Transition to a sustainable future: factors influencing investments in renewable energies across Europe

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ABSTRACT

In recent years, raising concerns around the emerging catastrophic impacts of climate change has led countries to re-think their renewable energy policy implementation. This report aims to explore the potential renewable energy production of European countries based on factors such as geographical location and available resources. Further, we address the role of politics as a determinant of investments. The results show that right-wing parties have allocated remarkably smaller capitals towards renewable sources when compared to left-wing and centre parties. We conducted our data cleaning and analysis using Python and collaborated via a Github repository (www.github.com/Batto1300/renewable-energy-analysis).

KEYWORDS

Renewable Energy, Politics

1 INTRODUCTION

Following the 2007 EU summit on international climate change, the European commission drafted a series of proposals to boost the member countries' transition towards a renewable and sustainable future. Precisely, the main set targets are to "reduce greenhouse gas emissions by 20% and increase the proportion of final energy consumption from renewable sources by 20%" [1]. In particular, at the national level, each member state has been appointed to a different target value depending on their 2005 renewable energy capacity and GDP figures. The targets have to be met by 2020. A growing population and the resulting increase in energy demand render this task very challenging, which is why cooperation among EU countries, efficient policy implementation and political support are of utmost importance in order to reduce the dependence on fossil fuels.

Since the summit, there has been significant growth in investments in renewable power sources, especially driven by the technological development of renewable energy systems and the consequent reduction in costs. Nevertheless, a report from the International Renewable Energy Agency (IRENA) states that, as of 2015, the true potential for renewable energy capacity is still far out of reach for many European countries [2].

This report aims to explore the potential renewable energy production of a European country based on their geographical location (meridian), climatic factors (wind power production), available resources (number of dams) and economic advancement (GDP) and its relationship with the actual energy capacity figures. Since we expect countries having higher potential energy return with respect to a particular form of renewable to have invested more - greater capacity - we are able to identify which countries, if any, deviate greatly from such expectation. Consequently, we investigate the policy implementation of countries who are indeed harnessing their full potential and sustain such policies could serve as a model for other countries.

Further, having controlled for the above factors we address the extent to which political factors determine countries' investments. In particular, we consider the historical political orientation of a country, as measured by the percentage of right, centre and left seats (1960 - 2015) and correlate these indexes with energy capacity figures. The aim is to determine whether countries who have experienced a greater polarisation towards a certain band of the political spectrum have persistently allocated more resources towards renewables. Our report focuses on three types of renewable sources: solar, hydro and wind.

The rest of the paper is organised as follows. Section 2 discusses the work of other researchers addressing the role of politics in the deployment of renewable energy sources. Section 3 outlines the data collection and cleaning process. Section 4 presents the main results of the investigation. Section 5 discusses the implications of our findings and the main limitations, while section 6 makes recommendations on future work.

2 RELATED WORK

Annual reports by the European Environment Agency (EEA) [3] divulge the EU member states' progress in the renewable energy sector, for example forecasting whether or not the 2020 targets will be met. However, a mere description of the ongoing trends can not unveil the underlying causes, factors driving the investments, which indeed would aid in devising better policies and might consequently lead to outmatch the targets.

Hence, our work differs from this approach. First we explore whether countries that invest greatly in renewable energy are backed up by more efficient policies. Secondly or otherwise we address whether the national political orientation of a country affects the level of investments. In recent years, natural catastrophes around the world caused by climate change have raised global awareness which has led to significant efforts in an attempt to reduce fossil fuel consumption. However, despite the serious social and economic losses following these disasters, many important political and public figures have denied the phenomenon of climate change. This inevitably influences the public's perception and therefore affects the amount of capital allocated towards renewables. Similar work investigating the role of politics as a driver of renewable energy policies has been carried out by Cadoret et al. in [4]. Their main finding suggests that left-wing parties promote the transition towards a renewable future more than right wing parties. Our research not only differs in how the political profile of a country is measured but also answers whether such promotion has led towards concrete investments.

3 DATASETS

Several datasets were sourced, the reason for each is detailed in its relevant section. As with all data science processes this data require cleaning to suit our purposes. One form of general of cleaning was filtering through by year and by country. Many of these datasets spanned several decades and covered numerous countries in the world. We limited our data to a set of countries and a time frame for which he had complete data. To do this we manually compiled a list of countries and for which the data were complete in the years we wanted to examine.We used this list to filter the datasets to the form we desired.

