Global Electricity Production: Renewables, Fossil Fuels and CO_2 Emissions

Inhaltsverzeichnis

1. Motivation

We have only one Earth. To protect it and to secure a sustainable future for humanity is, in my opinion, the most important challenge of any generation. For many decades, since humans learned how to produce, store, and use energy, human life has improved significantly. Electricity is today the basis for wealth, technological progress, and global connectivity. At the same time, this development also has a dark side. At least since the 20th century, it has been recognized that the use of fossil fuels such as coal, oil, and gas contributes to global warming. This is because fossil fuels release greenhouse gases that increase global temperatures. These rising temperatures cause extreme weather events, rising sea levels, and other serious impacts on life.

International agreements such as the Paris Climate Agreement show that the problem has been recognized at a political level. Plans have been made to try to control the problem and reduce the effects of climate change. Whether these plans will actually be put into action is a question that deeply interests me. This curiosity is what motivated me to choose this topic for a data story.

By analyzing publicly available energy and emissions data, this project aims to explore whether the world is on track toward a sustainable energy transition. Furthermore, I want to show how the consumption of fossil fuels is directly linked to CO_2 emissions, highlight the growth and adoption of renewable energy sources, and demonstrate that clean energy can be economically competitive. Carefully designed visualizations will help communicate complex data in an accessible way.

1.1 Objective

To make the process of creating this data story easier for myself, I defined five fundamental questions regarding energy production and CO_2 emissions that I wanted to address:

- How has global electricity production evolved over time across different energy sources?
- How do renewable and fossil fuel electricity generation compare historically?
- When does the global energy transition become visible in the data?
- How cost-competitive are renewable technologies compared to fossil-based electricity?
- How is the relationship between renewable electricity share and CO_2 emissions per capita?

2. Data and Exploratory Work

Using my defined questions, I knew exactly what data I needed to answer them. I required data on global energy production, levelized costs of electricity, and CO_2 emissions for countries around the world. However, at this point, I was not sure how to present the data effectively.

2.1 Data Exploratory

Before designing the final visualizations, exploratory data research was conducted to determine how to present the data and to identify suitable datasets. Since this topic is widely discussed, many analyses already exist online. I used these existing analyses both as inspiration and to better understand the data created around this topic.

I relied on the following resources:

- The Our World in Data article on the global electricity mix provided an overview of how electricity production has evolved across different energy sources and inspired the use of a stacked area chart to address my first question (Our World in Data, 2020 -a).
- The article "The World's Energy Problem" helped me understand the challenges of current energy production and helped me to build the overall narrative of the data story, although it did not directly inspire any visualizations (Our World in Data, 2020.-b).
- The Our World in Data page on renewables illustrated the growth of different renewable sources over time (Our World in Data, 2020 -c).
- An interactive chart showing CO_2 emissions per capita versus renewable electricity share served as inspiration for creating a scatter plot for a similar visualization (Our World in Data, 2024 -d).
- Finally, a YouTube video discussing nuclear energy and climate challenges provided guidance on explaining complex energy topics clearly and inspired the use of a boxplot to compare prices across different energy sources (Terra X Lesch & Co, 2025).

2.2 Choice of Data Sources

With a clear understanding of what to show the audience, I was able to collect the following datasets:

Global Electricity Production by Source (Kaggle. Electricity mix data)
This dataset provides time-series data on annual electricity generation by source for countries worldwide. It was obtained from Kaggle and is based on data compiled by Our World in Data (Our World in Data, n.d.-a).

Levelized Cost of Electricity (Worldbank. Datacatalog LCOE)
The Levelized Cost of Electricity **(**LCOE) dataset, provided by the World Bank, contains costs for various electricity generation technologies across different countries and discount rates. LCOE is a key economic metric that allows comparison between the costs of different technologies.

CO_2 Emissions Data (Our world in data. Co_2 data)
The CO_2 dataset from Our World in Data includes emissions data for countries over time, including CO_2 emissions per capita.

All datasets were already cleaned and then preprocessed by me in Python. This included filtering global and country-level data, aggregating energy sources into meaningful groups (renewables vs. fossil fuels), and aligning datasets by year and country to combine them.

3. Target Audience

Since my project addresses a topic that affects all of us, the visualizations were designed to be simple to interpret. This ensures that anyone with an interest in energy production, climate change, or sustainability can engage with the project. While the analysis itself is data-driven, the visualizations are intended to be understandable without requiring advanced technical knowledge.
This audience influenced several design choices:

- Use of intuitive chart types (stacked area charts, line charts, scatter plots).
- Clear labeling and annotations highlighting key takeaways of the different charts.
- Colorblind-friendly color palettes, to make it accessible for as many as possible.
- Logical ordering of charts to maintain interest for the audience and make it easy to follow.

4. Visualizations and Design Choices

I decided to create one chart for each of the questions I wanted to answer with this work.

