Global Energy Consumption

Group 3:

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Analyzing World Data to Project Global Energy Trends

Research Questions:

What are the most common energy sources? How has this changed over time?

Does an increase in energy consumption impact the distribution of energy sources among specific countries?

What are the projected carbon footprints of countries in the next 10-20 years, considering population growth and the distribution of energy sources?

Data

Statistical Review of World Energy: Energy Institute

Accessing Data:

Home | Statistical Review of World Energy → 'Download the data'

→ Download 'Statistical Review of World Energy Data.xslx'

→ Convert selected sheets as separate csv files:

- **Primary Energy Consumption**
- **Primary Energy Consumption - Cons by fuel**
- **Primary Energy Consumption - Cons Capit**
- **CO2 Emissions from Energy**

Analyzing World Data to Project Global Energy Trends

Global Energy Use of 47 Participating Countries **(1990 - 2021)**

Measuring:

1. Total Energy Consumption (exajoule)
2. Total Energy Consumption per Capita (gigajoule)
3. CO2 Emissions (million tonnes of carbon)

Analyzing World Data to Project Global Energy Trends

Further Segmenting Energy Use by Source:

1. Energy Source: Nuclear
2. Energy Source: Coal, Peat and Oil Shale
3. Energy Source: Oil Products
4. Energy Source: Electricity
5. Energy Source: Natural Gas

Data Cleaning & Merging: Process

Data

Separately read in each csv file using `os.path.join` and display as a DataFrame

Converted to array

Create an array from the DataFrame with a `for` loop to organize columns for results

Save new csv file

Filter columns necessary for analysis and output into clean data `to_csv`

Merge 4 datasets

Using `process_file`, merge first 3 csv files. Once complete use `pd.merge` for final result

Data Cleaning

```
# Path to input files
World_data_file_path = os.path.join("Data/csv/World_Energy_Data.csv")

# Read the energyata and the study results
World_Data_df = pd.read_csv(World_data_file_path)#.query("Flow == Total_final_consumption")
World_Data_df
```

	Country	Product	Flow	1990	1991	1992	1993	1994	1995	1996	...	2013
0	Australia	Coal, peat and oil shale	Production (PJ)	4442	4805	4988	5023	4969	5352	5441	...	11075
1	Australia	Coal, peat and oil shale	Imports (PJ)	0	0	0	0	0	0	0	...	3
2	Australia	Coal, peat and oil shale	Exports (PJ)	-2816	-3275	-3434	-3585	-3564	-3709	-3824	...	-9101
3	Australia	Coal, peat and oil shale	Total energy supply (PJ)	1461	1519	1542	1573	1554	1570	1703	...	1831
4	Australia	Coal, peat and oil shale	Electricity, CHP and heat plants (PJ)	-1209	-1254	-1286	-1294	-1311	-1356	-1430	...	-1734
...	...	...	...	...	...	...	...	...	...	...	...	...

Data Cleaning

- ➔ Find overlapping column values between the DataFrames
- ➔ Create a set to store the unique values of the first DataFrame
- ➔ Filter the dataframe to keep only values in the list per column
- ➔ Return the filtered DataFrame for final merging of all 3 datasets

```python
def process_file(file_name, column_name):
    # Create array to store data for merging
    df_array = []

    # Read the csv file
    input_df = pd.read_csv(os.path.join(input_folder, file_name))

    # Loop over the columns of the dataframe skipping the first column
    for column in input_df.columns[1:]:
        # Create a new dataframe with the country and the year
        temp_df = input_df[['Country', column]].copy()

        # Adding a new column to the dataframe and positionong
        temp_df.insert(0, 'Year', column)

        # Rename for column
        temp_df.rename(columns={column: column_name}, inplace=True)

        # Adding the new dataframe to the array
        df_array.append(temp_df)

    return pd.concat(df_array, ignore_index=True)
```

```
[     Year                          Country Energy CO2 Emissions
 0    1985                           Canada                403.5
 1    1985                           Mexico                233.9
 2    1985                               US               4576.0
 3    1985            Total North America               5213.4
 4    1985                        Argentina                 94.6
 ..    ...                              ...                  ...
 98   1985             Total Asia Pacific               4149.4
 99   1985                    Total World              19219.9
 100  1985                of which: OECD               10920.3
 101  1985                    Non-OECD                  8299.6
 102  1985               European Union#                3790.3

 [103 rows x 3 columns],
      Year                          Country Energy CO2 Emissions
 0    1986                           Canada                393.4
 1    1986                           Mexico                230.4
 2    1986                               US               4598.2
```

