Electricity Production from Renewable Resources in the UK

Group 20

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ABSTRACT

The development of different types of energy, sustainable and friendly to the environment has been remarkably increased over the past decade. The exhaustion of conventional fuels and the growing pollution worldwide have played a key role in that increase. Most countries of the world can benefit from some or all of the renewable sources (wind, solar, biomass and hydro). In our research, we focus in the progress of renewable sources exploitation for covering the electricity production in the United Kingdom as a whole and in each of the UK countries (England, Wales, Scotland, Northern Ireland). By conducting our analysis, we are able to extract some important insights. We determine the two most productive sources in the UK which are wind and solar. We identify the differences in the renewable sources between the UK regions, in England and Wales, the prevailing source is solar, while in Scotland and Northern Ireland, on-shore wind. Further, it is illustrated that the production from renewables has a steady growth. We predict that the UK will meet the 2020 target[1] and there will be a further expansion to 2030. Finally, it is pointed out that the renewable electricity production for covering the demand has been increased over the past 5 years.

KEYWORDS

renewable energy, electricity production

1 INTRODUCTION

Over the past decade, there has been an increasing need for finding different types of energy sources which are environmentally friendly, help to reduce greenhouse gas emissions, lowers each country's dependence on imported fossil fuels and makes energy production more sustainable[1].

These renewable sources unlike conventional, are naturally replenished and include energy produced by wind, solar, biomass and hydro. Each country of the world can benefit from some or all of them, mostly depending on the weather conditions of the territory. The Climate Change Act formulated a legally binding target to reduce the UK's greenhouse gas emissions by at least 80% by 2050[6]. By 2020, the UK has planned to cover from renewable sources 30% of electricity demand, 12% of heating and 10% of transport fuel.

We were interested as data analysts in the advancement of the industry in contributing to power generation using renewable energy. Also by analysing data in the energy field, it helped us understand:

- Renewable energy systems and sources
- Issues and challenges of renewable energy use, including global warming and gas emissions
- Renewable Energy benefits for the countries
- The growth rate of using renewable energy sources in UK countries
- How data analysis can develop renewable energy's plans

The aim of our research is to analyse electricity production and demand data for the UK and understand how each UK country contributes to the 2020 EU target. The goal was achieved by studying the output volume per each generator type (on and off-shore wind, hydro, solar, biomass), learning the growth rate for each country and comparing the production - demand ratio on a quarterly basis. As a result, a set of graphs were produced and used to gain insights and find out where exactly the UK stands with a year left on the clock to meet the target.

For our research, we have conducted three types of data analysis, descriptive, exploratory and predictive and we set out to answer five main questions:

RQ1 - Which renewable source is the UK producing more electricity from?

RQ2 - At what rate the UK has grown in terms of production from renewable sources between 2015 to 2018?

RQ3 - Which of the renewable technologies are growing faster in each UK country?

RQ4 - By following this trend, is the UK going to meet the 2020 target?

RQ5 - How renewable electricity production covers the national demand through the year, month by month?

Our research makes two main contributions:

- Provides insights about the growth of the renewable energy sources in each UK country and the United Kingdom as a whole (Section 4).
- Predicts whether the 2020 target will be met and if there will be further expansion up to 2030 (Section 4.4).

2 RELATED WORK

This section aims to give some introduction of previous similar work and do some comparison between existing analysis and our project.

Fraser of Allander Institute, an independent research unit at the University of Strathclyde conducted an analysis[5] on the Scottish renewable energy generation and found that Scotland covered over 68% of electricity consumption by renewable sources in 2017. They

[1]By 2020, the UK has planned to cover from renewable sources 30% of electricity demand, 12% of heating and 10% of transport fuel. In our analysis, we focused in the electricity demand target.

also compared the electricity consumption and get that Scotland reached the goals for the recent year and the Scottish Government has now a revised target of generating the equivalent of 100% of Scotland's gross annual electricity consumption by 2020. By summarising their article, the analysis was limited to the area of Scotland and mainly on the GDP.

