to renewable energy sources like solar power that is cheaper in the long term as compared to other kinds, can help minimize carbon dioxide output while ensuring steady power supply, making it very important today. This shift is not only pivotal for mitigating climate change but also for promoting economic development, technological innovation, and improved public health.

A mix of policy initiatives, technological advancements, and market dynamics is pushing the uptake of renewable energy. Governments world over are setting up ambitious targets as well as incentives geared towards increasing renewable energy production and consumption. At the same time technological advancements make renewable energy solutions more efficient and cost effective making it easier to incorporate them into national and local energy grids. The market is responding with increasing investments in renewable energy projects, driven by both environmental responsibility and economic opportunity.

But there are significant disparities in the worldwide scenario of renewable energy diffusion. There are some nations and regions that are in front of the pack through making large investments and quickly through putting up renewable energy structures while others are being left behind because they are economically constrained, are faced by policy challenges or have infrastructural bottlenecks. This fluctuating advance indicates that there is a requirement for a broad examination to grasp the forces moving things and to pinpoint the successes as well as the barriers in relation to worldwide changes to renewable power.

The objective of this task is to scrutinize and illustrate global developments in renewable resources through making use of the openly obtainable information concerning renewable energy production, consumption as well as expenditures. In an attempt to discover major developments such as; how quickly distinct forms of renewable energy have been expanding within dissimilar nations among other things that would measure performance in this field by use of statistics found from international data systems. By employing several different visualizations like line charts or bar graphs along with maps that represent the entire world we will show you what's happening now in terms of renewable energy sources worldwide.

The report is anticipated to be an elaborative graphical presentation focusing on the progress as well as the challenges experienced in harnessing renewable energy on a global scale. Insights derived from the same will assist policy makers, scholars and industry players determine the extent to which any gains have been made while at the same time pointing out the areas that require further intervention. This project aims to feature both the achievements and gaps highlighted and advance the continuous discussion on sustainable energy advocating for a greener future that would be more stable globally.

2. DESCRIPTION OF THE SOLUTION

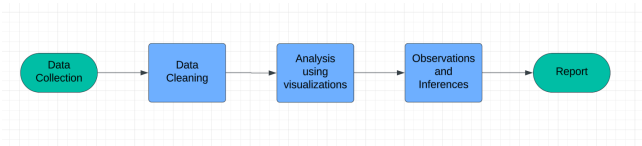

Figure 1: *Flowchart of the solution*

2.1 Data Collection and Preparation

To comprehensively analyze global renewable energy trends, our team began by sourcing publicly available datasets from reputable international databases. These datasets included information on renewable energy production, consumption, and investments from the International Energy Agency (IEA), the World Bank, and various national energy departments. Ensuring the credibility and accuracy of our data was paramount, so we focused on regularly updated and peer-reviewed datasets.

