Analysis of Worldwide Clean Energy Development

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Abstract

Rising CO2 emission pose threats to the world's ability to self-regulate, but recent advancements in clean energy hope to reduce the amount of fossil fuel production by providing better alternatives. This paper assess the current state of clean energy while identifying correlations that can influence our next steps in clean energy. Such correlations consist of fossil-generated energy production and GDP with coefficient of correlation (R^2) being 0.9891, fossil fuel production and fossil fuel consumption ($R^2 = 0.9744$), fossil-generated energy production and clean energy production ($R^2 = 0.9998$). Overall a conclusion was reached of trends in development and energy production had shown statistical evidence to be strongly correlated in terms of the sample data that was gathered and analyzed.

Keywords
GDP, Emissions, Clean Energy, Renewable Energy, Fossil Fuels

1 Introduction

Clean energy is essential for the future conservation of the planet; despite the significance of the sea levels rising, forests being destroyed, gas emissions into the atmosphere remain the more prominent and concerning issue. Carbon dioxide emissions in the atmosphere have risen from 320 parts per million (ppm) in the start of the second half of the 20th century to more than 420ppm now [1], indicating a change of more than 30%. Furthermore, the concentration of greenhouse gases (GHG)—a type of gas responsible for the majority of the atmospheric climate change, namely global warming—has risen to over 390ppm (39%) above pre-industrial levels[2][3]. This data depicts the imminence and severity of the energy problems that the world is currently facing.

Understanding the 'who', 'what', and 'how' in gas emissions is crucial in enabling further understanding and development in the energy industry. Renewable energy being explained through the name prescribed to energy obtained from natural sources and is not limited to a finite amount such as the sun and the air. Similarly, nuclear energy, despite being non-renewable, generates considerably less gas emissions in contrast to fossil fuels, which remains as the predominant source of energy in the world [4]. Such knowledge thereby allows further understanding when determining if transitioning the current primary energy production method from traditional fossil fuels—which are nonrenewable—to 'clean energy' can possibly be viable as a next step to creating a better future through reducing harmful emissions to the atmosphere.

Before proceeding into implementation details of clean energy, the authors believe that it is important to support the hypothesis that clean and renewable energy effectively offer a real decrease in CO2 emissions and/or GHG emissions, and how well the usage of them reflects concrete and measurable benefits for our world.

We are interested in finding if clean energy really 'cleans' the environment as it claims. Therefore we first settled to investigate the relationship between non-clean energy and co2 using data for fossil energy. We started by posing several hypotheses, these crucial hypotheses may help us better understand the energy problem. In the first hypothesis, we are interested in the relationship between fossil fuels and CO2. It is commonly believed that when less fossil fuels are being consumed for energy, the CO2 level will go down. Although this statement makes logical and intuitive sense, rigorous data and verification are needed to verify this. We have therefore acquired data from Our World In Data's Energy dataset [5] and compared every country's fossil fuel consumption to their CO2 emission levels year over year to visualize and analyse the relationship between these two variables.

In the second hypothesis, the authors address the fundamental problem of how fossil fuel consumption relates to fossil fuel production. This specific topic is useful for the study of clean energy because in the previous hypothesis,..

In the third hypothesis, the authors address another factor in clean energy: R&D (Research & Development), which can be interpreted as investment into the energy industry. A problem naturally rises: what kind of relationship does the investment in clean energy have with the actual clean energy production and consumption? If the results were to present themselves like "more investment, more production", then it can be confidently said that the investments have 'paid' off. This is useful to the research because the sustainability and development of clean energy largely depend on its profitability and worthiness, knowing it is very useful for countries that are willing to develop it in the future.

Finally, using the current state of clean energy to analyse what works best for countries is very valuable. Therefore the authors have also done research on what types of clean energy are the most beneficial, that is what types of clean energy reduce fossil fuel production the most. Since it's been proven in hypothesis 1 that less fossil fuel production signifies less CO2 emission, this helps understand for countries the priority of types of energy to develop, to reduce the most gains possible.