The government also analysed the renewable electricity generation in the UK in 2018[2]. They found that 10.2 per cent of total energy consumption came from renewable sources; a rise of 1% from 2016. Renewable electricity represented 27.9 per cent of total generation; In addition, renewables' share of electricity generation hit a record of 31.7 per cent in Q2|2018, a raise by 1.1% from the share in Q2|2017, reflecting an increased capacity as well as a lower overall electricity generation. The article shows that the capacity of the renewable energy increases year by year and although it does not increase each quarter, had a growth trend annually.

Another study[7] shows that electricity generation in the UK from renewable sources increased by 19 per cent between 2016 and 2017. Further, it illustrates that the demand for renewable energy for electricity become higher and higher each year. Also, bio-energy account for 66% of the renewable fuel use in 2017.

In another research by the government[3], it was found that England has 86% of the offshore wind capacity in the full UK region, and Scotland has 58% of the onshore wind capacity in the full UK region. The report also shows that the growth in overall renewables capacity in the UK has primarily come from onshore wind (40%), offshore wind (35%) and solar (18%). They also summarise that in capacity terms, England had more than two and a half times more renewable electricity capacity than Scotland. This is mainly because of England's considerable bioenergy (88% of the UK's bioenergy capacity) and solar PV capacity (85% of the UK's solar PV capacity). For similar reasons, generation from renewable sources in England during 2017 was two and a half times higher than Scotland, with the higher utilisation rates of bioenergy offset by the lower rates of the more intermittent solar PV which accounted for 16% of English renewable generation.

While the above works do an excellent job in finding and analysing the trends in the renewable energy, they are limited to a specific region or the UK as a whole. In our research we focus more in comparing different regions in the UK and evaluating the changes among different regions and types of generators.

3 EXPERIMENTAL APPARATUS

This section aims to describe the methods and resources being used in the project. All the information treated here are, indeed, a preparation of what has been used later on the analysis.

3.1 Approach

We have tried to answer the questions addressed by using as much of the technologies treated in the course and, at the same time, create a homogeneous environment. The common ground for all the analysis has been the Python environment (on Anaconda) and github as version control system for the code. Within it, we have used Pandas for handling the data as dataframes, Seaborn and Matplotlib for plotting purposes, datetime for managing the date columns and NumPy for simple numerical computation on our data. In addition, scikit-learn has helped in building a regression model and forecast future trends. Also, for plotting a map in python, geopandas and descartes libraries were used.

3.2 Methods

The main question of the research - is the UK going to meet the 2020 goal - has been answered by analysing the time series of the production from renewable resources in the last 20 years. The problem has initially been treated by building a linear regression model. Although it gave a reasonable result, a more specific approach has been used. The best solution for this scenario - time series analysis - has been found in the Autoregressive Integrated Moving Average (ARIMA): a model specific for non-stationary data.

3.3 Datasets

In total, we have selected three datasets from two different UK authorities. The production and demand statistics were obtained from https://www.gov.uk/government/statistics/, the UK government website that releases aggregated statistics under the energy trends section. Both files are in an Excel format and the extracted tables can be found in specific worksheets. The electricity production dataset is published and updated in a quarterly base and the version used for this work was last updated in 25 October 2018. The dataset shows quantities for either renewable electricity generators (on-shore wind, off-shore wind, solar, bio-energy and hydro), and non-renewable. The quantity of electricity is expressed in terawatt per hour (TWh). The observations cover a period of about 20 years that starts in Q1||1998 and finishes in Q2||2018.

The electricity demand dataset contains information such as the amount of electricity used in UK and losses metric per each month and quarter. It gives either total amounts for all the UK and details of each country: England and Wales, Scotland, Northern Ireland. The measurements are reported in TWh and the observations start in 1995 and end in 2018.