2.2 Data Cleaning

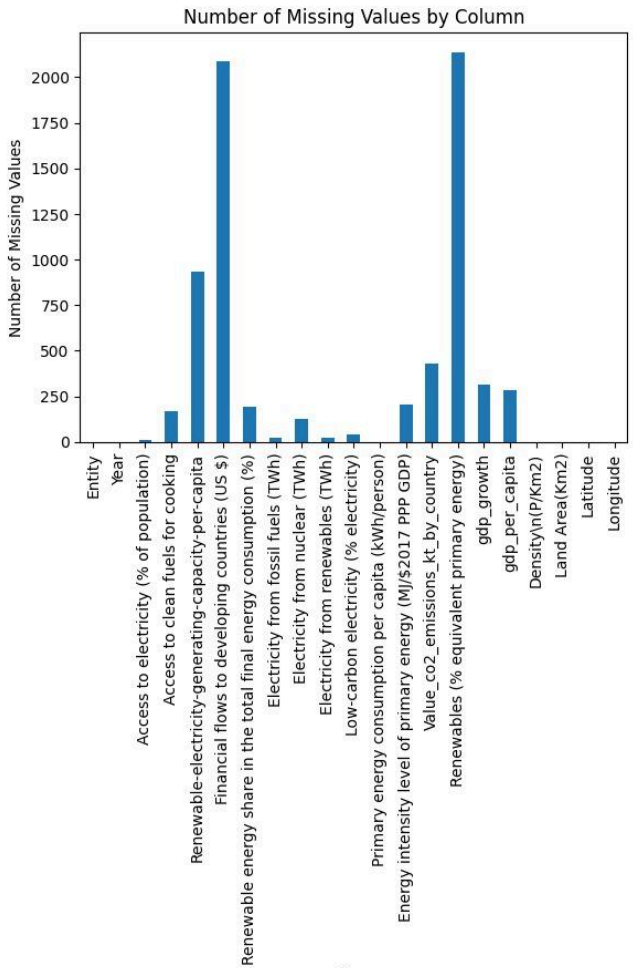

Figure 2: *Missing Values Count For Each Dataset Column*

Data cleaning was an essential step to guarantee the reliability of our analysis. The raw datasets contained inconsistencies, missing values, and errors that needed to be addressed. Our team utilized Python libraries such as pandas to identify and treat missing values, outliers, duplicates, and inconsistent formatting. For missing values, we did not consider columns that had a lot of missing values in our analysis. Outliers were carefully examined to determine if they were genuine or erroneous data points, and necessary corrections or removals were made to ensure the integrity of the data.

2.3 Data Analysis

With clean and prepared datasets, we proceeded to analyze the data to uncover trends and insights. Our analysis focused on the growth rates of different renewable energy sources (solar, wind, hydroelectric) across various countries. We used statistical methods and tools like Python's matplotlib and seaborn libraries to perform trend analysis, identifying key patterns and significant changes over time. Additionally, we conducted comparative analyses to highlight disparities in renewable energy adoption among different regions and countries.

2.4 Visualization

Visualization played a crucial role in making our findings accessible and understandable. We created a series of visualizations, including line graphs, bar charts, and world maps, to illustrate the trends and disparities in renewable energy adoption globally. Line graphs depicted the growth rates of various renewable energy sources over time, bar charts compared renewable energy investments and consumption across different countries, and world maps provided a geographic representation of renewable energy production and adoption. These visualizations were designed to be intuitive and informative, aiding stakeholders in grasping complex data quickly.

2.5 Reporting

The final step was to compile our analysis and visualizations into a comprehensive report. This report provided an elaborate graphical presentation of the state of global renewable energy, highlighting key areas of progress and regions lagging behind. Our goal was to offer insights that would assist policymakers, scholars, and industry players in understanding the extent of renewable energy adoption, the successes achieved, and the challenges that remain. The report aimed to contribute to the ongoing discussion on sustainable energy and advocate for further advancements towards a greener, more stable global future.

By following this methodology, our team was able to effectively analyse and visualize global renewable energy trends, providing valuable insights into the progress and challenges in this critical area.

3. RESULTS

3.1 Correlation Matrix

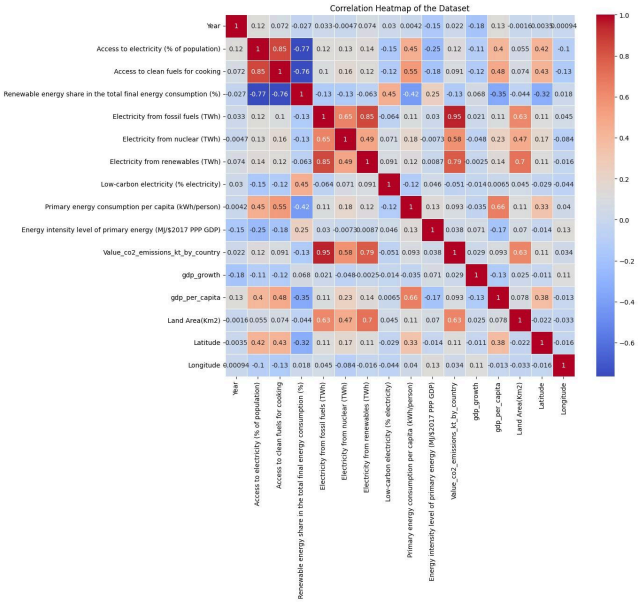

Figure 3: Correlation Matrix of various attributes

Our first visualization was a correlation matrix of all the columns (Figure - 3). Here are some interesting findings we observed from the visualization:

- **GDP per Capita** shows a strong positive correlation (0.4) with **Primary Energy Consumption per Capita** and a moderate positive correlation with **Access to Clean Fuels for Cooking** (0.3). This indicates that higher economic wealth often accompanies higher energy consumption and better access to clean cooking fuels.

- **GDP Growth** exhibits a strong positive correlation (0.4) with **Electricity from Renewables** and a moderate positive correlation with **Primary Energy Consumption per Capita**. This suggests that economic growth is linked with increased renewable energy usage.
- **Value of CO2 Emissions** is highly correlated with **Primary Energy Consumption per Capita** (0.93) and **Electricity from Fossil Fuels** (0.95), indicating that higher energy consumption and fossil fuel use contribute significantly to CO2 emissions.

