 

Germany and UK Renewable Energy

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Jabbering Jaguars

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2. INTRODUCTION

Germany and the United Kingdom,two members of the European Union are strong proponents of Green Energy and committed to achieving net zero emissions by 2050. The 1970s was a turning point for both the countries, where the impact of climate change became clear to them.The West German government decided to move to green energy giving birth to an initiative called Energiewende while UK followed path establishing an alternative energy research centre. While both the countries are aligned in this common goal, they have chosen different paths.

We have made an attempt to compare and analyse the renewable energy production, consumption patterns of these two nations and tried to understand the interplay between policies and energy patterns.Germany and UK were selected based on multiple factors: each is recognized as a global leader implementing renewable energy as a part of their target of zero emissions,both countries have similar populations and energy demands and both are aggressively applying economic policies related to renewable energy. Fundamentally there is a 3-pronged approach for both the nations: reduction in overall energy consumption, utilization of renewable energy sources in place of non-renewable sources, and replacement of items powered by non-renewable energy sources with electricity power created by renewable sources.

3. PROBLEM STATEMENT

The objective of this project is to compare the renewable energy production and consumption patterns between Germany and the UK during the period 2007 to 2017,to assess their policy effectiveness and identify potential factors limiting their timely achievement of their Green Energy targets.

DATA SOURCE AND DESCRIPTION

The data has been taken from the International Energy Agency(IEA) **[9]** and includes data pertaining to different energy sources, both renewable and nonrenewable in different OECD countries. However,we have chosen to limit the data to renewable energy sources in Germany and the UK .

4. COMPARISON BETWEEN UK AND GERMANY

4.1 RENEWABLE ENERGY CONTRIBUTION BY SOURCE

The primary sources of renewable energy in Germany include wind,solar and biomass. The highest and consistent contributor has been Onshore wind energy followed by biomass and hydropower. In the period 2007 to 2017 there has been a steady rise in contribution of renewable energy with the growth in production by 113.1% in Germany and a 401.17% in the UK.

