

European Electricity Production by Sector and Relation to GDP





Introduction

The shift towards alternative energy sources over the past few decades, be they renewable or nuclear, has been an interesting phenomenon to observe. Because of the importance of energy production in modern economies, I found it to be a topic worth exploring.

The data-set I worked with is the **EU Open Data Portal's 'Energy statistical datasheets for the EU countries' data set**, found at the following: <https://bit.ly/3dHem3U>

To follow along with more detail, **the .ipynb file** used in my exploration of this data-set is available at the following: <https://bit.ly/2Hq0G0R>



Description of Data

This data set was produced by European Union organizations and, as such, contains information pertaining to the European Union as a whole as well as the individual member countries of the European Union. It pertains to the Energy Production, Exports, Imports, and related statistics for European Union countries (such as emissions and economics).

The data is presented in an .xlsx Excel document and is divided into several sheets.

In each sheet are tables describing Energy Balance, Electricity Production, Market Indicators, Heat Production, Transport Fuels, Main Energy Indicators, Emissions, and Population and GDP. Of concern to me are **Electricity Production, Production by Sector, and GDP**.

Energy Statistics for:	Germany	Deutschland																									
	DE																										
Mtoe (unless otherwise specified)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Energy Balance																											
Production 1	167.5	168.8	163.7	152.4	165.4	145.3	143.5	143.7	136.1	137.3	135.6	136.0	136.2	137.0	138.8	138.8	140.6	139.3	134.4	129.3	132.4	126.0	126.8	124.9	124.2	123.7	119.9
Solid Fuels 5	121.8	106.2	97.6	97.8	100.9	78.9	73.9	70.8	64.9	63.2	60.6	58.2	58.4	57.7	58.3	56.5	53.2	54.4	50.1	46.4	45.9	46.7	47.6	45.1	44.1	43.0	39.7
of which Hard Coal	49.3	47.2	46.8	41.4	37.2	38.1	34.3	33.2	29.5	28.6	24.2	19.7	19.9	19.6	19.7	19.0	15.3	15.5	12.4	9.9	9.2	8.6	7.6	5.5	5.5	4.6	2.8
Petroleum and Products 2	6.1	5.0	4.8	4.5	4.3	4.3	4.3	4.2	4.1	4.2	4.1	4.7	5.8	6.5	6.9	6.9	7.2	7.1	7.0	6.5	7.2	7.5	7.2	7.9	8.1	7.8	7.5
of which Crude and NGL	3.7	3.5	3.3	3.1	3.0	3.0	2.9	2.8	3.0	2.8	3.2	3.3	3.5	3.7	3.5	3.5	3.4	3.4	3.0	2.8	2.5	2.6	2.6	2.4	2.4	2.3	2.3
Gases 3	13.9	13.5	13.7	13.8	14.3	15.1	16.3	16.1	15.7	16.7	15.8	16.0	16.0	15.9	14.5	14.5	14.5	14.9	13.2	13.0	11.1	10.9	9.6	8.9	6.9	6.3	6.6
of which Natural Gas	13.5	13.5	13.7	13.8	14.3	15.1	16.3	16.1	15.7	16.7	15.8	16.0	16.0	15.9	14.5	14.3	14.9	14.9	13.2	13.0	11.1	10.9	9.6	8.9	6.9	6.3	6.6
Nuclear	39.4	38.0	41.0	39.6	38.9	39.5	41.3	44.0	41.7	43.8	43.8	44.2	42.5	42.6	43.1	42.1	43.1	38.3	39.3	34.8	26.3	27.9	25.7	25.1	25.1	23.7	21.9
Renewables	5.3	5.1	5.4	5.5	5.8	6.0	6.2	7.1	7.7	8.0	9.6	10.8	12.6	14.6	16.9	20.0	23.3	23.1	24.3	27.7	29.5	32.1	33.7	36.0	38.9	39.5	
Waste, Non-Renewable	1.0	1.0	1.2	1.2	1.3	1.4	1.6	1.7	1.9	1.5	1.7	2.2	2.1	1.2	1.3	1.8	2.2	2.5	3.3	3.8	3.9	3.9	4.0	4.1	4.3	4.3	4.5
Imports 4	188.7	198.1	207.9	210.4	216.6	217.8	232.0	232.6	237.3	228.7	235.2	244.8	238.3	243.5	250.2	259.5	263.5	245.6	252.7	235.2	245.1	237.6	239.1	252.2	244.4	255.7	254.9
Solid Fuels	115	118	123	10.8	12.6	12.3	13.7	15.9	18.0	17.5	22.2	26.3	25.1	25.5	28.3	26.6	33.4	32.6	31.7	28.4	32.6	33.3	33.3	37.4	37.2	37.5	39.6
of which Hard Coal	8.7	9.7	9.8	8.2	9.7	9.5	10.4	12.7	14.0	14.3	17.4	20.8	20.6	21.9	25.3	23.9	30.2	29.4	28.7	24.5	29.3	30.6	30.9	34.9	34.7	35.3	37.9