3.2 Choropleth map: Depicting Energy intensity levels

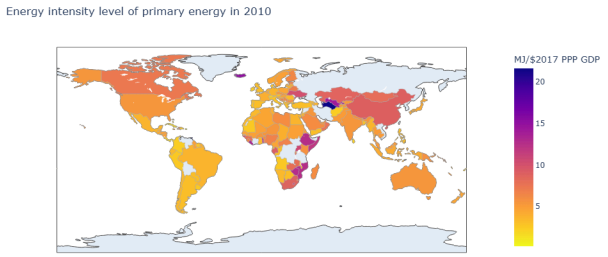

Figure 4: showing the energy intensity levels of primary energy in 2010

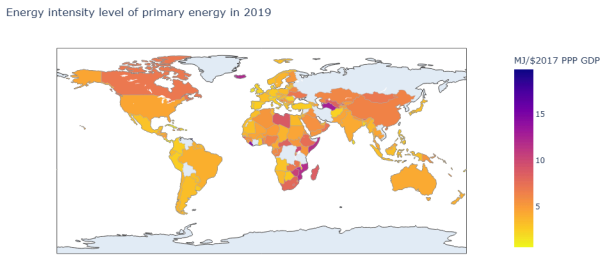

Figure 5: showing the energy intensity levels of primary energy in 2019

Our Second Visualization is the Comparison between the primary energy intensity levels of the world depicting us the global energy trends among countries (*Fig. 4, Fig. 5*). Here are some of the findings observed from the visualization:

- Developed countries like USA, Germany, etc. consistently showed lower intensity levels in both 2010 and 2019.
- Developing countries like India, China, etc., showed a considerable decrease in energy intensity levels, reflecting better efficiency.

Regions that previously exhibited **high energy intensity** levels have shown marked improvements, reflecting efforts to adopt more efficient energy practices and technologies. However, there are still regions, particularly in the Middle East and parts of Africa, where energy **intensity levels** remain high, suggesting ongoing challenges in **achieving optimal** energy efficiency.

3.3 Countries with Highest GDPs

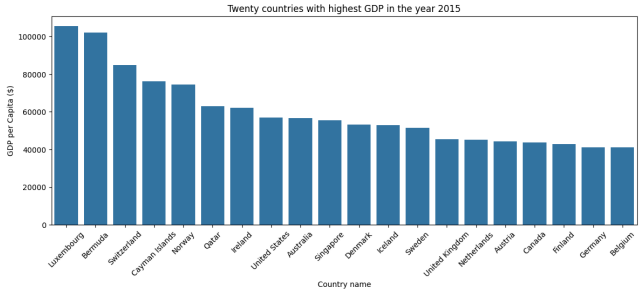

Figure 6: Top twenty countries with the Highest GDPs in 2015

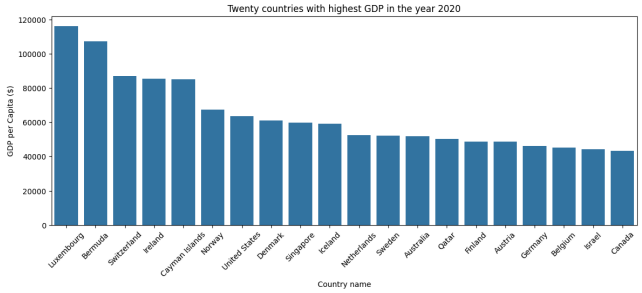

Figure 7: Top Twenty counties with the Highest GDPs in 2020

Our Third Visualization is the Comparison between the GDPs of Countries in 2015 as compared to 2020 (*Fig. 6, Fig. 7)*. Here are some the interesting findings from the visualizations above:

- **Energy Efficiency Improvements:** The significant reduction in energy intensity from 2010 to 2019 highlights global efforts and success in improving energy efficiency.
- **Economic Stability:** Countries like Luxembourg and Switzerland show consistently high GDP per capita, indicating stable and robust economies.
- **Emerging Economies:** The rise of new countries in the top GDP per capita rankings reflects changing economic landscapes and the potential of emerging markets.