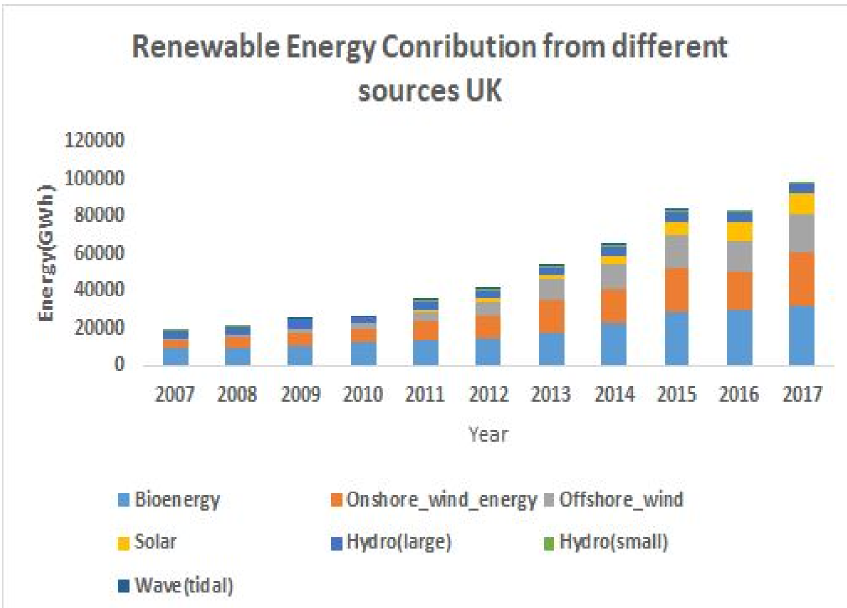

Figure 1: Renewable Energy from different sources, UK

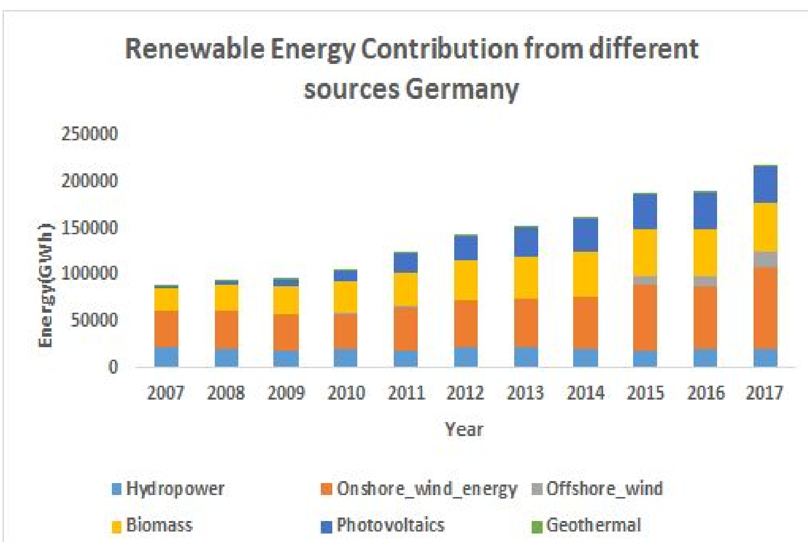

Figure 2: Renewable Energy from different sources, Germany

From the Fig 2 it is clear that Germany has had a rise in renewable energy production by around 145% from 2007 to 2017 while for the UK it has been as high as 401.71%. As far as Germany is concerned, the highest renewable energy contribution in Germany has been from Onshore wind energy followed by biomass and hydropower in 2017.The contribution from onshore and offshore wind energy sources has almost been equal and consistent in the period 2007 to 2017.Other contributors include solar energy,geothermal energy and hydropower. As far as the UK is concerned, the highest renewable energy contributors have been bioenergy,onshore wind energy and offshore wind energy.Other contributors include bioenergy,wave(tidal) and hydro power.

4.2 ENERGY PRODUCTION AND IMPORTS

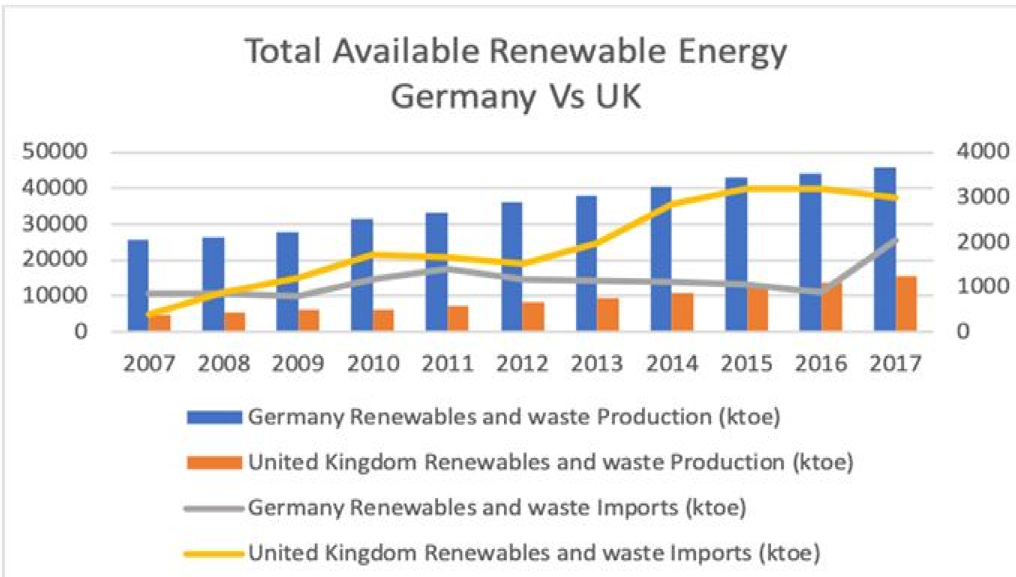

Figure 3: Available Renewable Energy

In 2007, the European Council agreed to a common strategy for energy security and tackling climate change. It set a target of 20% of the EU's energy to come from renewable sources. From the data it seems clear that renewable energy production of the UK is considerably less than that of Germany. This is due to Germany's shift towards clean energy in the early period. The increase in the production of renewable energy in Germany is due to its Renewable Energy Source Act.In Germany renewable energy makes up 32 percent of the nation's total electricity generation while in the UK it is less around 25 percent. As of 2014, Germany had the largest photovoltaic installed capacity, which is one of the reasons renewable energy production in Germany is greater than that of the UK

Considering the imports, before 2008 the UK was less dependent on imported renewable energy. With Britain on the road to the EU exit, the scope of energy cooperation seems diminished. Ultimately, this means that Britain could end up paying higher prices for energy imports which in turn means that the power station will have a higher cost of generation due to which it was economical for the UK to import energy.While Germany has benefited significantly from the integrated European power grid due to which it imports less energy and produces for itself.