Data Merging

```
# Find year and country intersection between the two dataframes
years = find_overlap([merged_dfs, merged_energy_source_df], 'Year')
countries = find_overlap([merged_dfs, merged_energy_source_df], 'Country')

# Filter the dataframes
filtered_df = filter_df(filter_df(merged_dfs, 'Year', years), 'Country', countries)
filtered_energy_source_df = filter_df(filter_df(merged_energy_source_df, 'Year', years), 'Country', countries)

# Merge the dataframes based on year and country
final_df = pd.merge(filtered_df, filtered_energy_source_df, on=['Country', 'Year'], how='outer')

# Write the final dataframe to a csv file
final_df.to_csv(os.path.join(output_folder, 'final_data.csv'), index=False)

final_df
```

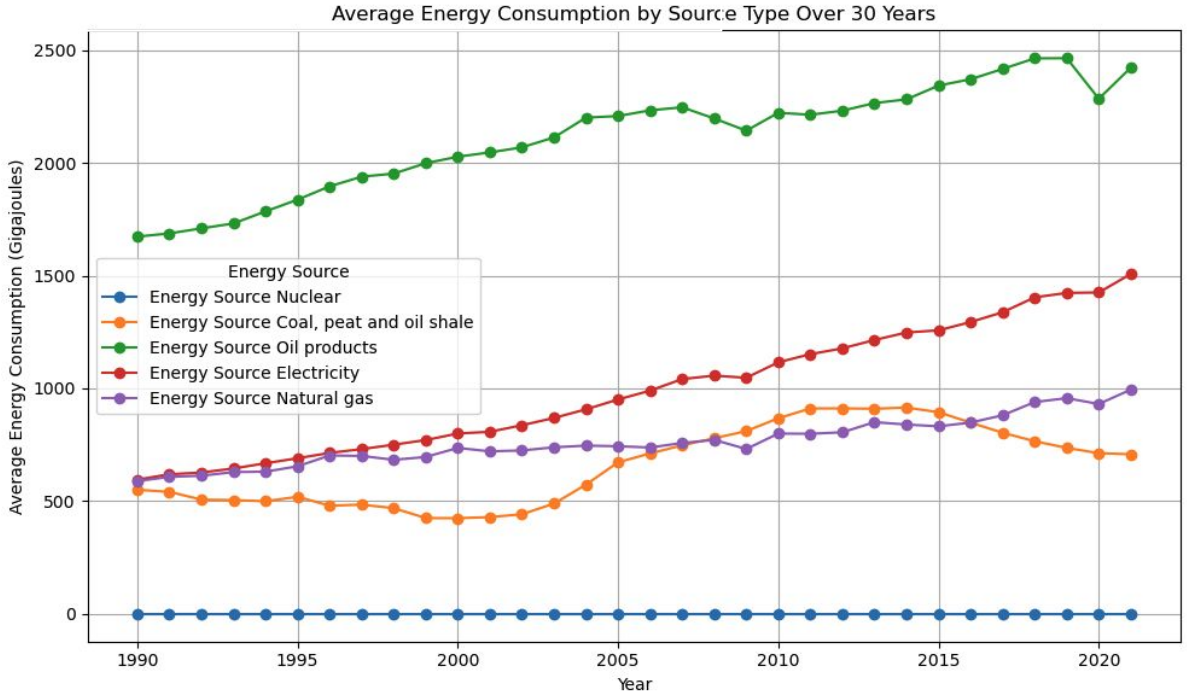
	Year	Country	Primary Energy Consumption	Energy Consumption per Capita	CO2 Emissions	Energy Source Nuclear	Energy Source Coal, peat and oil shale	Energy Source Oil products	Energy Source Electricity	Energy Source Natural gas
0	1990	Canada	10.83	391.6	444.8	0	134	2740	1505	1813
1	1990	Mexico	4.75	58.1	280.8	0	46	2141	361	582
2	1990	US	81.38	328.0	4970.5	0	2329	28608	9481	12689
3	1990	Argentina	1.85	56.6	100.3	0	18	620	146	421
4	1990	Brazil	5.64	37.4	206.4	0	154	2238	759	106
...	...	...	...	...	...	...	...	...	...	...
1499	2021	Indonesia	7.76	28.3	519.6	0	881	2647	1030	689
1500	2021	Japan	17.94	144.0	1066.6	0	843	5510	3355	1182
1501	2021	New Zealand	0.85	165.3	32.5	0	22	270	140	94
1502	2021	Singapore	3.28	551.9	213.3	0	8	519	193	65
1503	2021	Thailand	5.01	69.9	270.3	0	338	2235	686	225