Petroleum and Products 2	121.8	135.3	147.7	148.0	149.9	146.8	152.3	152.4	156.7	148.0	151.2	143.2	143.2	144.8	147.7	147.0	155.6	140.5	131.0	128.9	123.3	125.6	128.3	127.3	128.1	130.2	
of which Crude and NGL	59.2	58.1	60.4	60.2	60.7	60.4	60.0	60.7	60.1	60.1	60.4	60.3	60.6	60.5	60.3	60.3	60.5	60.3	59.3	58.0	58.0	58.0	58.0	58.0	58.0	58.0	58.0
Gases 3	42.7	44.4	45.5	48.7	51.1	55.3	62.8	61.2	59.3	61.6	61.1	62.4	65.9	70.4	75.8	79.9	78.0	72.6	78.1	73.5	78.8	75.1	74.1	81.9	75.3	85.9	81.6
of which Natural Gas	42.7	44.4	45.5	48.7	51.1	55.3	62.8	61.2	59.3	61.6	61.1	62.4	65.9	70.4	75.8	79.9	78.0	72.6	78.1	73.5	78.8	75.1	74.1	81.9	75.3	85.9	81.6
Renewables	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.4	1.0	0.9	0.8	1.2	1.4	1.2	1.1	1.1	1.0	0.9
Electricity	2.7	2.6	2.4	2.9	3.1	3.4	3.2	3.3	3.3	3.5	3.9	3.9	4.2	4.2	4.1	4.9	4.2	4.0	3.6	3.6	3.7	4.4	4.0	3.4	3.5	3.2	2.4
Heat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Waste, Non-Renewable	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Exports 4	21.9	17.0	20.2	20.8	23.8	22.6	23.7	23.7	23.9	26.8	30.5	29.1	29.8	35.2	41.9	50.0	47.7	48.7	45.2	39.6	42.9	40.3	40.9	47.2	49.5	59.7	51.6
Solid Fuels	8.1	4.7	2.7	1.7	2.7	2.0	1.3	0.5	0.6	0.4	0.5	0.5	0.6	0.5	0.5	0.6	0.6	0.7	1.0	0.8	0.9	0.9	1.1	1.1	1.5	1.3	1.3
of which Hard Coal	3.9	2.5	1.3	0.7	1.5	1.3	0.7	0.4	0.2	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.3	0.2	0.1	0.2	0.2	0.1	0.1	0.2
Petroleum and Products 2	10.2	8.7	12.5	15.0	16.8	15.2	16.0	16.3	16.8	18.6	22.1	19.7	20.1	19.5	25.0												
of which Crude and NGL	0.0	0.0	0.2	0.1	1.1	0.8	1.8	3.6	1.4	1.8	3.2	1.0	1.3	0.6	1.1												
Gases 3	0.9	0.9	1.1	1.3	1.4	2.4	2.8	3.0	3.3	4.3	4.2	5.2	5.9	10.7	12.0												
of which Natural Gas	0.9	0.9	1.1	1.3	1.4	2.4	2.8	3.0	3.3	4.3	4.2	5.2	5.9	10.7	12.0												
Renewables	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0												
Electricity	2.6	2.7	2.9	2.8	2.9	3.0	3.7	3.5	3.3	3.4	3.6	3.6	3.3	4.5	4.4												
Heat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0												
Waste, Non-Renewable	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0												
Net Imports 4	166.9	181.1	187.7	189.6	192.9	195.2	208.3	208.9	213.4	202.9	204.7	215.8	208.5	208.2	211.2												
Solid Fuels	3.4	7.1	9.6	9.1	9.9	10.3	12.4	14.9	17.4	17.4	21.7	25.8	24.5	25.0	27.8												
of which Hard Coal	4.8	7.2	9.5	7.6	8.2	8.2	9.7	12.3	13.8	14.1	17.2	20.7	20.4	21.9	25.2												
Petroleum and Products 2	121.6	126.6	134.1	132.0	132.1	131.6	136.3	136.0	140.0	129.1	125.9	134.4	123.1	123.7	119.9												
of which Crude and NGL	89.2	90.1	100.2	101.1	106.6	101.6	103.2	98.1	103.3	103.3	101.4	105.2	104.7	105.8	109.0												
Gases	41.8	43.4	44.4	47.4	49.6	52.9	60.0	58.2	56.0	57.3	56.9	58.2	60.1	59.7	63.8												
of which Natural Gas	41.8	43.4	44.4	47.4	49.6	52.9	60.0	58.2	56.0	57.3	56.9	58.2	60.1	59.7	63.8												
Renewables	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0												
Electricity	0.1	-0.1	-0.5	0.1	0.2	0.4	-0.5	-0.2	-0.1	0.1	0.3	0.3	0.9	-0.3	-0.2												
Heat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0												
Waste, Non-Renewable	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0												
Gross Inland Consumption	356.3	348.8	342.3	339.4	337.9	341.6	352.9	350.0	348.0	340.5	342.3	352.2	344.5	341.5	343.6												
Solid Fuels	128.5	114.7	104.4	98.2	95.7	91.6	90.7	86.9	84.8	80.7	84.8	86.4	84.1	84.6	85.6												
of which Hard Coal	60.4	55.6	53.6	50.9	49.6	47.3	46.6	44.4	42.0	40.3	43.0	45.3	45.6	47.3	49.0												

EU Commission, DG ENER, Unit A4

ENERGY STATISTICS

Energy datasheets: EU

update: 20-Aug-18

(next update estimate: February 2019)