4.3 EXPORTS

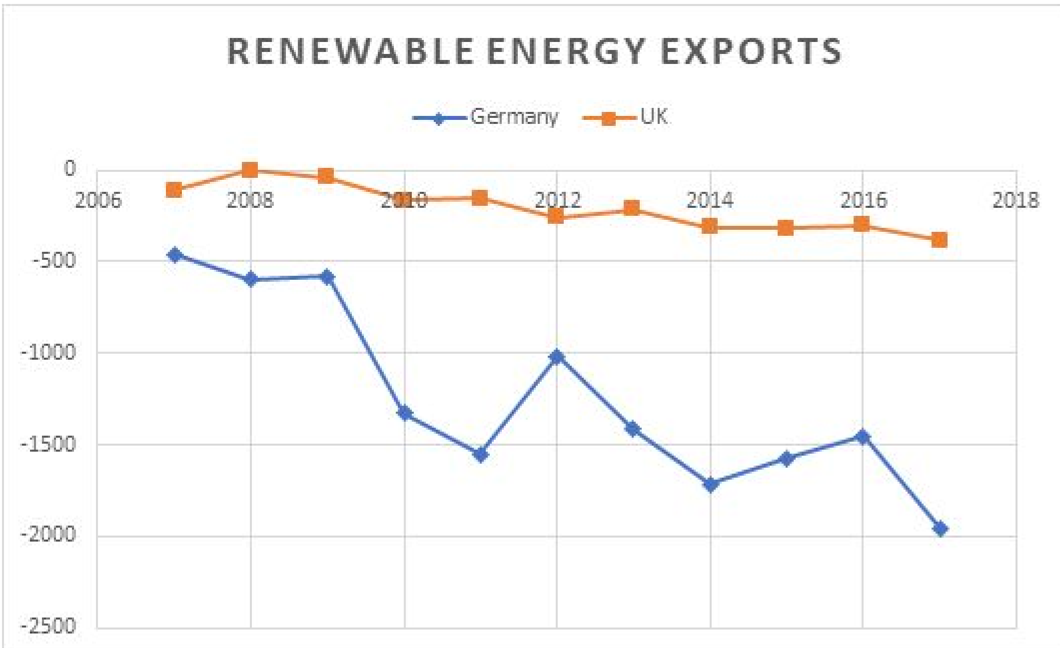

Figure 4: Renewable Energy Exports

Renewable energy products and services are being exported to dozens of countries worldwide. UK-based onshore and offshore wind, wave and tidal energy companies are now exporting their products and services to 37 countries across 6 continents. UK exports of wind energy products and services totaled £525m a year, according to the Offshore for National Statistics.

Germany's renewable energy industries and energy policymakers are working to broaden the world market for German-made renewable energy technologies. Exports account for approximately 20% and 10% of wind and solar PV production, respectively, in Germany. According to one recent study, exports of solar energy technologies appear to be slowing, while those for wind technologies and related services are growing rapidly due to Germany's strong competitive position and an expanding global market. This study estimates Germany's overall annual renewable energy technology exports at 350 million Euro, or 10% of domestic production. The same study projects a world market share of 4-5% for German renewable technology firms by 2010. Germany lags behind other industrialized countries, such as the U.S. and Denmark, as an exporter of renewable technologies. In 2001, German wind turbine producers exported 693 turbines (518 MW)—100% more than in the previous year. While the number of turbines exported grew again in 2002, strong growth in domestic demand and production actually reduced the share of exports in that year.