What are the most common energy sources? How has this changed over time?

Historical Energy Use by Type

- Oil products are historically the most common source of energy
- Electricity has seen an exponential increase over the past 30 years

*Nuclear data was lost in data cleaning

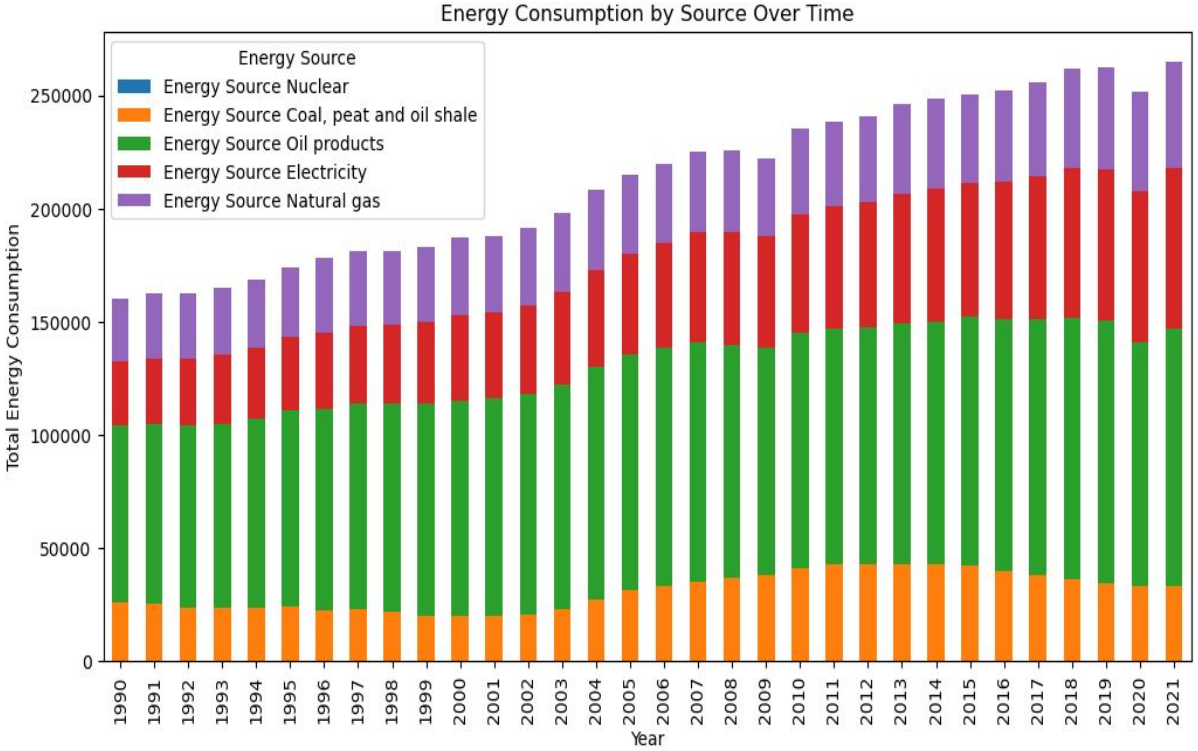


What are the most common energy sources? How has this changed over time?

Historical Energy Use by Type

Energy consumption has seen an exponential increase over the past 30 years with dips during recorded historical economic recessions *(2008 housing crisis and 2020 COVID-19)*

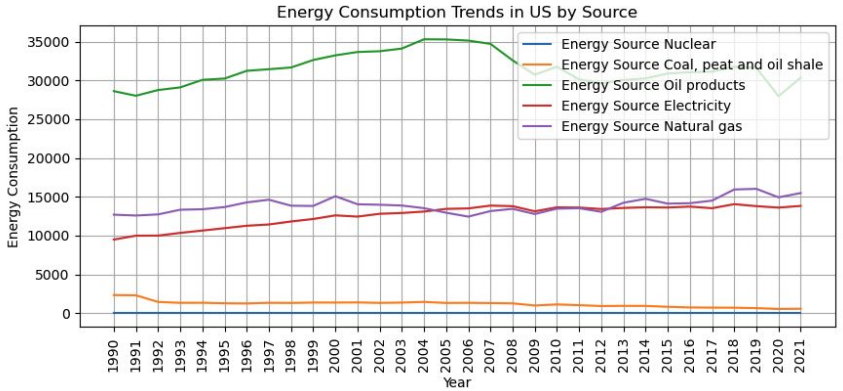
- ➔ Availability and commercialization of each energy source plays a role in its total consumption (not every country has access to specific energy sources, etc.)
