Energy Trends and CO2 Emissions Analysis (1980 - 2019): Exploring Global Patterns and Environmental Impact

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Introduction

This project focuses on analyzing energy consumption and CO2 emissions data to gain insights into global energy trends and their environmental impact. This report presents the findings and key insights from the analysis, providing a comprehensive understanding of the energy landscape.

Methodology

The project utilizes SQL queries to extract and manipulate data from a database containing information on energy consumption, energy production, GDP, population, and CO2 emissions. The SQL code provided in the project allows for the calculation of trend analysis, correlation coefficients, regional analysis, and country-level analysis. External data analysis tools, such as Python's matplotlib or Power BI, can be employed for further visualization and interpretation of the data.

Columns and Units

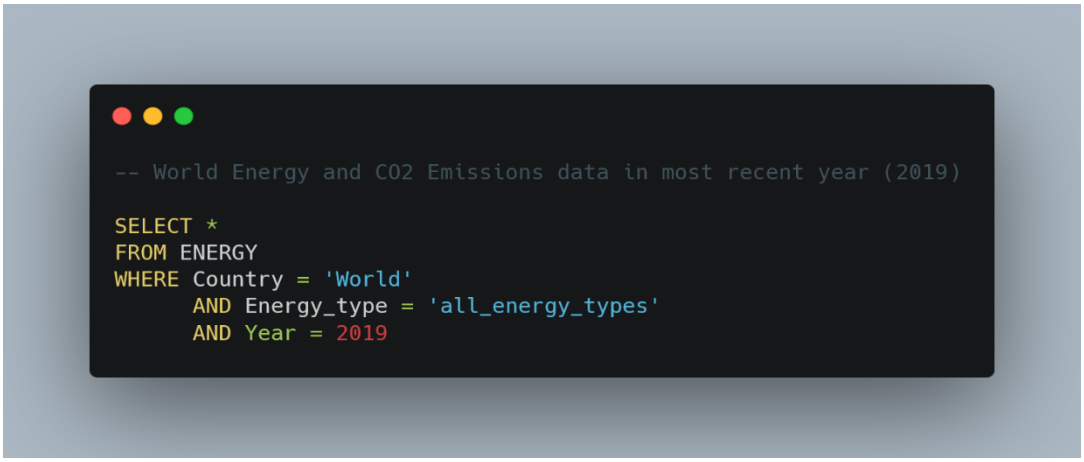
Country, Energy Type, Year (1980 - 2019), Energy Consumption (quad Btu), Energy Production (quad Btu), Gross Domestic Product - GDP (Billion 2015$ PPP), Population (MPerson), Energy_intensity_per_capita (MMBtu/person), Energy_intensity_by_GDP (1000 Btu/2015$ GDP PPP), and CO2 Emissions (MMtonnes CO2).

Analysis and Findings

Trend Analysis

The trend analysis reveals that energy consumption and CO2 emissions have generally increased over the years, while energy production has shown some variations. The year-on-year growth rates indicate the pace of change and highlight periods of significant shifts in energy consumption and emissions.