2 Materials & Methods

In the process of this research and compiling this report, many different technologies were used. Using Python 3.9 as the language of analysis, Git version 2.30.1 as version control, and the software Jupyter 4.8.1 to compute and graph our datasets. These tools are used with Python Libraries Pandas, SciPy, MatPlotLib, NumPy to visualize and analyse our data. We acquired our data from two credible sites, the four datasets we used are owid-energy-data and owid-co2-data from Our World In Data[5], the GHG Emissions from Energy dataset from the International Energy Agency(IEA)[6], and the *Energy Technology R&D Budgets* dataset[7] from the IEA. The first dataset owid-energy-data gives a detailed view of every country in the worlds' energy situation with a wide range of features like change, production quantity, consumption quantity and share for virtually all types of energy. The owid-co2-data dataset allows us to access numbers that describe the CO2 emission for each country. Additionally, the GHG emissions from Energy dataset contains information about each country's Greenhouse Gas (GHG) emissions .The last dataset we utilised was Economic Indicators and R&D(Research and Development), it develops how much investment a country has injected into its energy industry for development. Using Pandas and Numpy, we manipulated these datasets by combining, dividing, and applying mathematical and statistical operations to them so they present meaningful data.

3 Results

3.1 World Feature Data

3.1.1 Clean Production vs Fossil Fuel Production

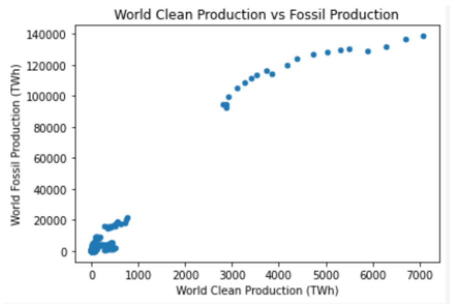

Figure 1: World Clean Production vs Fossil Production

$R^2 = 0.9998$

3.1.2 Fossil Fuel Production vs Fossil Fuel Consumption

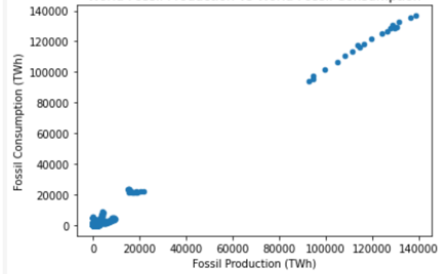

Figure 2: Fossil Fuel Production vs Fossil Fuel Consumption

$R^2 = 0.9744$

3.1.3 Fossil Fuel Production vs GDP

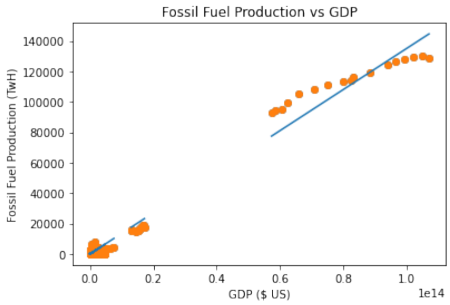

Figure 3: Fossil Fuel Production vs GDP

$R^2 = 0.9891$

3.1.4 R&D Investment vs Electricity Generated

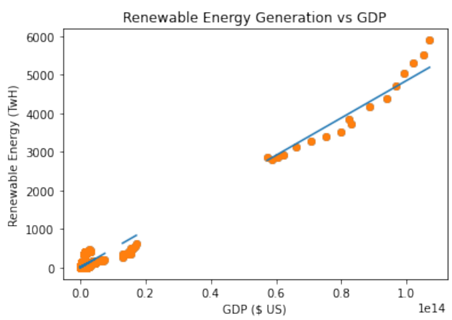

Figure 4: R&D Investment vs Electricity Generated

3.1.5 Change in Fossil Fuel Production vs Solar and Wind Generation

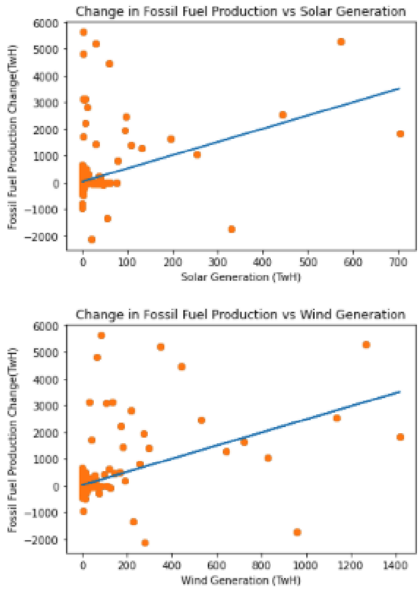

Figure 5: Change in Fossil Fuel Production vs Solar and Wind Generation

$R^2 = 0.3808$

3.1.6 Change in Fossil Fuel Production vs Hydro + Nuclear

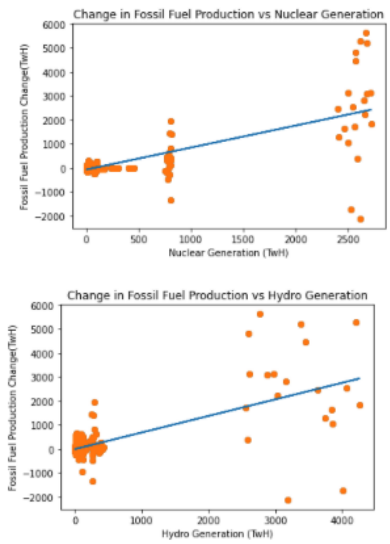

Figure 6: Change in Fossil Fuel Production vs Hydro + Nuclear

$R^2 = 0.7220$

3.1.7 Change in Fossil Fuel Production vs Biofuel

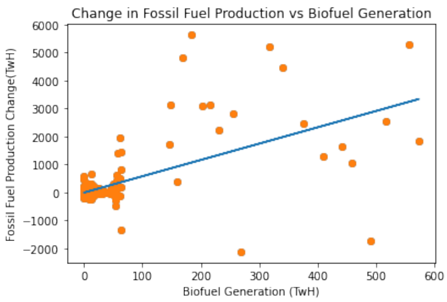