- ➔ The oil industry is very large, explaining their dominance in global energy consumption

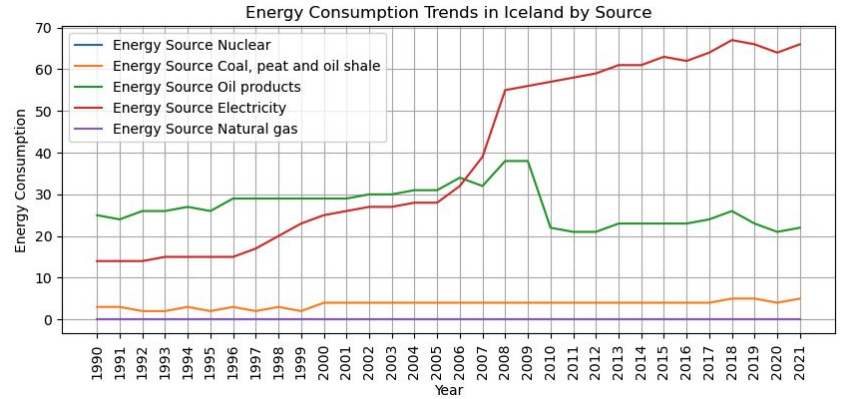


Does an increase in energy consumption impact the distribution of energy sources among specific countries?

Energy Consumption Trends by Country

- Specific country energy consumption follows a very similar pattern to global trends
- Oil products are more commonly consumed and electricity has seen a substantial growth in the recent decade
- Multiple countries have strong positive correlations between their electricity production and various outcomes, indicating a consistent pattern of reliance on electricity as a significant energy source.





Does an increase in energy consumption impact the global carbon footprint (measured by CO2 emissions)?