- **World Energy and CO2 Emissions Data in the most recent year (2019)**

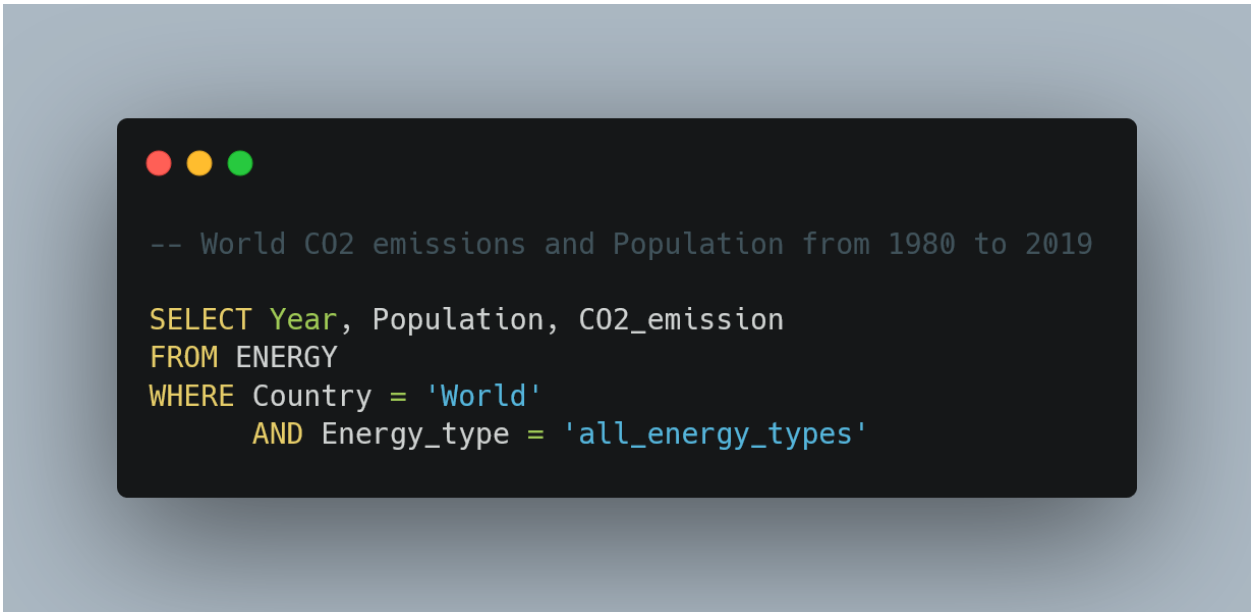


```sql
-- World Energy and CO2 Emissions data in most recent year (2019)

SELECT *
FROM ENERGY
WHERE Country = 'World'
      AND Energy_type = 'all_energy_types'
      AND Year = 2019
```

	S/N	Country	Energy_type	Year	Energy_consumption	Energy_production	GDP	Population	Energy_intensity_per_capita	Energy_intensity_by_GDP	CO2_emission
1	54054	World	all_energy_types	2019	601.040489953885	611.508968647626	127690.247059	7714631.06383	77.9091683038298	4.70701955550427	35584.933497695

- **World CO2 emissions and Population from 1980 to 2019**

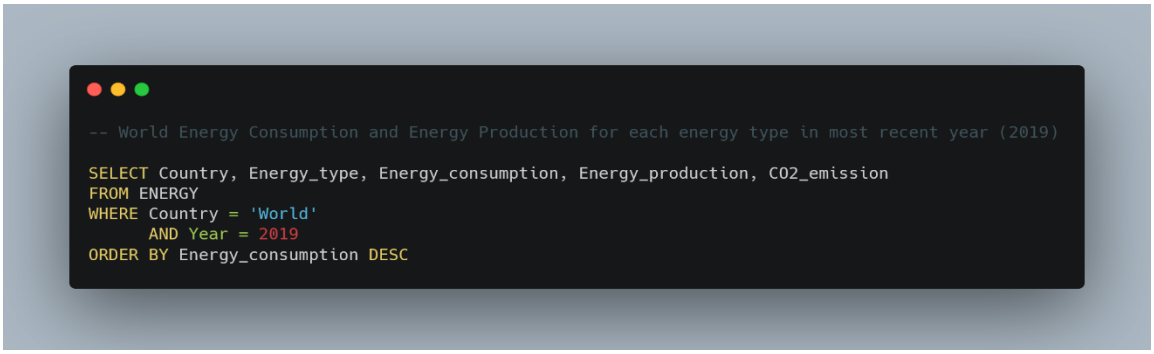


```sql
-- World CO2 emissions and Population from 1980 to 2019

SELECT Year, Population, CO2_emission
FROM ENERGY
WHERE Country = 'World'
      AND Energy_type = 'all_energy_types'
```