The last dataset is the Renewable Generators and was extracted from REF's[2] website https://www.ref.org.uk/generators/index.php. The database describes 15,402 sites with a capacity of 40,018 MW. It contains data for all the renewable generators in the UK and for each reports the technology being used, the UK country, the installed capacity, the accreditation year[3] and the Latest MWh p.a.[4] It is released as a multi-page table in a web page, thus we have decided to facilitate the download by coding a Python script that iterates and append the data into a CSV file.

3.4 Data Preprocessing

This section describes how the data used in the project have been collected and prepared for the analysis. All three datasets have been imported from the original source, processed and converted into a format easy to manipulate in a Python environment.

[2]The Renewable Energy Foundation (REF) is a registered charity promoting sustainable development for the benefit of the public by means of energy conservation and the use of renewable energy.
[3]The date at which the generator was accorded accredited status with Ofgem, the government regulator for gas and electricity markets in Great Britain.
[4]MWh generated in the latest year for which data is available.

The datasets downloaded from Gov.uk were both in Excel format. Due to the structure of the file, it has been decided to extract the tables manually and move them to CSV files with a tabular delimiter.

The electricity production dataset has been saved into Excel with year/quarter as columns, thus, a transpose operation is the first transformation applied right after importing the data in Python. Since the decimal separator in the numerical data is set to 'comma', a specific configuration in the read CSV method of Pandas has been applied. After having observed null values for the off-shore measurements we have decided to filter out data before 2010. Then, the on-shore wind and solar has been computed by subtracting the off-shore component to the total wind and solar electricity generated. Finally, the values of all the non-renewable source have been grouped in a new column named non-renewable.

The consumption data have been initially extracted from the Excel file and moved into a CSV format. Afterwards, the dataset has been imported in Python and wrapped into a Pandas dataframe. We had to set the decimal delimiter to 'comma'. At this point, we have converted the quarter column into a number (1 to 4) and selected only the columns needed for the analysis. Finally, before exporting the dataframe to CSV we have filtered only observations from 2010.

The UK generators dataset has been collected by using a Python script that iteratively loaded the content of the web page, added the partial table to a CSV, and moved to the next page. Unlike the datasets above, this one required to perform an aggregation phase. Before starting the analysis phase, in fact, the observations have been grouped by technology and by country. In this dataset, solar generators were named as "photovoltaic". In order for the information from this dataset to match the others, this term has been replaced with "solar". Also, some rows that were missing the accreditation year have been dropped as they could not be used for our time series analysis. Technologies with an installed capacity less than 1 GWh were merged to "Other".

4 RESULTS

In this section, we describe the results we have collected to answer our five research questions.

4.1 RQ1 - Which renewable source is the UK producing more electricity from?

As seen from the results (Table 1) there is substantial increase in the amount of energy generated from renewable sources each year from 2010 to 2017. For the most recent years, 2016 and 2017, out of the total energy generated by renewables, 55% is produced from wind and solar generators, 35% from bio-energy, 6.5% comes from hydro and 3.5% from pumped storage.

Also, in table 2, we present the latest amount of energy in MWh generated from renewable sources in UK between January and June 2018. Data is obtained from renewable energy generators, it shows that so far Wind is the most productive, but until the end of the year more data will be available and then we can make correct percentage contribution because different renewable energy sources are available at different times in a year.

4.2 RQ2 - At what rate the UK has grown in terms of production from renewable sources between 2015 to 2018?

In order to answer this question, the data for electricity generation were chosen. Some rows related to non-renewable energy sources were dropped from the whole dataset and some latest year data remained to analyse. Figure 1 shows the growth trend for three recent periods; each period contains four quarter data.

In this figure 1, x-axis labels three periods in the past three years and the y-axis ticks the percentage of the growth rate for each renewable resources. It is obvious that the total energy is rising every year though it has a lower growth trend.

Table 3 shows the growth percentage for each type of renewable source. Wind and solar increase at least 10% per year on electricity generation and bio-energy has a high rate in the first period. The electricity generation is growing every year especially between 2015 and 2016, when it was increased by 33%.