Hydroelectric, solar and wind capacities.
For the first dataset, we wanted a measure for the renewable energy capacities for the countries in question. From the International Renewable Energy Agency (IRENA), we collected the energy capacities per country for hydroelectric, solar and wind power. This data, gathered by IRENA, comes from questionnaires submitted to the relevant countries and if they cannot acquire the data by this means then from desk research at IRENA. The energy capacities from each three forms of energy are given in megawatts (MW). The reason we seek capacity data it to see what a country is potentially capable of generating given their current resources (http://resourceirena.irena.org/).

GDP per capita for European countries.
Secondly, we sourced the Gross Domestic Product (GDP) per capita as a measure for comparing countries. Through analysis we could determine any relationship between GDP and a country's renewable energy generation. From here we also obtained the GDP data and used this in the analysis. This data was sourced from the National Accounts of the United Nations Statistics Division. They gather this data directly from countries via questionnaire, if this data is not provided then they estimate it using other data available to them. Once the GDP for each country is collected then it is converted into US dollars. This data takes the value of the US dollar in 2010 (https://unstats.un.org/unsd/snaama/dnllist.asp).

Political orientation of European countries.
Thirdly, we sought out a way of quantifying the political alignment of the countries in Europe. With this data our aim was to determine whether or not there was a relationship between parties in power and renewable energy generation. Specifically, we wanted to investigate if left-leaning countries were generating a greater amount of energy from renewable sources. This data was sourced from the Comparative Political Data Set, based at the University of Bern in Switzerland and is funded by the Swiss National Science Foundation. The data is presented in three columns: they are the percentages of seats held by left, centre and right political parties within a country (http://cpds-data.org/).

Latitude and longitude for all European countries.
Fourthly, we wanted the latitude and longitude for the European countries. Our aim with this data was to determine if there is a correlation between solar energy generation and a country's distance from the equator. This data was taken from Google, who have the coordinate data for each country. The data is given in degrees which we converted into distance from the equator in kilometres. As we are seeking a measurement from the equator, only the latitudinal data was required: longitude was not used (https://developers.google.com/public-data/docs/canonical/countries_csv).

Number of dams for all European countries.
Fifthly, for investigating the potential for hydroelectric energy we sourced the quantity of dams for each European country. This was obtained from the International Commission on Large Dams (ICOLD). This gives numerical value

of how much 'large' dams a country has. They define a large damn as either fifteen meters or greater in height. The ICOLD are regarded as the best database for number of dams worldwide. Unlike the other sources for data, the ICOLD do not estimate any data, using only what is available to them (https://www.icold-cigb.org/article/GB/world_register/general_synthesis/number-of-dams-by-country-members).

Wind Power production at European county level.
Similar to the aims for hydroelectric and solar energy, we sourced the actual wind production data in order to compare with the renewable energy capacities. This data was collected from the Strategic Energy Technologies Information System (SETIS), a branch of the European Commission. This data comes in the form of an hourly time series. Unfortunately, they do not detail exactly how the receive this time series data (https://setis.ec.europa.eu/EMHIRES-datasets).

Energy consumption for world countries.
This data was used to make relative comparisons between the countries since they all have differing energy demands. As an example, to explain how Cyprus relies more heavily on solar power yet in numerical terms produces less than Germany, the reason being that Germany is much larger in size and has a a greater population with a greater energy demand. The data was sourced from BP however they do not detail how they obtain it. Unlike with the other energy related datasets, the numerical values represent 'million tons of oil'.(https://www.bp.com/content/.../corporate/.../energy.../bp-stats-review-2018-all-data).

3.1 Manipulation

Since the datasets were obtained from different sources and collected with different methods, we transformed them to a common easy to handle format. We moved unique values of the year column as column headers. This transformation was possible in almost all the datasets because generally, apart from time, and location, only another variable was registered (e.g: GDP only contains years, the GDP for that year and the countries in which the GDP was registered). Politics data is an exception due to the fact that orientation is expressed as the percentage of seats of right, center and left leaning parties. Every original dataset covers different states and different timeframes, we choose to analyze only locations and periods shared among every dataset for consistency; in order to accomplish that, we generated 2 files containing all the common time and location values and used them to filter out all the unwanted rows (countries) using the merge method and columns (years) using the filter function.

4 RESULTS

In the following subsection we present our main descriptive results.