	Year	Population	CO2_emission
1	1980	4298126.5224	4946.62713
2	1981	4377059.5593	18701.974390117
3	1982	4456829.97443	18327.413968122
4	1983	4537793.89383	18284.002342435
5	1984	4572800.78237	18478.512213667
6	1985	4657357.404	19602.547366601
7	1986	4745135.92538	20027.312840344
8	1987	4835605.8458	20511.371402668
9	1988	4927545.0842	21163.840556468
10	1989	5056794.37357	21842.542051064
11	1990	5294251.48698	22158.630157995
12	1991	5396473.6766	22144.802907335
13	1992	5481774.19023	21974.86771129
14	1993	5581568.66482	21766.142146958
15	1994	5663996.1634	21891.921080269
16	1995	5745283.94102	22064.884266997
17	1996	5826303.733	22552.701540911
18	1997	5906491.02599	23042.161849148
19	1998	5985040.94597	23112.850596809
20	1999	6063581.745	23152.164345777
21	2000	6141880.59902	23494.916283117
22	2001	6220160.56762	24258.080886456
23	2002	6298597.4702	24463.109021826
24	2003	6377289.06582	25016.047459541
25	2004	6456652.84538	26169.805807764
26	2005	6536810.245	27602.319534239
27	2006	6618223.73697	28689.676654606
28	2007	6700371.898	29632.540125273
29	2008	6783134.44	30083.781880617
30	2009	6865794.1842	30795.450937338
31	2010	6948810.014	30621.827233626
32	2011	7041712.689	32519.305374489
33	2012	7126262.29402	33633.324487296
34	2013	7211822.209	34423.41474807
35	2014	7297269.981	34839.904249264
36	2015	7379227.32003	34894.260052604
37	2016	7464042.84623	34751.60559312
38	2017	7548343.78937	34572.38070396
39	2018	7632247.01155	35002.900777162
40	2019	7714631.06383	35584.933497695

- **World Energy Consumption, Energy Production, and C02 emission for each energy type in the most recent year (2019)**



```sql
-- World Energy Consumption and Energy Production for each energy type in most recent year (2019)

SELECT Country, Energy_type, Energy_consumption, Energy_production, CO2_emission
FROM ENERGY
WHERE Country = 'World'
      AND Year = 2019
ORDER BY Energy_consumption DESC
```

	Country	Energy_type	Energy_consumption	Energy_production	CO2_emission
1	World	all_energy_types	601.040489953885	611.508968647626	35584.933497695
2	World	petroleum_n_other_liquids	196.077357607228	192.134558117039	12203.9225391026
3	World	coal	163.971775859575	171.840424322821	15773.0743407378
4	World	natural_gas	146.92339602648	149.401588457235	7607.936617844
5	World	renewables_n_other	67.7589767390692	70.472506878998	0
6	World	nuclear	27.6598908715322	27.6598908715322	0

Correlation Analysis

The correlation analysis examines the relationships between energy consumption, GDP, population, and CO2 emissions. The findings indicate positive correlations between energy consumption and CO2 emissions, with varying strengths across different countries. This suggests that as energy consumption increases, so do the corresponding CO2 emissions.