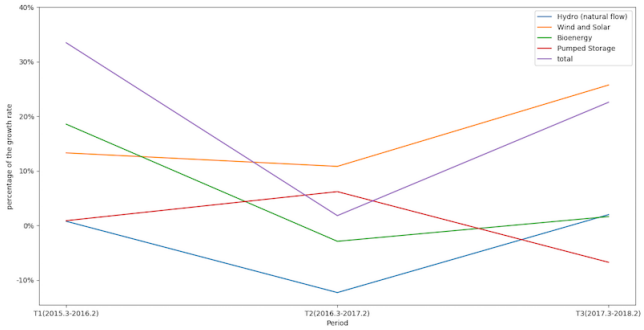

Figure 1: Growth rate per technology between 2015 and 2018

4.3 RQ3 - Which of the renewable technologies are growing faster in each UK country?

In order to answer this question, we first examined the total installed capacity in each country (Fig. 2) until June 2018. It can be seen that England has the highest installed capacity with 25.9 GWh, Scotland follows with a capacity of 10.4 GWh, Wales comes third with 2.75 GWh and Northern Ireland is in the last place with an installed capacity of only 1.41 GWh.

Further, we evaluated the total capacity per renewable source in the UK (Fig. 3) and we found that on-shore wind and solar come first with 21 GWh, followed by off-shore wind with 7.8 GWh. Biomass and hydro also contribute to the total renewable capacity with 4.9 and 2.45 GWh respectively.

By examining the total installed capacity per country (Fig. 4), we can see that there is a difference in the technologies used in each country. In England, the main technologies are solar, off-shore wind and biomass. In Scotland, most of the capacity comes from on-shore wind and hydro. In Wales, capacity is approximately equally divided between solar, on-shore and off-shore wind. In Northern Ireland (NI) which seems to have the lowest installed capacity, the main technology is on-shore wind.

Source	2010	2011	2012	2013	2014	2015	2016	2017
Hydro (natural flow)	5.23	3.6	5.7	5.31	4.7	5.89	6.3	5.62
Wind and Solar	9.3	10.33	16.21	21.2	30.41	36.01	47.81	47.67
Bio-energy	10.71	12.26	13.31	14.73	18.1	22.62	29.26	30.07
Pumped Storage	3.7	3.15	2.9	2.97	2.9	2.88	2.74	2.96
Total	**28.93**	**29.33**	**38.12**	**44.21**	**56.12**	**67.41**	**86.1**	**86.3**

Table 1: Electricity production (in TWh) from renewable sources in the UK

Source	Latest MWh per annum
Advanced Gasification	45,354
Anaerobic Digestion	2,035,124
Biomass co-firing	35,980
Dedicated biomass	16,183,240
Hydro	4,910,667
Landfill Gas	3,680,164
Off-shore wind	23,696,339
On-shore wind	29,270,697
Solar	7,123,112
Sewage Gas	884,614
Standard Gasification	74,350
Tidal Stream	9,227
Unknown Biomass	990
Waste	2,296,280