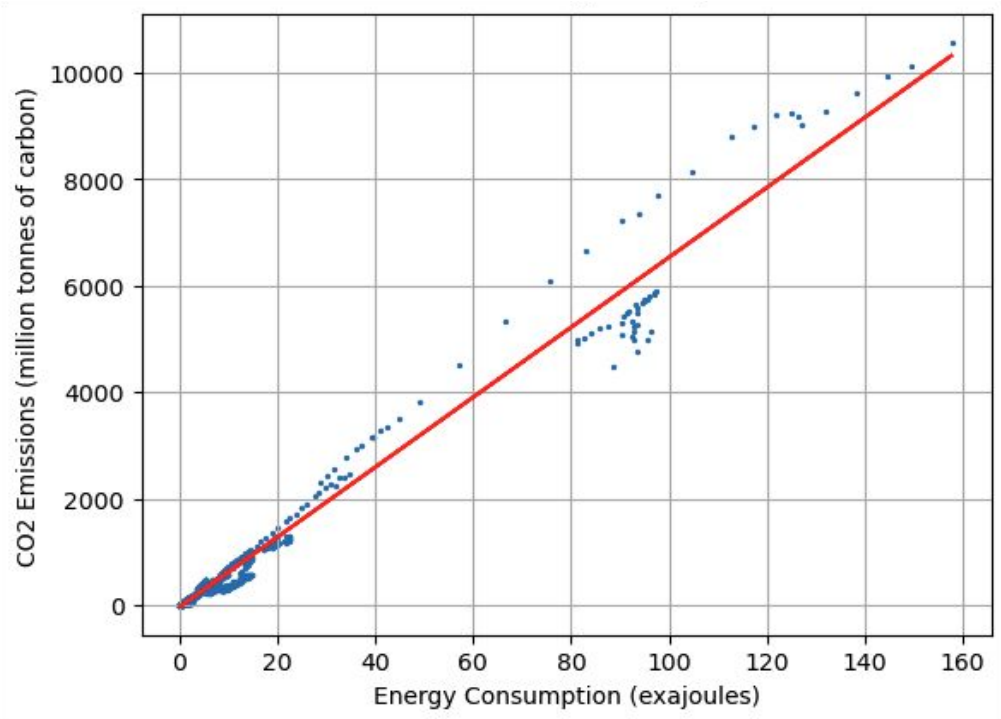
Correlation: CO2 Emissions / Energy Consumption

- **CO2 emissions** and **energy consumption** have a very strong positive correlation

  0.9881976603478702

- There is a strong linear relationship between CO2 emissions and energy consumption

- As energy consumption increases, CO2 emissions tend to increase



Does an increase in population impact the global carbon footprint (measured by CO2 emissions)?