EU Commission, DG ENER, Unit A4

ENERGY STATISTICS



Energy datasheets: EU28 countries

update: **20-Aug-18** (next update estimate: February 2019)

Data sources and updates as comparing to previous version:

EUROSTAT energy statistics - energy data 1990-2016 ([update May 2018](#))

EUROSTAT RES survey 2015 - final data 2004-2016 (update February 2018)

EEA UNFCCC-GHG inventory 1990-2015 ([update June 2018](#))

ECFIN/AMECO and EUROSTAT macro-economic data 1990-2015 ([update May 2018](#))

EUROSTAT electricity and gas markets survey ([update May 2018](#))

EUROSTAT CHP survey 2016 - ([update August 2018 preliminary results*](#))

* Preliminary results for 2016, i.e. values may be still slightly amended by Eurostat in the verification procedure; data from Estonia in 2016 not yet reported at the time of this publication.



Description of Data

The very first row of the data set is one of the axes, representing the time in years.

In the tables of interest, by year, numbers are given on electricity generation by fuel and by type (Electricity Production); emissions are described in two categories, CO₂ and GHG, by source (Emissions); and Population and GDP provides total population (in thousands) of the particular country, as well as both nominal and real GDP in euros.

In Main Energy Indicators, Energy Intensity, Energy Per Capita, Final Electricity Per Capita, Primary Energy Intensity, Import Dependency, Gross Inland Consumption by Product, Gross Electricity Generation by Type, and Final Energy by Sector over time are described. Of particular interest here are the per capita statistics as well as import dependency.



Research Question

From analysis of this data, I hope to clarify the trends for energy production and, in relation, GDP, over time for European countries, and I hope to ascertain from the data the correlation between particular changes in the energy sector and changes in overall GDP.

Because of the scope of this data and the sheer size of it, comparing every single country will be difficult. Rather than comparing all data between the different countries, my questions can be applied to three selected countries (**Germany, France, and Portugal**), very different countries, to see if any trends hold true between them. **Is there correlation between GDP and different sector production levels, and what does that mean?**



Usage of Python

- The libraries utilized in this project were Pandas, Seaborn, Matplotlib, Chart Studio, and Plotly

Getting the Data into the Project:

- The data was formatted in an Excel spreadsheet and stored as an XLSX file.
- The Pandas `pd.read_excel` function was utilized to import the data for each of the three countries I wanted to look at.
- Dataframe methods such as the `drop` and `rename` methods were used to remove junk or invalid data in order to clean up the resulting dataframes for country GDP and electricity production.

```
import pandas as pd
import seaborn as sns
import matplotlib
import matplotlib.pyplot as plt
from sklearn import preprocessing
```

```
import chart_studio.plotly as py
import plotly.graph_objs as go
import chart_studio
```

```
file="countrydatasheets_august2018.xlsx"
dfGermanElectricityProduction = pd.read_excel(file, 'DE', header=7, index_col = 2)
#by choice, the data that will be focused on will be electricity production, with GDP as a dependent variable
dfGermanElectricityProduction = dfGermanElectricityProduction[170:185]
#the following four lines drop blank/invalid columns and rename the label to accurately reflect the table being shown
mappingRemoval = {dfGermanElectricityProduction.columns[0]:'Remove This'}
dfGermanElectricityProduction=dfGermanElectricityProduction.rename(columns = mappingRemoval)
dfGermanElectricityProduction=dfGermanElectricityProduction.drop(["Unnamed: 1"], axis=1)
dfGermanElectricityProduction=dfGermanElectricityProduction.drop(["Remove This"], axis=1)
dfGermanElectricityProduction=dfGermanElectricityProduction.rename_axis("Electricity Production (Germany)")
#show the table
dfGermanElectricityProduction.head(17)
```