4.1 Descriptive Analysis

As of 2015, the renewable energy capacity for solar, wind and hydro power varies markedly across European countries as illustrated in Figure 1. Interestingly, the distribution exhibits the Pareto principle: top 20% of the European countries hold approximately 80% of the total renewable energy capacity. This is despite the absence of a competitive environment where resources are limited. We can infer that investments in renewable resources are facilitated by previous investments which effectively reduce marginal costs.
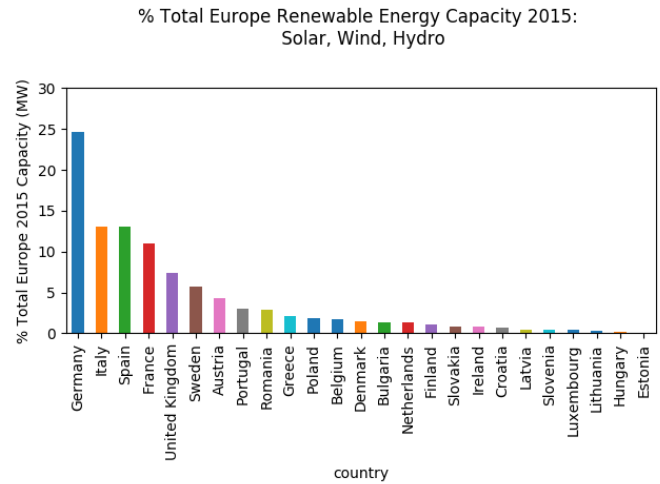
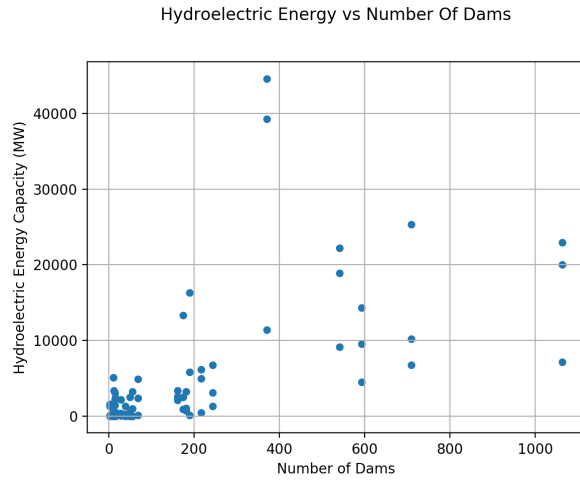Figure 1: 2015 renewable energy capacity (MegaWatt) - sum of Solar, Hydro and Wind.

Across our analysis we consider energy capacity as an indicator of the level of the countries' investments. We investigate the hydroelectric and solar capacity, as a proxy of investments, with respect to number of dams and geographical location (meridian distance) respectively. We find that the number of dams is highly positively correlated with the 2015 hydro capacity levels (see Figure 2). With regards to solar capacity we observe a negative correlation as expected: countries that are closer to the equator invest more. To be statistically sound we divided the energy capacity by the country's total energy consumption summed over the 2000-2015 time period 3.
Further, we correlated the GDP and GDDPC levels with the total capacity over the years, showing that differences among different GDPPC levels tend to alleviate with time. GDP, on the other hand, shows a lack of correlation with low GDP

countries and less variance among high GDP states (accounting for overall energy consumption).

Once having accounted for these controlling factors, we consider the role of political orientation of a country. As previously stated, it's easier to pursue new investments when the infrastructure is already developed. In order to take account of this phenomenon when looking at political government orientation we adjusted the differences in energy capacity over the years by a logarithmic scale. We measured the political orientation of a country (right, centre or left) by looking at the most represented political view in the government. This enabled us to calculate the mean levels of energy capacity for a country based on its political view and compare them globally. We found that right leaning governments are less likely to engage in investments of renewable energy (right = 210.412 MW, left = 302.602 MW, centre = 332.765 MW).
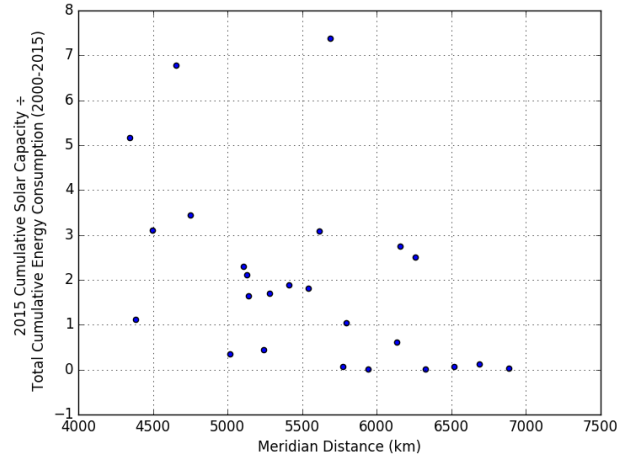
Investigating the relationship between hydroelectric power and number of damns, the descriptive analysis suggests there is a reasonable positive correlation between the two.