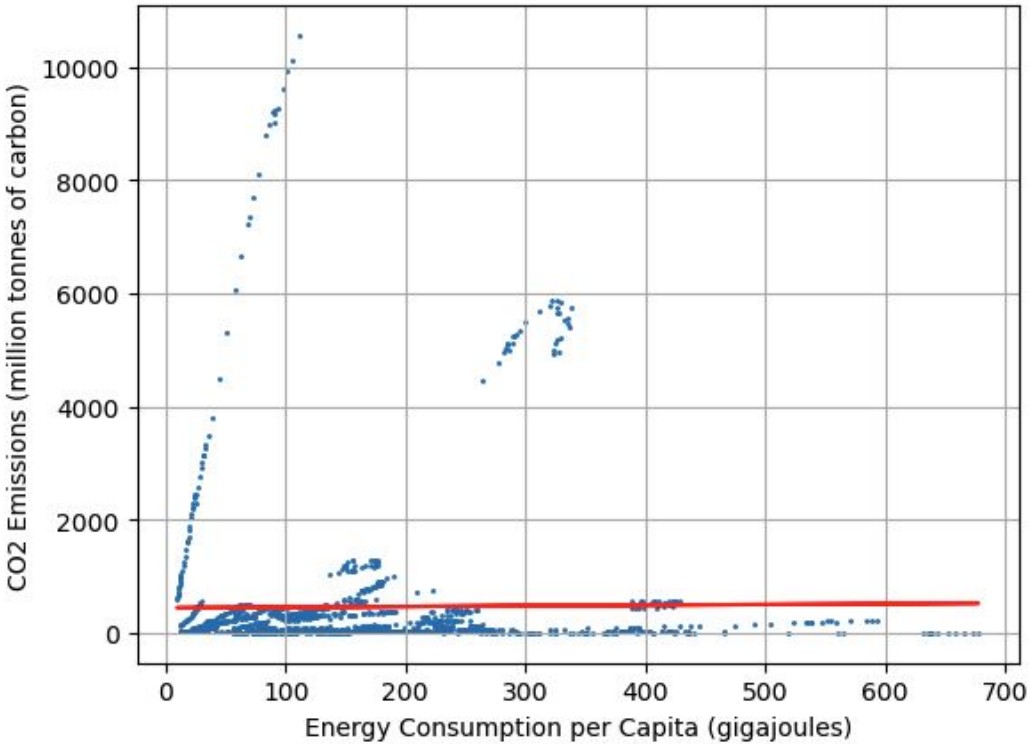
Correlation: CO2 Emissions / Energy Consumption per Capita

- **CO2 emissions** and **energy consumption** have a weak positive correlation

  0.011499329184246069

- As energy consumption per capita increases, there is a slight tendency for CO2 emissions to also increase

- This indicates that there may be other factors influencing CO2 emissions



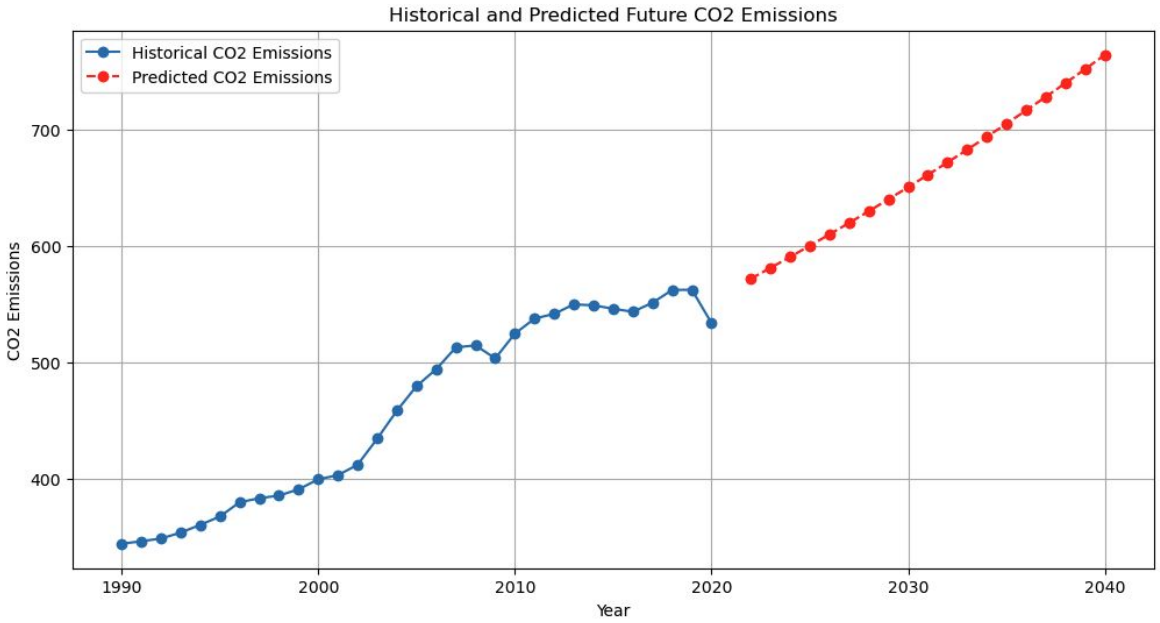
What are the projected carbon footprints of countries?