- **Correlation Coefficients between energy consumption, GDP, population, and CO2 emissions**

```sql
-- Correlation Coefficients between energy consumption, GDP, population, and CO2 emissions

SELECT
    (SUM(Energy_consumption * CO2_emission) - (SUM(Energy_consumption) * SUM(CO2_emission) / COUNT(*)))
    /(SQRT((SUM(POWER(Energy_consumption, 2)) - POWER(SUM(Energy_consumption), 2) / COUNT(*)) *
    (SUM(POWER(CO2_emission, 2)) - POWER(SUM(CO2_emission), 2) / COUNT(*)))) AS
Consumption_Emission_Correlation,
    (SUM(GDP * CO2_emission) - (SUM(GDP) * SUM(CO2_emission) / COUNT(*))) /
    (SQRT((SUM(POWER(GDP, 2)) - POWER(SUM(GDP), 2) / COUNT(*)) *
    (SUM(POWER(CO2_emission, 2)) - POWER(SUM(CO2_emission), 2) / COUNT(*)))) AS
GDP_Emission_Correlation,
    (SUM(Population * CO2_emission) - (SUM(Population) * SUM(CO2_emission) / COUNT(*))) /
    (SQRT((SUM(POWER(Population, 2)) - POWER(SUM(Population), 2) / COUNT(*)) *
    (SUM(POWER(CO2_emission, 2)) - POWER(SUM(CO2_emission), 2) / COUNT(*)))) AS
Population_Emission_Correlation
FROM ENERGY
WHERE Energy_type = 'all_energy_types';
```

	Consumption_Emission_Correlation	GDP_Emission_Correlation	Population_Emission_Correlation
1	0.995261774733923	0.9732066640072	0.963319847366154

Regional Analysis

The regional analysis allows for a comparison of energy consumption, energy production, and CO2 emissions across different regions. It reveals regional patterns and disparities, with regions having higher GDP tending to exhibit higher energy consumption and CO2 emissions. However, variations in energy intensity levels across regions indicate differing levels of efficiency in energy usage.

Asia, with its robust economy and large population, emerges as a dominant contributor to global CO2 emissions. In 2019, Asia accounted for the highest GDP, Population, and CO2 emissions, releasing a staggering 57.18% of the total global emissions. The Americas ranked second, responsible for 21.44% of CO2 emissions, while Europe closely followed at 16.4%. These regional disparities underscore the significance of addressing emissions reduction strategies, particularly in Asia, to effectively combat climate change on a global scale.

- Regional GDP, Population, Energy consumption, Energy production, and CO2 Emissions, Percentage of Total, ranked by CO2 Emissions in 2019

```sql
-- Regional GDP, Population, CO2 Emissions, and Percentage of Total in most recent year (2019)

SELECT Region,
       SUM(GDP) AS GDP,
       SUM(Population) Population,
       SUM (CO2_emission) AS Regional_CO2_emission,
       ROUND(SUM(CO2_emission) / (SELECT SUM(CO2_emission)
                                  FROM ENERGY
                                  WHERE Year = 2019
                                        AND Energy_type = 'all_energy_types'
                                        AND Country != 'World') * 100, 2) AS Percentage_of_Total
FROM ENERGY
LEFT JOIN CONTINENTS
ON ENERGY.Country = CONTINENTS.Country
WHERE Energy_type = 'all_energy_types'
      AND Year = 2019
      AND Region is NOT NULL
GROUP BY Region
ORDER  BY Regional_CO2_emission DESC
```

	Region	GDP	Population	Regional_CO2_emission	Percentage_of_Total
1	Asia	61093.65288	4603480.366	20346.134976169	57.18
2	Americas	31171.492913	1015472.3605	7630.730396985	21.44
3	Europe	27282.44866	746266.743	5836.047602744	16.4
4	Africa	6668.619427	1307711.03433	1301.879105138	3.66
5	Oceania	1474.033179	41700.56	470.127634372	1.32
6	Antarctica	NULL	NULL	0.013782287	0

Country Analysis

The country-level analysis delves into energy profiles, CO2 emissions, and energy intensity metrics for individual countries. It identifies countries with notable energy intensity or CO2 emissions levels, providing insights into potential areas for improvement and policy interventions. This analysis helps in identifying best practices and lessons learned from countries that have successfully managed their energy consumption and emissions.