Table 2: Latest production in MWh per technology until June 2018

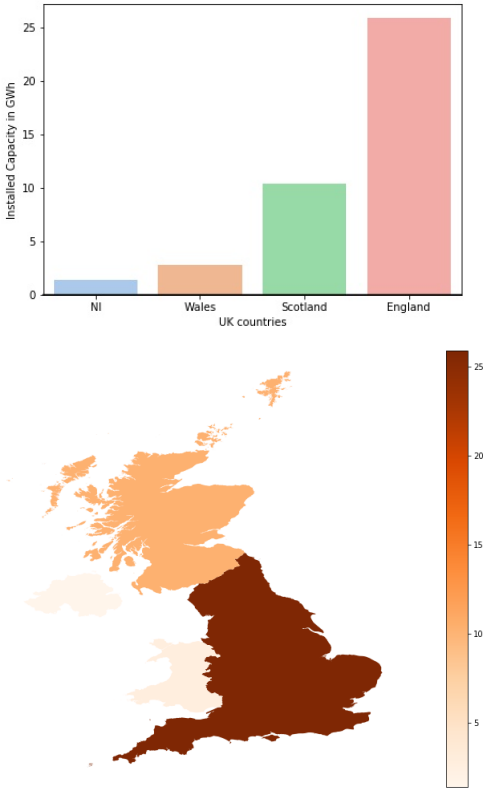

Figure 2: Total installed capacity (in GWh) in each UK country

Source	T1 (2015.3-2016.2)	T2 (2016.3-2017.2)	T3 (2017.3-2018.2)
Hydro (natural flow)	0.76	-12.31	1.98
Wind and solar	13.29	10.82	25.73
Bioenergy	18.56	-2.91	1.62
Pumped Storage	0.87	6.19	-6.76
Total	**33.48**	**1.79**	**22.57**

Table 3: Growth percentage per renewable source between 2015-2018

4.4 RQ4 - By following this trend, is the UK going to meet the 2020 target?

Through this section, a forecast for the amount of renewable energies for the years 2020 and 2030, has been calculated. The data use the 'Fuel used in electricity generation and electricity supplied' provided by gov.uk, The Annual sheet was used. To do so, the amount of energy that is produced between 1998 to end of 2017, has been reviewed and considered. Preliminary, the total amount of energy produced from renewable resources is calculated and subsequently, the percentage ratio of renewable energy from all applicable resources such as renewable and non-renewable is calculated (Table 4). Finally, by utilising Linear regression and Time series methods with confidence level of 95%,the obtained results indicate that the

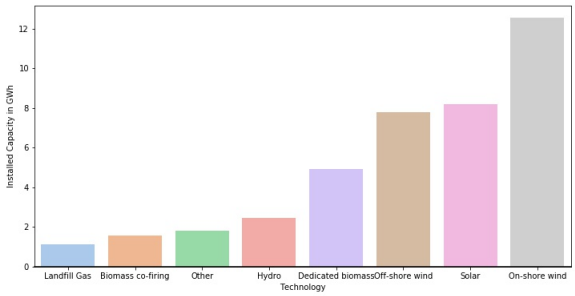

Figure 3: Installed Capacity per technology in the UK

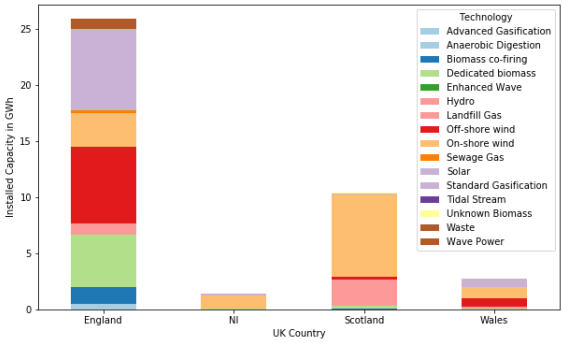

Figure 4: Installed Capacity per technology and country

renewable energy will cover 32% in 2020 and 38.99% of the whole production in 2030 (Fig. 5).

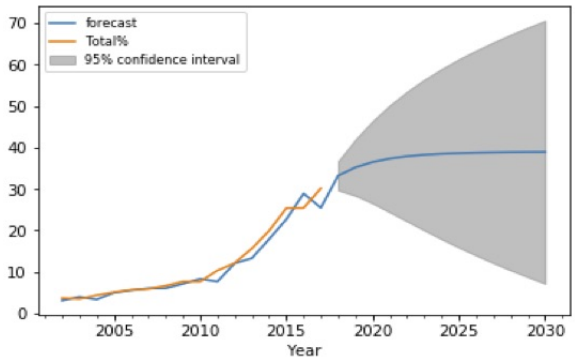

Figure 5: Renewable energy percentage of the total electricity production per year

4.5 RQ5 - How renewable electricity production covers the national demand through the year, month by month?

By analysing the consumption data, a correlation between the demand for electricity and the month of the year (Fig. 6) has been found. Winter months have higher values (peak above 32 TWh) - probably because of the cold and the few hours of light - and Q2 and Q3 show a decrease. March appears as the only month not following the general trend. It is also observed that the demand has slightly declined in the last 8 years (Fig. 6).