Figure 3: Countries closer to the equator invest more in solar renewable sources.

Correlation between wind capacity and wind production

Figure 4: Correlation between wind capacity and wind production

Hydroelectric Energy vs Number Of Dams

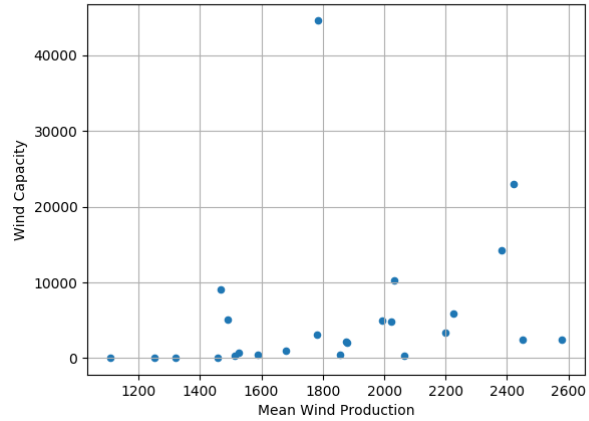Figure 2: 2015 figure for number of damns vs hydroelectric energy

Figure 4 represents the wind production of the countries with relation to their wind capacity. A number of assumptions can be concluded based on this graph. First, the blue dots on the lower right part of the graph represent countries with high wind production compared to their wind capacity, which means that they are utilising their wind capacity efficiently compared to the countries with similar wind capacity but lower wind production.

5 DISCUSSION

This investigation dealt with examining different factors that might influence renewable energy investment among countries in Europe. Based on the data analyses, multiple conclusions can be drawn. Firstly, we find that countries are not investing efficiently, and they are not exploiting the full potential of their landscape. In particular, the data shows that Germany's investments in renewable energy is inefficient. This is supported by the data represented on Figure 4, which indicates that Germany's wind capacity does not align with their annual wind production. The reason behind this might lie in substantial government subsidies, enclosed
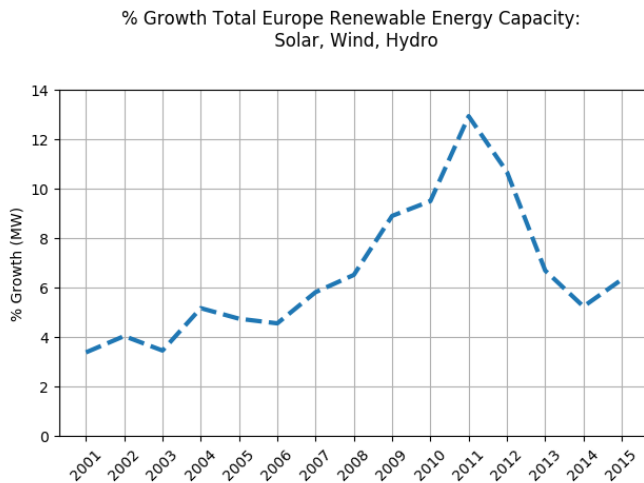
Figure 5: Europe's Growth (% MW) In Renewable Energy Capacity: Solar, Hydro and Wind

under the "Renewable Energy Sources Act". This policy has been extremely beneficial in favouring the country's transition towards a renewable and sustainable future. During only the first half of 2015, the combination of its entire renewable system (solar, hydro, bio-mass ...) generated enough electricity to power every house-hold in the country for a year [5].Secondly, the political orientation of the countries examined shows to be an influencing factor with regards to investments. This could provide a basis for predictive analysis based on the current political landscape. Furthermore, this paper contributes to existing literature by providing empirical evidence to the assumption that left wing parties are more inclined to invest into renewable energy [4]. Finally, our data indicates that renewable energy investment does not correlate with GDP adjusted by overall energy consumption.

6 CONCLUSION

This document dealt with the investigation of factors that might influence renewable energy investments in countries across Europe. We found that there are several factors that influence investments, such as political landscape or meridian distance. However, our study has some limitations. First of all, we used capacity as a direct indicator for investments, which could cause bias in the interpretations of the results. Indeed, it takes time for the investments to take effect. We are aware of the fact that it is also plausible that investments made by one political party in charge could increase the capacity in the coming years. Therefore, further research should use data about actual investments.

Secondly, we used wind production data to investigate the efficiency of wind capacity in EU countries. However wind velocity data could be a better predictor for measuring the potential wind production in a country. Unfortunately, wind velocity data is only available for commercial use, and only accessible for funded studies, hence our choice of wind production data. Further research could use velocity data in order to produce more accurate results.