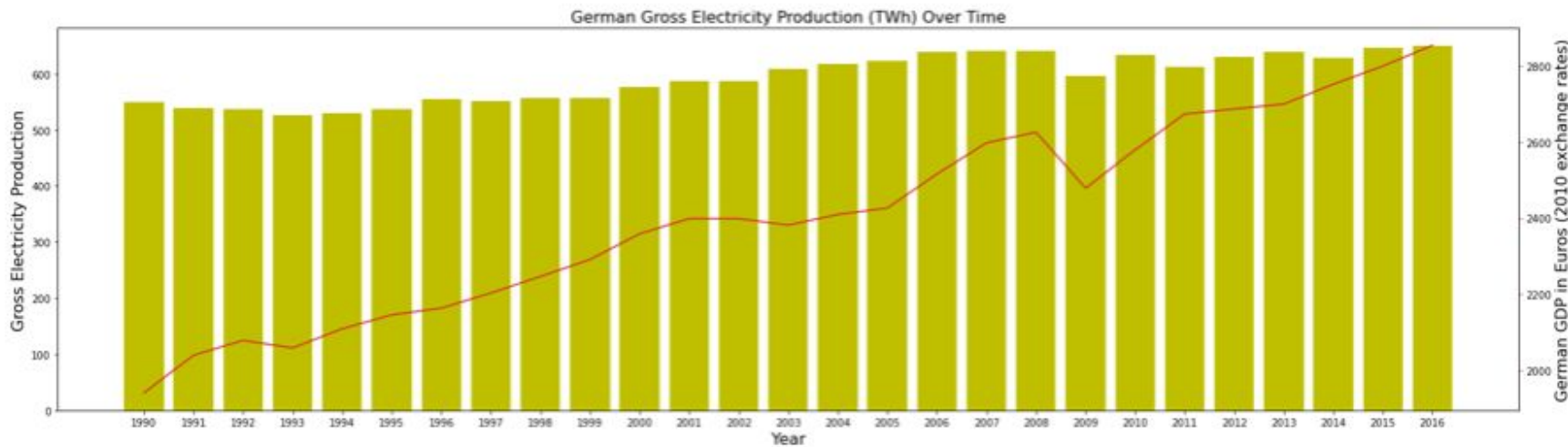
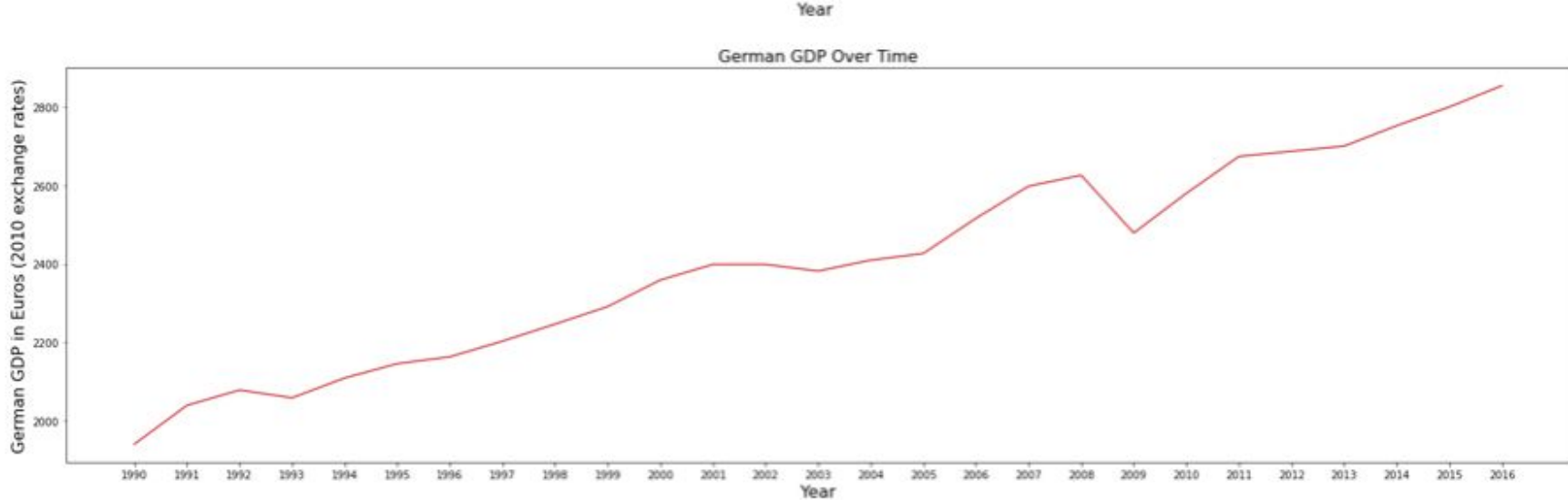
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	...	2007
Electricity Production (Germany)												
Gross Electricity Generation, by Fuel - TWh	5.500150e+02	539.634	5.374700e+02	526.276	5.291600e+02	5.372840e+02	5.553720e+02	5.515540e+02	5.563930e+02	5.563000e+02	...	640.578
Solid Fuels	3.108770e+02	307.673	2.956720e+02	293.243	2.902840e+02	2.891420e+02	2.959920e+02	2.843400e+02	2.922580e+02	2.812700e+02	...	297.106
Petroleum and Products 2	1.039700e+01	14.740	1.321700e+01	10.091	8.774000e+00	8.983000e+00	7.966000e+00	6.866000e+00	6.376000e+00	5.845000e+00	...	10.007
Gases	5.122400e+01	45.354	4.207400e+01	41.126	4.685500e+01	5.040300e+01	5.468900e+01	5.779900e+01	6.051700e+01	6.197000e+01	...	90.779
Nuclear	1.524680e+02	147.229	1.588040e+02	153.276	1.507030e+02	1.530910e+02	1.600160e+02	1.703280e+02	1.616440e+02	1.700040e+02	...	140.534
Renewables	2.145800e+01	20.787	2.353300e+01	24.309	2.738800e+01	3.040200e+01	3.123200e+01	2.660500e+01	2.892000e+01	3.247200e+01	...	95.235
Hydro	1.979100e+01	18.699	2.119500e+01	21.667	2.388500e+01	2.625000e+01	2.663800e+01	2.090000e+01	2.123400e+01	2.340200e+01	...	28.084