- **View a Particular country's energy and CO2 emissions data for most recent year (2019). Nigeria and the United States as examples**

```sql
-- View a Particular country energy and CO2 emissions data for most recent year (2019)

SELECT *
FROM ENERGY
LEFT JOIN CONTINENTS ON ENERGY.Country = CONTINENTS.Country
WHERE ENERGY.Country = 'Nigeria' /*(Edit this to any country)*/
      AND Year = 2019

SELECT *
FROM ENERGY
LEFT JOIN CONTINENTS ON ENERGY.Country = CONTINENTS.Country
WHERE ENERGY.Country = 'United States' /*(Edit this to any country)*/
      AND Year = 2019
```

	S/N	Country	Energy_type	Year	Energy_consumption	Energy_production	GDP	Population	Energy_intensity_per_capita	Energy_intensity_by_GDP	CO2_emission	Country	alpha_2
1	54954	Nigeria	all_energy_types	2019	1.70141462820609	6.02430532719017	1015.889	201050.8	8.46261058501678	1.67480367265133	101.193925365	Nigeria	NG
2	54955	Nigeria	coal	2019	0.00248113938249176	0.00140577613564464	1015.889	201050.8	8.46261058501678	1.67480367265133	0.231429757630855	Nigeria	NG
3	54956	Nigeria	natural_gas	2019	0.6946624279836	1.711803515766	1015.889	201050.8	8.46261058501678	1.67480367265133	36.354922607	Nigeria	NG
4	54957	Nigeria	petroleum_n_other_liquids	2019	0.949338189	4.25616316344853	1015.889	201050.8	8.46261058501678	1.67480367265133	64.607573	Nigeria	NG
5	54958	Nigeria	nuclear	2019	NULL	NULL	1015.889	201050.8	8.46261058501678	1.67480367265133	0	Nigeria	NG
6	54959	Nigeria	renewables_n_other	2019	0.05493287184	0.05493287184	1015.889	201050.8	8.46261058501678	1.67480367265133	0	Nigeria	NG

	S/N	Country	Energy_type	Year	Energy_consumption	Energy_production	GDP	Population	Energy_intensity_per_capita	Energy_intensity_by_GDP	CO2_emission	Country	alpha_2	alpha_3
1	55374	United States	all_energy_types	2019	100.434067942	101.400918072	19925.43	330043.8	304.30527082163	5.04049688975344	5277.192754	United States	US	USA
2	55375	United States	coal	2019	11.315594693	14.255763025	19925.43	330043.8	304.30527082163	5.04049688975344	1262.555409	United States	US	USA
3	55376	United States	natural_gas	2019	32.252006995	35.187183375	19925.43	330043.8	304.30527082163	5.04049688975344	1626.410978	United States	US	USA
4	55377	United States	petroleum_n_o...	2019	38.329385876	31.910981733	19925.43	330043.8	304.30527082163	5.04049688975344	2388.226367	United States	US	USA
5	55378	United States	nuclear	2019	8.451851513	8.451851513	19925.43	330043.8	304.30527082163	5.04049688975344	0	United States	US	USA
6	55379	United States	renewables_n...	2019	11.436136015	11.595138426	19925.43	330043.8	304.30527082163	5.04049688975344	0	United States	US	USA

- **Top 10 Countries by GDP, Population, Energy_consumption, Energy_production, and CO2 Emissions, Percentage of Total, ranked by CO2 Emissions**