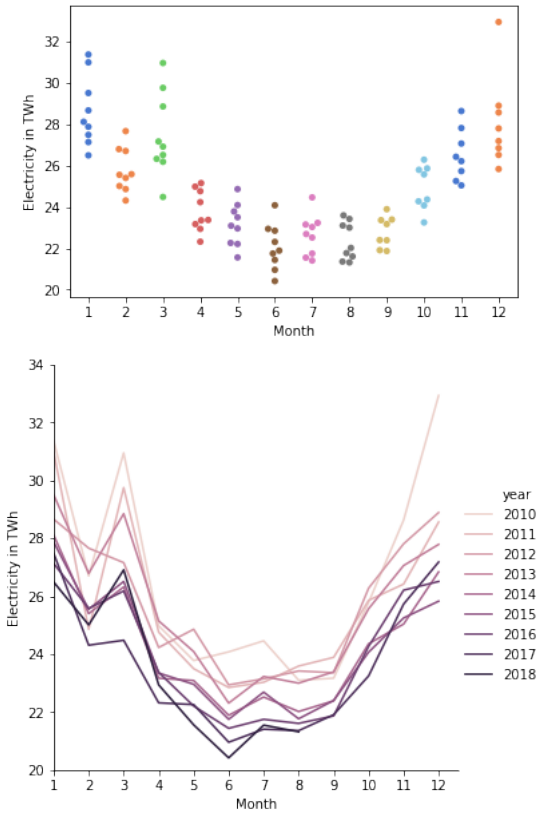

Figure 6: Demand of Electricity

The electricity production data follow the same trend of the demand, high in Q1 and Q4 and low in Q2 and Q3 (Fig. 7). Moreover, as expected, is observed that the production of electricity has increased over all the quarters in the last 5 years. An in-depth analysis of the different types of renewable sources tells us which is the most affected from the change of season. While the generation of bio-energy seems not influenced from the period, on the other hand, off-shore wind, solar and hydro present a big decrease. On-shore wind and solar, probably due to a combined variable, only lightly drop in Q3.

The production and demand data have been compared by taking into account measurements from 2017. While for consumption has been possible to analyse the values month by month, the production data available were split by quarter, hence, the value for a month

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
%	3.46	3.25	3.70	3.50	4.41	5.13	5.69	5.93	6.67	7.68	7.68	10.36	12.15	15.66	19.94	25.41	25.44	30.18

Table 4: Percentage of electricity production from renewable sources out of the total between 2000-2017