4.1 Global Electricity Production by Source

A stacked area chart was chosen to visualize global electricity production over time. This chart type effectively shows both total production growth and the relative contribution of each energy source. Fossil fuels were displayed in shades of gray to clearly show that they belong together in a group. Renewables were highlighted using colorblind-friendly colors and hatching patterns. The renewable energy sources are stacked on top of the fossil fuels to create a clear distinction and make the chart even easier to interpret.
This design makes it immediately visible that, despite growth in renewables, fossil fuels still dominate global electricity production.

4.2 Renewables vs. Fossil Fuels

To simplify the comparison between renewables and fossil fuels, energy sources were grouped into two categories: renewables and fossil fuels. A line chart was chosen because it is simple and suitable to show the change over time. Since there were noticeable anomalies in the data, I wanted to explain them directly in the visualization. Therefore, annotations were used to highlight key moments such as the financial crisis in 2008, the COVID-19 pandemic in 2020, and the acceleration of renewable energy growth in the early 2000s.
This visualization clearly shows the progress of renewable energy and its comparison to fossil fuel production over time. It also highlights and explains anomalies in the data.

4.3 Share of Renewables Over Time

A line chart showing the renewable share of global electricity production was used to emphasize proportional changes rather than absolute values. An annotation highlights the point where the energy transition becomes clearly visible in the data. In combination with the previous chart, this allows me to make an important point: it is not only important how fast renewables are growing, but also how quickly we can reduce the use of fossil fuels. This visualization shows that significant progress has been made, but the pace of the energy transition is still not fast enough to meet climate goals.

4.4 LCOE Distribution by Technology

A boxplot was chosen to visualize the distribution of LCOE values across technologies. Boxplots allow for comparison of median costs and variability, which is exactly what I needed to highlight. Outliers were not shown as they were not necessary for making the point and could reduce the clarity of the chart. Renewable technologies were colored

green, and fossil-based technologies are shown in grey to maintain a consistent color scheme. The results show that several renewable technologies, particularly solar and wind, are now cost-competitive or even cheaper than fossil fuel alternatives, countering one of the common arguments against the expansion of renewable energy sources.

4.5 Renewable Share vs. CO_2 Emissions per Capita

A scatter plot was used to show the relationship between renewable electricity share and CO_2 emissions per capita. Marker size represents total electricity production, and selected countries were highlighted to provide clear examples. The renewable share is indicated by marker color, with brighter colors representing higher shares.
The plot shows that countries with higher renewable shares generally have lower CO_2 emissions, while also highlighting exceptions and other influencing factors.

5. Tools and Libraries Used

The following libraries were used to create my visualizations:

Tool / Library	Purpose / Use	Reason for Choice
Pandas	Data loading and aggregation	Existing experience with this library
NumPy	Numerical operations	Existing experience with this library
Matplotlib	Core plotting and customization	Existing experience with this library
Seaborn	Improved styling on statistical visualizations	To enhance the design of my charts
openpyxl	Reading Excel-based data (LCOE data)	No known alternative at the time
Quarto	Generating the interactive HTML data story	Recommended by a lecturer
Jupyter Notebook	Run and organize the analysis	Existing experience with this library

The following other tools were used to complete this project:

ChatGPT: Used to support research, assist with coding, help draft the README file, improve the structure and clarity of the data story, and improve the readability of this report.

Grammarly: Used to correct grammar and spelling in this report and the data story.

6. Conclusion

This project shows that the global energy transition is clearly visible in the data, yet it also reveals important limitations. While renewable electricity production has grown rapidly and become economically competitive, fossil fuels continue to dominate global electricity generation. Similarly, the relationship between renewable energy share and CO_2 emissions is evident, but it is shaped by broader economic factors.

Taken together, these findings highlight that, although progress is being made, achieving climate targets will require not only a continued expansion of renewable energy and a reduction in fossil fuel use, but also systemic changes across sectors beyond electricity generation.

7. Work summary

The work summary is included in the submitted ZIP folder.

8. References

- Our World in Data. (2020 -a). Electricity mix. - https://ourworldindata.org/electricity-mix
- Our World in Data. (2020 -b). The world's energy problem. - https://ourworldindata.org/worlds-energy-problem
- Our World in Data. (2020 -c). Renewable energy. - https://ourworldindata.org/renewable-energy
- Our World in Data. (2024 -d). CO_2 emissions per capita vs. renewable electricity. - https://ourworldindata.org/grapher/co2-per-capita-vs-renewable-electricity
- Terra X Lesch & Co 2025. Alles Kernkraft, alles bingo? Transmutation erklärt | Harald Lesch | Terra X Lesch & Co. - https://www.youtube.com/watch?v=7oP2Cx-ssOc&t=799s
- Kaggle. Electricity mix data. - https://www.kaggle.com/datasets/valchovalev/electricityprodsourcestacked
- Worldbank. Datacatalog LCOE.- https://datacatalog.worldbank.org/search/dataset/0038036/global-data-on-levelized-cost-of-electricity-generation-lcoe
- Our world in data. Co_2 data. - https://github.com/owid/co2-data?tab=readme-ov-file