The results in the table below reveal the energy profiles and CO2 emissions of several countries. China stands out as the top contributor in terms of GDP and population, accounting for 29.81% of global emissions with a substantial energy consumption of 151.61 quad Btu and CO2 emissions of 10,608.60 million metric tonnes. The United States follows closely, with 14.83% of global emissions, a high energy consumption of 100.43 quad Btu, and CO2 emissions of 5,277.19 million metric tonnes. India showcases a relatively lower energy consumption of 31.78 quad Btu and CO2 emissions of 2,308.33 million metric tonnes, representing 6.49% of global emissions. Other countries like Russia, Japan, Germany, South Korea, Iran, Canada, and Saudi Arabia also contribute significantly. These findings highlight the varying energy dynamics and emphasize the need for global collaboration to transition towards cleaner and more sustainable energy systems, considering each country's unique energy profile.

```sql
-- Top 10 Countries by GDP, Population, CO2 Emissions, and Percentage of Total Ranked by CO2 Emissions

SELECT Top 10 Country,
       GDP,
       Population,
       Energy_consumption,
       Energy_production,
       CO2_emission,
       ROUND (CO2_emission / (SELECT SUM(CO2_emission)
                      FROM ENERGY
                      WHERE Year = 2019
                      AND Energy_type = 'all_energy_types'
                      AND Country != 'World') * 100, 2 ) AS Percentage_of_Total
FROM ENERGY
WHERE Year = 2019
      AND Energy_type = 'all_energy_types'
      AND Country != 'World'
ORDER BY CO2_emission DESC
```

	Country	GDP	Population	Energy_consumption	Energy_production	CO2_emission	Percentage_of_Total
1	China	23128.34	1434512	151.608886044361	123.591359592981	10608.600386434	29.81
2	United States	19925.43	330043.8	100.434067942	101.400918072	5277.192754	14.83
3	India	9310.29	1368140	31.7827394992927	17.785372015287	2308.332020002	6.49
4	Russia	3770.42	145876.3	33.2465332341981	64.2779955622652	1798.242238512	5.05
5	Japan	5359.05	126840.2	18.9836723013104	2.77044094852106	1140.949687525	3.21
6	Germany	4182.05	83111.4	13.5333010710942	4.52892340508467	781.596225481	2.2
7	South Korea	2160.64	51224.18	12.4139984032263	1.65446961080787	702.961082317	1.98
8	Iran	1099.27	82886.6	12.0632983996151	16.0544382934347	642.964293906	1.81
9	Canada	1737.87	37601.23	14.9779051795062	23.5186004308814	613.089866972	1.72
10	Saudi Arabia	1771.04	34218	10.161014745852	27.8611604322172	567.98859898	1.6

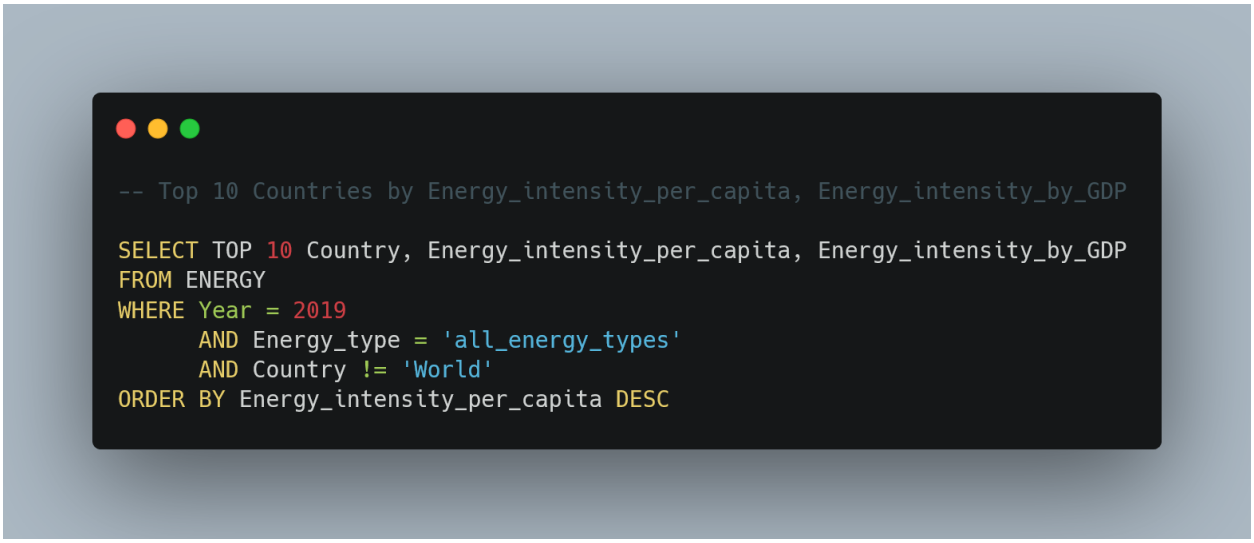
- **Top 10 Countries by Energy_intensity_per_capita, Energy_intensity_by_GDP**