3.4 Distribution GDP per capita across countries

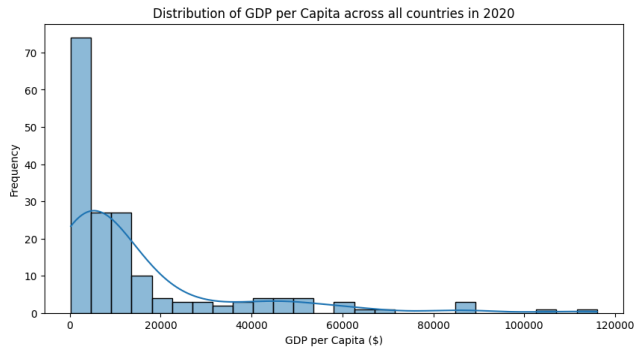

Figure 8: Distribution of GDP per Capita for all countries in 2020.

Our Fourth Visualization is the Comparison between the GDPs per Capita of all Countries in 2020 (*Fig. 8)*. Here are some of the interesting findings from the visualizations above:

- **Economic Disparity:** The distribution of GDP per capita in 2020 underscores the economic disparity between wealthier nations and developing countries, emphasizing the need for targeted economic policies and support.
- Many Countries **GDP per capita** lie between the **0-20000** dollar range that reveals that many of the countries are still developing countries and need investments for becoming efficient in renewable energy.

The economic data reveals the dominance of developed nations in GDP per capita but also shows emerging players, indicating dynamic changes in global economic standings. These insights allow countries to form policy decisions and strategic investments in renewable energy development.

4. Your Contribution

Avneet Ahuja:
I took the lead in the initial data collection phase, sourcing datasets from reputable international databases such as the International Energy Agency (IEA) and the World Bank. My primary responsibility was ensuring the data's accuracy and comprehensiveness. Once the data was collected, I cleaned the datasets using Python's pandas and NumPy libraries, addressing missing values, correcting inconsistencies, and standardizing data formats. In the data analysis phase, I examined the growth rates of various renewable energy sources across different countries, generating detailed statistical summaries and visualizations using Matplotlib and Seaborn. Additionally, I contributed to the visualization component by designing line graphs that depicted temporal trends. I synthesized our findings into a coherent narrative for the final report, highlighting key successes and challenges in global renewable energy adoption.

Pavit Bagga:
I enhanced the data collection process by identifying additional data sources that provided more granular information on renewable energy investments and consumption. Collaborating with Avneet Ahuja, I assisted in the data cleaning phase, using advanced imputation techniques to handle missing values and ensure data robustness. In the data analysis phase, I conducted comparative analyses to highlight disparities in renewable energy adoption between regions, employing statistical techniques to examine the factors influencing these disparities. I created bar charts to compare renewable energy investments and consumption across different countries, ensuring these visualizations were intuitive and effectively communicated our findings. My contributions to the final report included writing detailed sections on the economic drivers behind renewable energy adoption and the observed regional disparities.

Pranav Mittal:
My role involved integrating various datasets into a cohesive structure during the data cleaning phase, using Python libraries to merge datasets and ensure consistency across different data points. In the data analysis phase, I focused on investment trends in renewable energy, using financial data to assess the impact of investments on renewable energy production and consumption. I employed econometric models to analyze the return on investment in renewable energy projects, providing insights into the economic factors driving renewable energy adoption. For the visualization component, I developed world maps that highlighted regional differences in renewable energy production and adoption, emphasizing geographic trends and disparities. I contributed to the report by detailing our methodology and findings related to investment trends, explaining their significance in the broader context of renewable energy growth.

Nidhi Thakkar:
I played a pivotal role in ensuring the cleaned data was ready for analysis by conducting thorough quality checks and data validation. During the analysis phase, I focused on consumption patterns of renewable energy, using time-series analysis to identify trends and project future patterns. I created interactive dashboards using tools like Plotly and Tableau, allowing users to explore the data dynamically and gain deeper insights. My visualizations emphasized the potential for growth in renewable energy consumption and identified regions with significant untapped potential. I compiled and edited the final report, ensuring coherence and consistency throughout. Additionally, I created a summary section that encapsulated the key insights and recommendations from our analysis, ensuring the report was polished and professional for presentation to stakeholders.

Through our combined efforts in data collection, cleaning, analysis, visualization, and reporting, we were able to produce a comprehensive and insightful overview of global renewable energy trends. Each team member's contributions were integral to the project's success, resulting in a valuable resource for understanding and advancing renewable energy adoption worldwide.

5 Lessons Learned

The analysis of global renewable energy trends and GDP per capita data reveals significant improvements in energy efficiency and economic growth. There are notable advancements in both developed and emerging economies in terms of renewable energy. However, persistent challenges in certain regions and economic disparities highlight the need for continued investment in sustainable policies and following support for developing nations.

5. 1 List of Team Members

1. Avneet Ahuja
2. Pavit Bagga
3. Pranav Mittal
4. Nidhi Thakkar

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