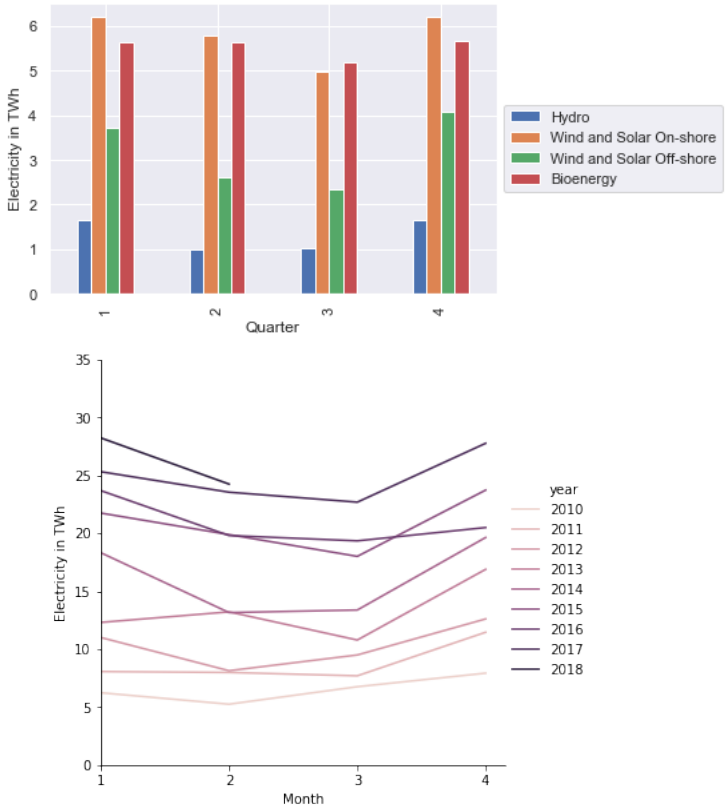

Figure 7: Production of electricity

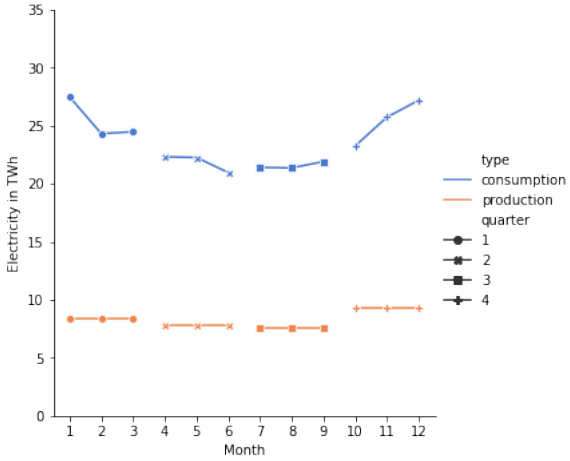

Figure 8: Production and demand comparison

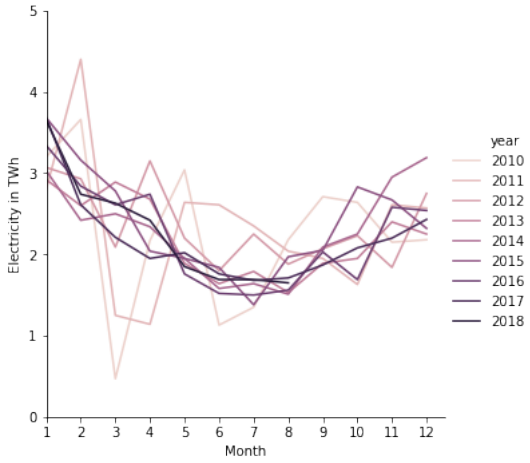

Figure 9: Energy Loss

has been obtained by dividing the quarter by 3. Here, we observed that for each month the consumption is covered for at least 30% by renewable sources (Fig. 8). October is the month where renewable energy production performs better with almost 40% of demand coverage. The worst performance, on the other hand, is observed in January with just 30%.

A final look at the losses metrics (Fig. 9) - the difference between what is produced and what is used - has shown that there has not been a considerable reduction of the leak of electricity during its transportation. The data shows that this is generally correlated to the amount of electricity used, meaning that the more is transferred the more is lost.

5 DISCUSSION

Being fully renewable dependant means having the ability to rely on nonpolluting sources, at any moment. The comparison of the production and demand data is necessary for the understanding of how the UK generation of electricity can cover the consumption in all the year, not just in certain days or weeks. Even though we are not able to build an hour-by-hour analysis- because of the shortage of information- we attempted to provide a yearly view and cover all the seasons.

From the results we see a continuous growth in the amount of total energy generated from renewable sources, it can be seen that for the year 2017 the total amount generated is nearly three times of what was generated in 2010. It is evident that wind and solar generators produce more energy in the UK and this is supported by the fact that UK has more installed capacity generators for solar and wind. In 2018 so far, Wind is the most generated energy, Solar

energy is mostly generated from April-September since these are the months with most sunshine hours as per UK average weather data. That is why as of latest data the energy from sunlight is not among the leading.