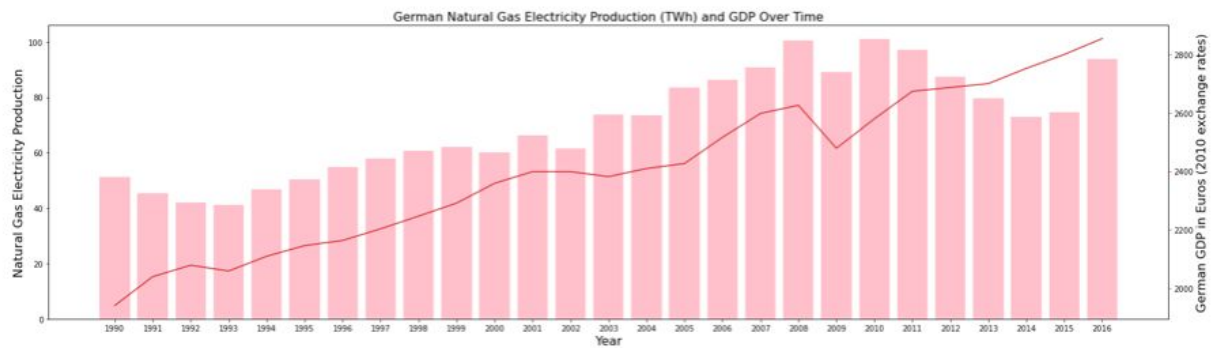
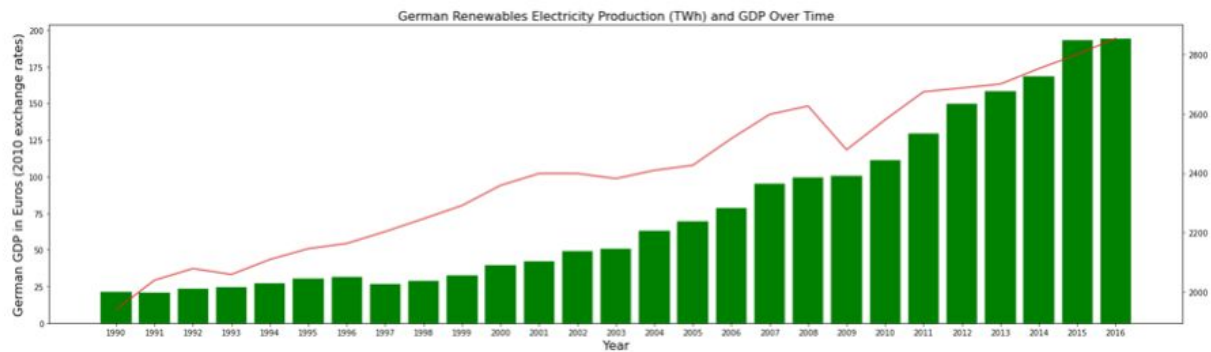
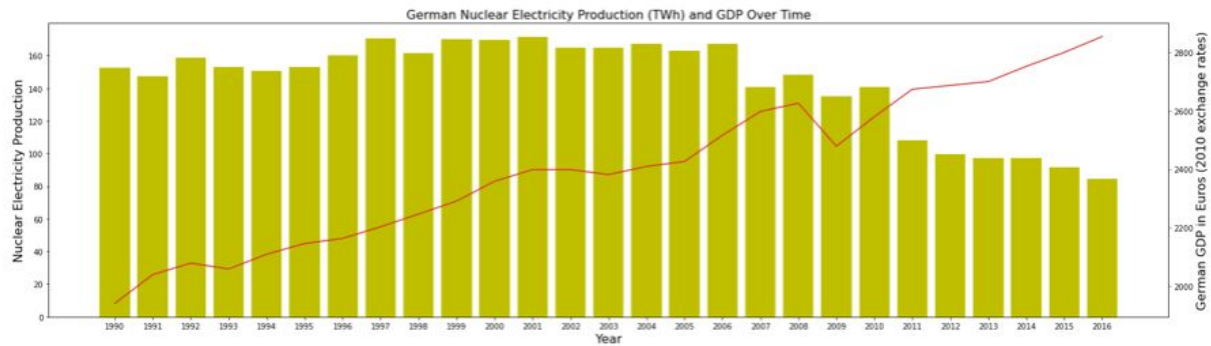


Usage of Python

First Graphs:

- After using Pandas functions to get the data read in and formatted in proper data frames, charts were made for GDP over time, Gross Electricity Production over time, and Electricity Production over time for Nuclear, Renewables, and Natural Gas, for each of the three countries.
- Graphs overlaying GDP over time onto different electricity production graphs were also created.







Usage of Python

- These graphs were created by first creating transposed dataframes for each country's GDP and Electricity Production dataframes in order to read data from columns.
- After converting specific columns to lists, Plotly was utilized to create and format bar charts and line graphs for different types of data.
- Plotly was also used to compare 2011 and 2016 breakdowns of electricity production in each of the three countries to help highlight the changes in such a short span of time. This was achieved with Plotly Pie Charts/Donut Charts and with the help of Chart Studio.

These will be shown later in the presentation



Usage of Python

- The main goal of this project, to look at correlation between GDP and changes in different electricity sectors since the 1990s, was achieved using both Pandas and Seaborn library functions.
- Correlation coefficients were calculated by comparing columns for each type of energy production to the inflation adjusted GDP column; this was done for each country and using the `.astype()` method to cast all values to float.
- Correlation heatmaps were generated using the `.corr()` function on new dataframes of just the relevant information, and then **Seaborn** `.heatmap()` was used to create labeled correlation heatmaps.