Figure 7: Change in Fossil Fuel Production vs Hydro + Nuclear

$R^2 = 0.6215$

3.2 Country Feature Tables

The following section displays maximum and minimum values, associated with a country, for a variety of selected features from the previously used OWID datasets. Each country's values from 2000 to 2019 were averaged to produce a single comparable value. Minimum tables contain the three lowest averages associated with its country, and maximum tables contain the three largest averages associated with a given country.

3.2.1 CO2 Production

Minimum	Countries
0.6315	Eritrea
1.1839	South Sudan
1.27575	Niger

Maximum	Countries
5685.403	United States
1700.69455	India
1242.46865	Japan

Tables 1-2: CO2 emissions (Million Tonnes)

3.2.2 Percentage of Energy Obtained With Renewables

Minimum	Countries
0.0007	Oman
0.00555	Turkmenistan
0.01015	Kuwait

Maximum	Countries
41.3054	Brazil
66.74215	Norway
75.95555	Iceland

Tables 3-4: Percentage of primary energy produced by renewable energy in an individual country

3.2.3 Renewable Energy Share of electricity

Minimum	Countries
0.00335	Oman
0.01225	Saudi Arabia
0.02135	Turkmenistan

Maximum	Countries
99.97145	Iceland
98.5895	Norway
84.26755	Brazil

Tables 5-6: Percentage of electricity obtained through renewable energy within an individual country

3.2.4 Energy Generation

Minimum	Countries
7.579	Trinidad and Tobago
9.1806	Lithuania
10.47805	Sri Lanka

Maximum	Countries
4032.6279	United States
1027.61285	Japan
865.6599	India

Tables 7-8: Total electricity produced

4 Discussion

Through the data that was collected, there had seemed to be an overall general trend to the distribution of the values, specifically in the datasets regarding GDP, Fossil and Clean energy production. Each graph depicting a very strong linear correlation (shown by R^2) between values alongside a very linear segment in the upper left of the graph and a very large cluster in the bottom left. The data suggests that there may be a correlation between the development or wealth of a country and its overall energy production. It is possible that due to the limited availability in economic spending on energy as a whole or population size, there may be limitations to this idea. Overall throughout the gathered data, there had been many datasets with strong correlation that seems to all lead to the overall development of a country. Furthermore, the data collected from the change in fuel production and the types of clean energy varied a lot and did not seem to have very strong correlation with many outliers, leading to difficulties creating inferences from the data.