We found that the UK has achieved good results so far, indeed, we have observed that the 30% of the demand is already satisfied by renewable sources. The diversification of generator type helps on this. Moreover, the small decline in consumption can result in a decrease in the production from non-renewable resources- the main objective after all.

United Kingdom is the land of renewable resources with robust research abilities, and could become a pioneer in renewable energy technologies. Becoming a leader in renewables would help the UK's goal of reducing carbon gas emissions and generate significant growth in green careers, reduce the UK's dependency on imported wholesale non-renewable resources and reduce the cost of renewable technologies. Strong resolution like achieving over 30% by 2020 and 40% renewables by 2030 has to be taken with long-term financial support system in order to rope in investments and cutting down prices. Our data analysis shows that by end of 2017 the UK gained 30% of its electricity needs from renewable sources, which means it already met the target for 2020. However, the obtained results indicate that the renewable energy will cover 38.99% of the whole production in 2030, then UK needs to invest and develop more in renewable technologies if wants to meet the target for 2030 which is 40% of energy from renewable sources.

By Increasing the number of investments on renewable resource and the construction of new generators the coverage through the year will certainly rise. Incidentally, particular attention should be given to the type of resources being used. A diversification strategy should be adopted in order to achieve full coverage under any condition: cloudy days or night, lack of wind, low-intensity waves.

Furthermore, reducing losses of energy during transport could bring sensible benefits in terms of costs and infrastructure maintenance. In this sense, producing electricity as close as possible to the consumers could help in achieving this result and increase the efficiency.

By comparing the renewable sources in each of the UK countries, we can see that there is a clear difference in the installed capacity of generators and the preferred source. England boasts the highest installed capacity than any other country, Scotland comes second while Wales and Northern Ireland take the third and fourth place respectively. Moreover, the prevailing source in each country seems to be affected mostly by the weather conditions. England enjoys more sunlight throughout the year and therefore solar generators have been preferred.

On the other hand, on-shore wind is the predominant source in Scotland where the average annual wind speed is 13-15 mph. Scotland has also been named the windiest place in Europe and this can illustrate the potentials of a further expansion in the renewables energy production. Furthermore, off-shore wind does not seem to have been exploited in Scotland as much as in England where it is the second dominant technology. Onshore wind generators are much cheaper and easier to install, however offshore winds are typically stronger and would allow more efficient production of electricity. In that aspect, UK and Scottish government should invest more in the construction and utilisation of offshore power generators.

Wales and Northern Ireland at the moment do not considerably contribute in the production of renewable energy. Wales, although it has similar weather conditions with England, hasn't taken advantage of the opportunity of solar energy with significantly less installed capacity. However, if we see Wales separately, a recent report[4] shows that nearly half of Wales' electricity came from renewable sources (approximately 48%) in 2017. Lastly, the main source in Northern Ireland is on-shore wind and the latest estimation show that 40% of the electricity will be produced by renewables by 2019.

6 CONCLUSION

Renewable energy in the UK has seen a steady growth in the last 10 years. From our analysis, it is expected that UK will elapse the 2020 EU target. The main reason for emphasis in renewable energy is its abundance and never-ending sources which are also environmentally friendly as compared to non-renewable energy sources which are finite and pollute the environment.

Despite the benefits of renewable energy, the main drawback is its heavily dependence on weather conditions (e.g wind and solar) and geographic location/topology (e.g hydro or geothermal). This uncertainty reduces the reliability of renewable energy. To counter this problem, a study on correlation between weather and renewable energy source has to be conducted so that proper measures and right investment are done appropriately. Another challenge on renewable energy is the huge initial investment cost and maintenance cost as compared to non-renewable and this is the main reason that many countries have not progressed much in renewable energy.

Can energy from renewable sources be sufficient 100% for UK's electricity demand? This is the ultimate question and the answer is Yes, as seen from our research. However, to successfully achieve this, we need to combine knowledge from other fields such as weather and topology in order to maximise the extraction of energy from renewable sources.

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