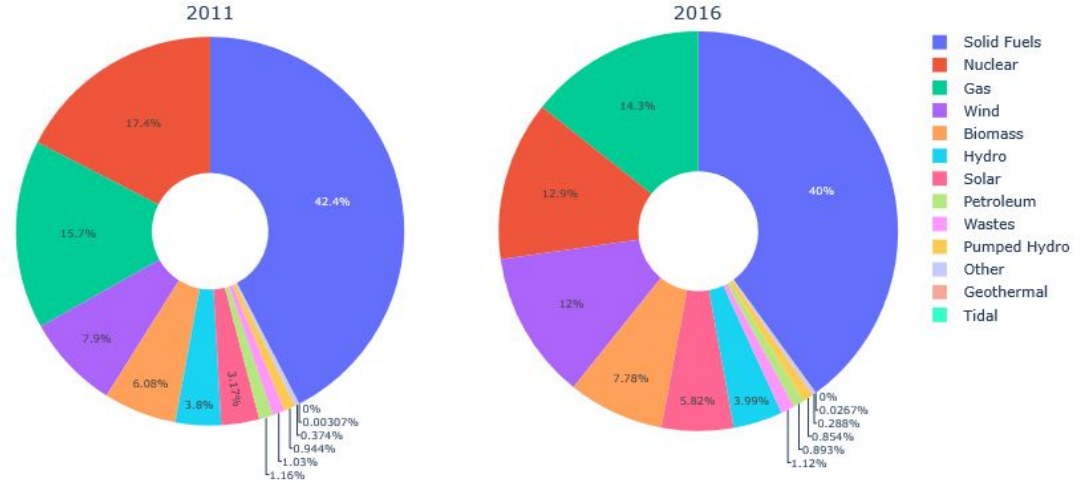
Results

From the donut charts, we can compare the general electricity production landscapes of each of the three countries between 2011 and 2016.

We can then ascertain any observations by looking at the correlation chart and heatmaps for the different countries.



Germany

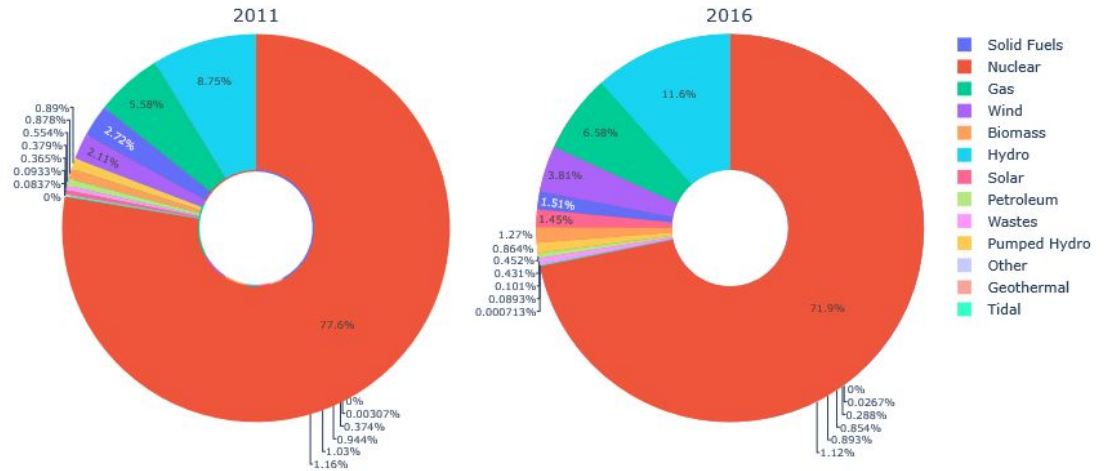


Between 2011 and 2016, we can see for Germany that nearly every type of renewable energy increased its share of electricity production while solid fuels, natural gas, and nuclear all declined in terms of percent share; however, hovering over the charts and looking at the numbers tells us that some of these changes weren't quite so drastic, even though there were real absolute declines. Particularly for natural gas, there was an evident percent decline.

French Electricity Generation Sources: 2011 vs 2016



France



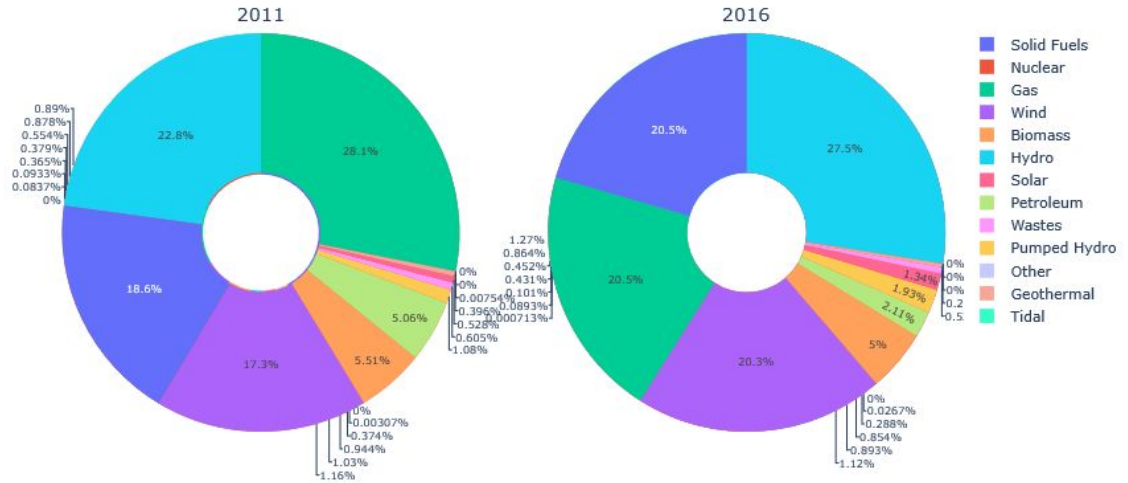
For France, natural gas actually increased alongside renewables, with nuclear energy production taking the biggest hit between 2011 and 2016

Many other changes weren't quite so drastic.