The provided results showcase the energy intensity of various countries, measured in terms of energy consumption per capita (Energy_intensity_per_capita) and energy consumption per unit of GDP (Energy_intensity_by_GDP).

Qatar exhibits the highest energy intensity per capita, with a value of 723.58 MMBtu/person. This indicates a relatively high energy consumption for each individual in the country. Singapore follows closely with an energy intensity per capita of 639.95 MMBtu/person, reflecting significant energy demands.

When considering energy intensity by GDP, Bahrain emerges as the country with the highest value at 11.54 thousand Btu/2015$ GDP PPP. This suggests a relatively high energy consumption in proportion to its GDP. Turkmenistan follows with a notably high energy intensity by GDP of 17.70 thousand Btu/2015$ GDP PPP.

These results highlight the varying energy efficiency levels among countries. Higher energy intensity values indicate higher energy consumption relative to population or GDP, whereas lower values reflect more efficient energy usage. The findings can serve as a basis for identifying countries with opportunities for improving energy efficiency and implementing sustainable practices to reduce energy intensity.



```sql
-- Top 10 Countries by Energy_intensity_per_capita, Energy_intensity_by_GDP

SELECT TOP 10 Country, Energy_intensity_per_capita, Energy_intensity_by_GDP
FROM ENERGY
WHERE Year = 2019
      AND Energy_type = 'all_energy_types'
      AND Country != 'World'
ORDER BY Energy_intensity_per_capita DESC
```

	Country	Energy_intensity_per_capita	Energy_intensity_by_GDP
1	Qatar	723.58188021386	8.2858130066101
2	Singapore	639.950721528686	6.68364072201817
3	Bahrain	547.976452136059	11.5417341387962
4	United Arab Emirates	471.788488357153	6.94560979170376
5	Brunei	415.184373646943	6.7476885538129
6	Canada	398.335511351789	8.61854176636127
7	Kuwait	382.712521712008	8.87911827477863
8	Norway	333.832642899126	5.41035339766828
9	Turkmenistan	330.622567300734	17.7030121510784
10	Luxembourg	310.067797764811	2.91017432747069

Conclusion

The analysis conducted in this project highlights the complex interplay between energy consumption, CO2 emissions, and environmental sustainability. The findings contribute to a better understanding of global energy trends, correlations between different variables, regional disparities, and areas for potential interventions. The project serves as a foundation for further research and exploration in the field of energy and environmental analysis, offering opportunities for predictive modeling and integration of additional data sources.

Future Work

To further enhance this project, potential future work includes deepening the regional and country-level analysis to identify specific factors influencing energy consumption and CO2 emissions. Additionally, conducting predictive modelling to forecast future energy trends and evaluating the effectiveness of mitigation strategies would provide valuable insights. Integration of additional data sources and exploring emerging energy technologies could also enhance the analysis.

By leveraging SQL and data analysis techniques, this project contributes to a better understanding of global energy patterns, their environmental impact, and the potential for sustainable energy practices. The insights gained can inform policy decisions, promote energy efficiency, and contribute to a more sustainable future.

References

Energy and CO2 Emissions: https://www.kaggle.com/datasets/lobosi/c02-emission-by-countrys-grouth-and-population

Country Mapping - ISO, Continent, Region: https://www.kaggle.com/datasets/andradaolteanu/country-mapping-iso-continent-region