4.0.1 Figure 1

The data that was collected from the clean production and fossil fuel production had shown a strongly positively correlated linear relationship. The initial expectation of the result having a negatively correlated relationship was not supported by the data that was obtained. It is interesting to note that since the coefficient of correlation (R^2) between the values had been 0.9998, it can be inferred that the increase in production of clean energy does not seem to have a correlation with decreasing fossil fuel production. Furthermore, there seems to be a cluster of countries that exists with low production of both fossil fuel and clean energy. The data shows that the cluster consists of less developed countries, suggesting that less developed countries generate less overall energy no matter if it is fossil or clean.

4.0.2 Figure 2

The production and consumption of fossil fuels was taken in order to help determine the conservation rate of fossil fuels. The R^2 the set of data was 0.9744 which leads to the belief that there is a very strong correlation between the production and usage of fossil fuels. Moreover the slope of the least squares regression line of the values had been approximately 1. This suggests that in this sample, it can be inferred that for each terawatt of energy generated, there would be approximately a terawatt being consumed leading to no excess fossil fuel energy.

4.0.3 Figure 3

This particular set of data regarding the production of fossil fuels and GDP shown in Figure 3. It had another very strong correlation coefficient of 0.9891. It also has quite similar clusters to the previous sets of data shown in Figure 1 and Figure 2 further indicating the disparity in terms of development of a country and its production of fossil fuel energy.

4.0.4 Figure 4

In contrast to the other graphs, this data presented in Figure 4 seemed to have a greater standard deviation. The overall shape of the data had shown that many were clustered while a few other countries with high investment in terms of percentage of GDP that had generated very few and on the contrary there are many countries that have invested little of their GDP that has generated great amounts of energy as well.

4.0.5 Figure 5

The change in fossil fuel production when compared to solar generation showed a graph with very little correlation. Furthermore, the R^2 value determined from the data had been 0.3808 which indicates that there is little overall relationship between the values that can be drawn from the sample.

4.0.6 Figure 6

In this set of data, there had been great clusters near the left side of the graph while having another large cluster near the right side of the graph. The R^2 value indicates that the correlation of the data is 0.7220 showing the somewhat linear correlation that is represented.

4.0.7 Figure 7

The change in fossil fuel production and biofuel energy generation seems to have a somewhat positively linear correlation with a cluster near the left side of the graph. Furthermore the R^2 had been 0.6215 which indicates the loosely positive correlation.

4.1 Country Feature Tables

Tables 1-8 give specific values context by associating data with a countries that can be further analyzed. Middle Eastern countries are found multiple times in the minimum sections of tables related to renewable energy due to their economic incentives tied to non-renewable energy. Iceland is the opposite, relying heavily on renewable energy and successfully reducing their CO2 emission to $\tilde{3}$ million tonnes. Finally, the three countries which produce the most amount of energy are the same three countries who create the most CO2. This suggest a relationship supported by the few high x and y values found in Figure 1. It appears that countries who produce a high amount of energy, rely on fossil fuels for a portion of production. Further analysis of specific countries and their practices can provide actionable steps for individual countries to achieve adoption of clean energy and reduction in fossil fuel usage.

Conclusions

Throughout our research, we have examined relationships between different variables in the world's clean energy problem and discovered some interesting facts about energy. We have found that a country's power to produce energy is dependent on its GDP and its electricity generated is correlated to its investment in the Research & Development of the industry. We also found some correlation in each type of clean energy with the change in fossil fuel production, this can act as experience for future countries developing in clean energy as to what types of energy are the most efficient. Importantly, the production of CO2 by fossil fuel production continues to grow with little change influenced by the increase in clean energy production. Shifting focus to reducing fossil fuel production rather than obsessing over clean energy development. Overall, the research has been fruitful and successful.

Acknowledgements

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