Portugal

Portuguese Electricity Generation Sources: 2011 vs 2016



With regards to Portugal, gas did see a decline, and interestingly enough, solid fuels saw an increase alongside renewables between 2011 and 2016.

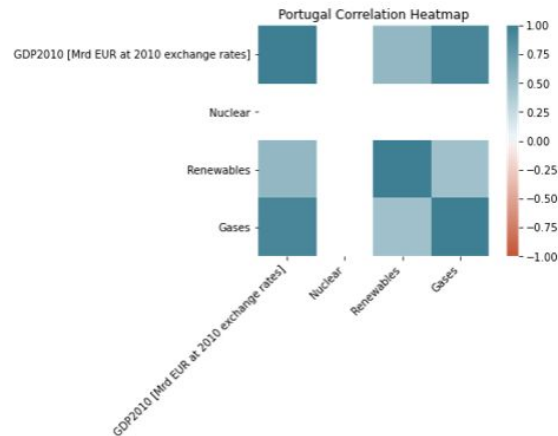
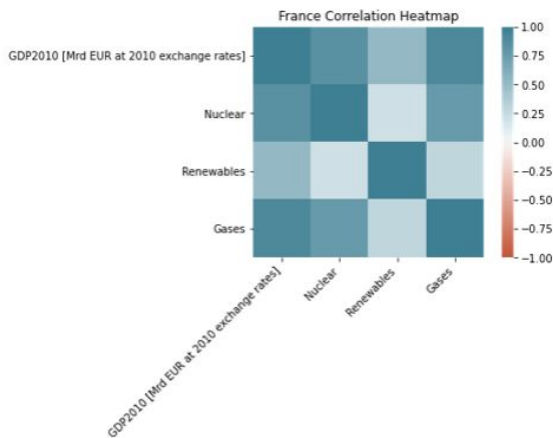
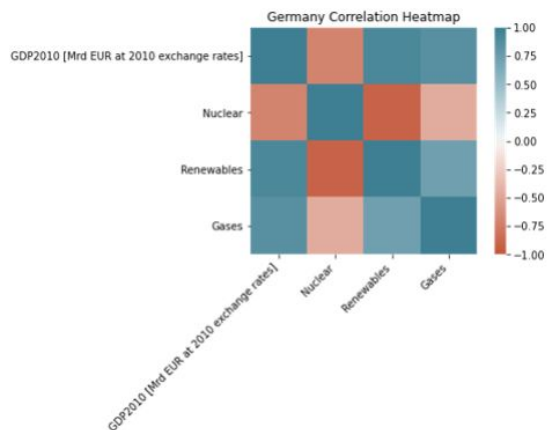
Portugal, of course, produces no electricity through Nuclear Energy.



Correlation

	Germany	France	Portugal
Correlation of GDP and Nuclear Energy Production	-0.706767	0.837219	0.000000
Correlation of GDP and Renewables Energy Production	0.929395	0.520251	0.537466
Correlation of GDP and Natural Gas Energy Production	0.846749	0.906628	0.933592

While the correlation between Renewables production and GDP is strong for Germany, it is not very strong for either France or Portugal.

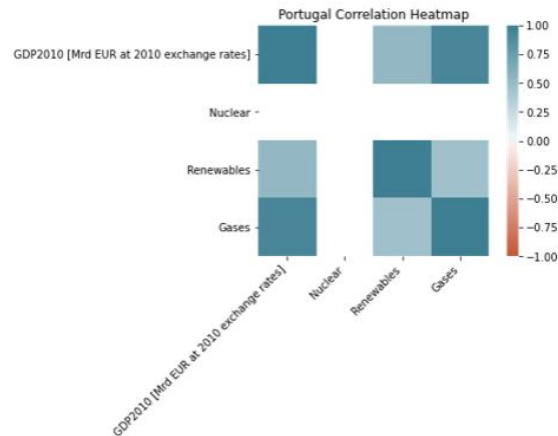
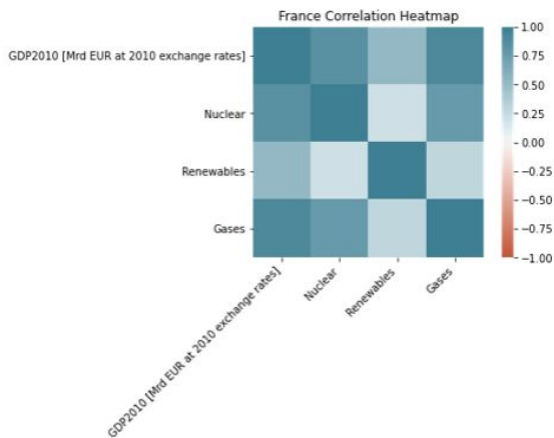
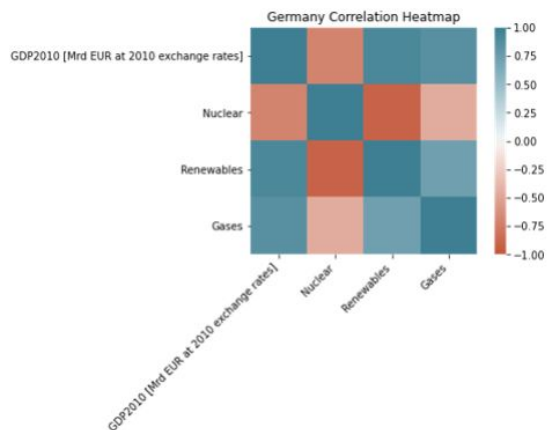