CO2 Emissions in the Future

➔ **CO2 emissions** experience an annual growth rate of

1.62%

```
Year 2022 | Predicted CO2 Emissions per Year: 571.85
Year 2023 | Predicted CO2 Emissions per Year: 581.14
Year 2024 | Predicted CO2 Emissions per Year: 590.57
Year 2025 | Predicted CO2 Emissions per Year: 600.16
Year 2026 | Predicted CO2 Emissions per Year: 609.90
Year 2027 | Predicted CO2 Emissions per Year: 619.80
Year 2028 | Predicted CO2 Emissions per Year: 629.86
Year 2029 | Predicted CO2 Emissions per Year: 640.08
Year 2030 | Predicted CO2 Emissions per Year: 650.47
Year 2031 | Predicted CO2 Emissions per Year: 661.03
Year 2032 | Predicted CO2 Emissions per Year: 671.76
Year 2033 | Predicted CO2 Emissions per Year: 682.67
Year 2034 | Predicted CO2 Emissions per Year: 693.75
Year 2035 | Predicted CO2 Emissions per Year: 705.01
Year 2036 | Predicted CO2 Emissions per Year: 716.45
Year 2037 | Predicted CO2 Emissions per Year: 728.08
Year 2038 | Predicted CO2 Emissions per Year: 739.90
Year 2039 | Predicted CO2 Emissions per Year: 751.91
Year 2040 | Predicted CO2 Emissions per Year: 764.12
Year 2041 | Predicted CO2 Emissions per Year: 776.52
```



Analysis

Overall Positive Correlation with Energy Sources:

The overall conclusion we can draw from our data shows a positive correlation between consumption and emissions. The higher consumption the consumption, the higher the emissions.

We found that this correlation matched as expected when measuring per capita emission data.

Countries from various regions across the globe, including Europe, Asia, North America, and Oceania, demonstrate this strong positive correlation with electricity usage. This indicates that the benefits of electricity consumption are widespread and not confined to specific geographical areas.

Multiple countries, including Italy, Iceland, United Kingdom, France, Germany, Japan, and others, have strong positive correlations between their electricity production and various outcomes, indicating a consistent pattern of reliance on electricity as a significant energy source.

While some countries have strong positive correlations with other energy sources (e.g., oil products, natural gas), electricity appears to be the predominant energy source with widespread usage across different region

Analysis

CO_2 emissions and energy consumption have a very strong positive correlation. This indicates that there is a strong linear relationship between CO_2 emissions and energy consumption. In practical terms, this means that as energy consumption increases, CO_2 emissions tend to increase as well.

On average, we've seen a 1.62% increase in CO_2 emissions since 1990.

Given years prior, we can expect this growth rate of about 2% year by year in terms of carbon released into our environment. Looking at energy sources with a lower correlation to CO_2 emissions can be a start for countries looking to improve their carbon footprint, as well as modeling after countries with seemingly low CO_2 emissions despite energy consumption (Iceland, Sweden, Switzerland, etc.)

Limitations:

Overall, we observed growth in energy sources such as electricity compared to oil and coal, for instance. Despite oil remaining the most used, our visualizations demonstrate the expanding role of electricity. Our analysis has sparked additional follow-up questions worth further exploration.

While cleaning our dataset, we encountered a challenge with data loss, resulting in zero values for the nuclear energy source. However, despite this setback, our project made significant progress. We were still able to effectively highlight oil as the primary energy source currently.

Further Questions

- ➔ What energy sources emit the most CO2 into our environment?
- ➔ What energy source is the most sustainable (least carbon pollution)?
- ➔ What energy sources are projected to be the most common over the next 20 years given historical data?
- ➔ How has nuclear energy changed over the last 30 years?