In conclusion, while there is enough evidence that European countries are on track to meet their 2020 targets, they are not investing as efficiently as they could. We suggest that countries should invest into technologies that are more compatible with the countries' landscape. Lastly, our methodology is independent from the countries examined in this research, thus making it suitable for similar studies outside Europe.

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SELF-DECLARATION

Report

- Team ⟹ Results, Discussion, Conclusion, Final Layout
- Ryan O'Hare ⟹ Abstract, 3.0 - Datasets Description, 4 - Results, 5 - Discussion, 6 - Conclusion
- Tommaso Ricci ⟹ 3.1 - Data Manipulation, Results, Discussion, Conclusion
- Michael Redenti ⟹ Abstract, 1 - Introduction, 2 - Related Work, 4 - Results, 5 - Discussion, 6 - Conclusion
- Sheriff Amoah ⟹ Results, Conclusion, Discussion
- Richard Nagy ⟹ Results, Discussion, Conclusion

BRIEF SUMMARY OF INDIVIDUAL CONTRIBUTIONS

Richard Nagy:

- Actively participated in the formulation and execution of the project.
- Conducted research and obtained a data set on the wind production of countries.
- Cleared the data set by removing the redundant columns and grouping it by the relevant years and countries that are present in every data set.
- Wrote codes for the wind production data set to format it according to the criteria established for this project.
- Performed analyses and coding on the relationship between wind production and wind capacity, including filtering the energy consumption data set, correlation analysis, plotting and descriptive analysis.
- Actively participated in writing up the results, discussion and conclusion sections.

Ryan O'Hare:

The data which I sourced was the data on number of dams. I obtained this from the International Commission on Large Damns. The data was cleaned by filtering out the countries that we did not investigate, resulting in a list of the countries we needed with their number of damns. I then conducted the damn related analysis. I wrote the abstract, the section 3.0 on the full dataset descriptions, and the results section relating to the dams.

Michael Redenti:

- Retrieved the data on renewable energy capacity for the European countries.
- Filtered the countries and years common to all data sets.
- Cleaned the following datasets: latitude and longitude distance, renewable energy capacity, total primary energy consumption.
- Converted the latitude into meridian distance for ease of interpretation.
- Predictive analysis - investigated the growth in renewable (solar, hydro, wind) energy capacity in time (2000 - 2015).
- Structure and layout of the research project.
- Further, my role in the analysis was to investigate the geographical location of a country - meridian distance from the equator
- and its relationship with the investments in solar energy taking into account the energy demand of the country.

Tommaso Ricci:

The data I was responsible for was the GDP and GDPPC data. I also organized the project structure, following the pep8 standards both for the code and the project. In doing so, I also managed to prevent compatibility issues between different machines (we all used different laptops) by programmatically creating paths to access the datasets and by making them accessible throughout the project (look at file_names package). I also created a simple test for the environment settings that can be run with pytest. I cleaned the data I gathered, and explored the relation between GDP and GDPPC with production of renewable energy and also analysed the political dataset applying non trivial operations to find differences in investments of renewable energy between left, centre and right leaning parties. I made myself available to help, and wrote a README.md and requirments.txt to help other team members to get their work done following general coding standards. In order to further ease the sharing of the code, I pushed for the use of GitHub which I personally set up.

Sheriff Amoah:

Took the responsibility to look into the politics (Governments) and it effect on Renewable Energy. I obtained the Dataset on political orientation from Comparative Political Dataset website.
-The Comparative Political Dataset was cleaned to get Countries from EU, years from 2010 - 2016 and these three political orientation namely, 'gov_right1', 'gov_cent1'and 'gov_left1.

Data Manipulation and Representation - Python Scripts

Richard Nagy:
Cleaning:

- wind_production.py

Analysis:

- Wind_Capacity_vs_Wind_Production.py

Michael Redenti:
Cleaning:

- common_countries.py
- common_years.py
- energy_capacity.py
- energy_consumption.py
- meridian_countries.py

Analysis:

- energy_capacity.py
- solar_energy_capacity_vs_meridian.py

Tommaso Ricci:
Cleaning:

- gdp.py
- gdppc.py

Analysis:

- exploratory_analysis_gdppc.py
- political_analysis.py

Other:

- project structure
- file_names package
- test_settings.py
- README.md
- LICENSE
- requirments.txt (created via terminal)

Sheriff Amoah:
Cleaning:

- political_parties.py

Analysis:

- politica_analysis

Ryan O'Hare:
Cleaning:

- dams.py

Analysis:

- damns_analysis