Correlation

	Germany	France	Portugal
Correlation of GDP and Nuclear Energy Production	-0.706767	0.837219	0.000000
Correlation of GDP and Renewables Energy Production	0.929395	0.520251	0.537466
Correlation of GDP and Natural Gas Energy Production	0.846749	0.906628	0.933592

Germany actually has negative correlation between Nuclear Energy and GDP, and Portugal produces no Nuclear Energy. Neither of these would serve as good indicators for GDP.

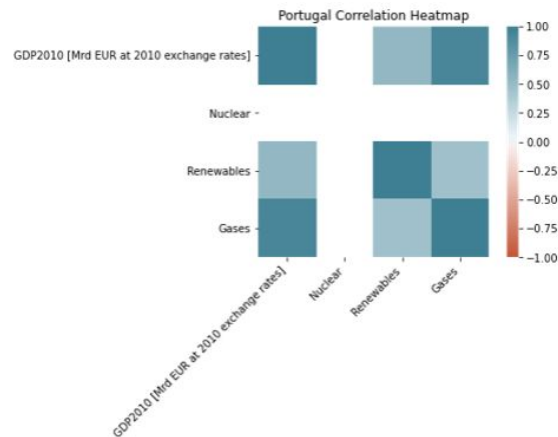
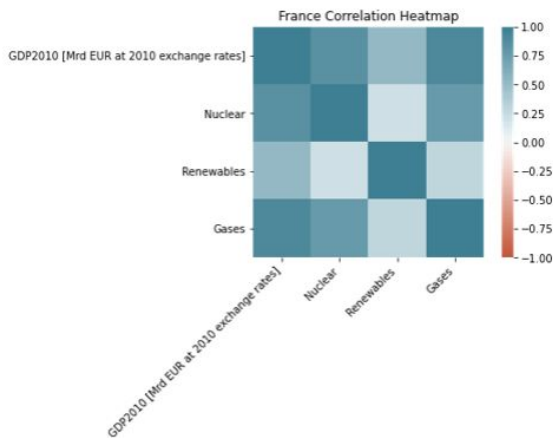
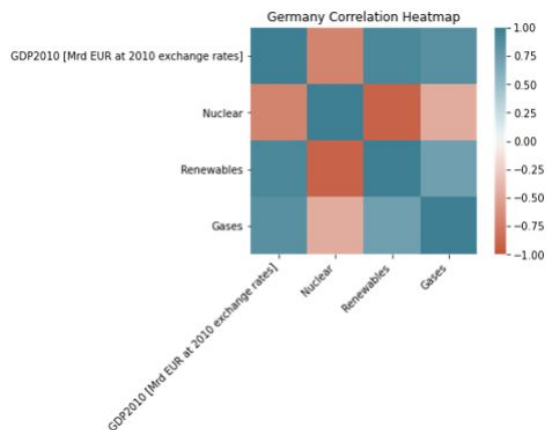




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Between all three countries, the correlation coefficient that is most similar and strongest among them is the correlation coefficient of Natural Gas Energy Production and GDP.





Correlation and Results

Correlation does not mean causation

Changes in GDP over time for each of these countries were not necessarily caused by changes in their energy production focuses, nor were sector changes in energy production changes necessarily caused by changes in GDP.

Why this is interesting

However, seeing such close correlation with between Natural Gas Electricity Production and GDP is interesting, and changes in one over time can be monitored in the future as a potentially useful way to get an indication of what changes may occur to the other.



Correlation and Results

Important to Consider

The fact that natural gas and GDP showed such a close relationship is interesting, as mentioned before. That being said, it is important to consider in ruminations on that interesting relationship the developments in natural gas technology and the role it plays in European geopolitics.

Beyond what is directly shown through this project, however, which is that there is strong correlation between domestic Natural Gas Energy production and national GDP, is not within the scope of what I or the data could authoritatively speak on right now.



Bibliography

- *Energy statistical datasheets for the EU countries* (The European Commission produces information on energy markets in EU countries including energy profiles which contain facts on the energy mix, energy security, competitiveness, sustainability and infrastructure of an EU country.). (n.d.). EU Open Data Portal. Retrieved 2020, from <https://data.europa.eu/euodp/en/data/dataset/information-on-energy-markets-in-eu-countries-with-national-energy-profiles/resource/fbb4045a-0552-4bb1-b88c-b9e3d465718c>.
- Pandas 1.13.3 Documentation