4.4 TOTAL PRIMARY ENERGY SUPPLY

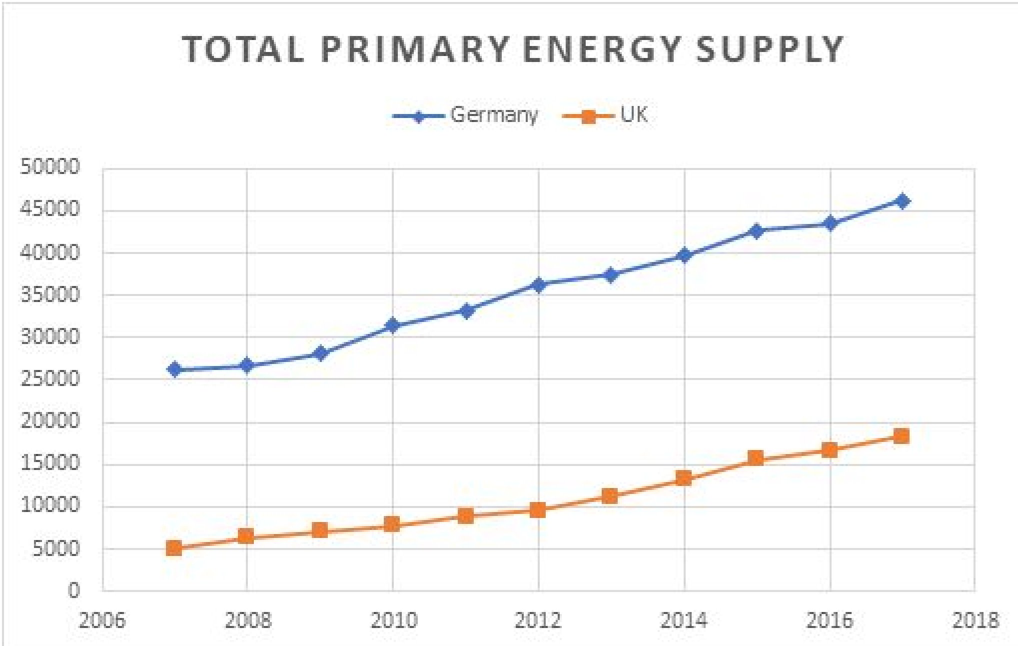

Figure 5: Total Primary Energy Supply

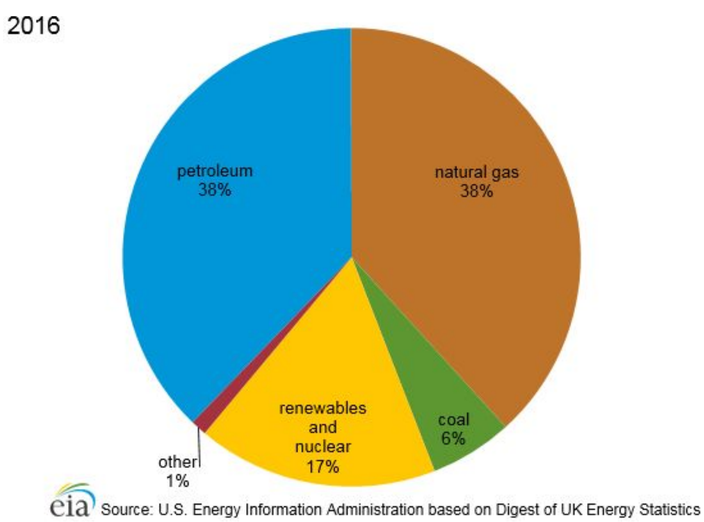

Figure 6: United Kingdom Total Primary Energy Supply in 2016

- United Kingdom (UK) oil and natural gas production have grown on average almost 9% and 4% per year, respectively, from 2014 through 2016. Oil consumption in the UK peaked in 1973 at about 2.4 million barrels per day (b/d) before declining to 1.5 million b/d in 1983, and recovering to average 1.8 million b/d from the late 1980s through 2007. Since 2007, consumption has been gradually declining, reaching 1.5 million b/d in both 2013 and 2014.

- UK production of hydrocarbon gas liquids (HGL) has been generally declining, reflecting the downward trend in UK natural gas production and refinery output. HGL refers to both the natural gas liquids and to olefins. HGL is produced in association with both natural gas and petroleum products.
- UK natural gas production peaked in 2000, and consumption peaked in 2004 with both generally declining through 2014. From 2014 through 2016, production has grown at an average rate of 5% per year, while consumption has grown 7% per year.
- At the end of 2017, the UK had 15 operating nuclear reactors, with a current capacity of slightly less than 9 gigawatt electric (GWe), according to the World Nuclear Association.. Nuclear power generation accounted for 20% of the country's total gross generation in 2016.
- Coal production in the UK is declining as a result of environmental regulations and falling consumption.

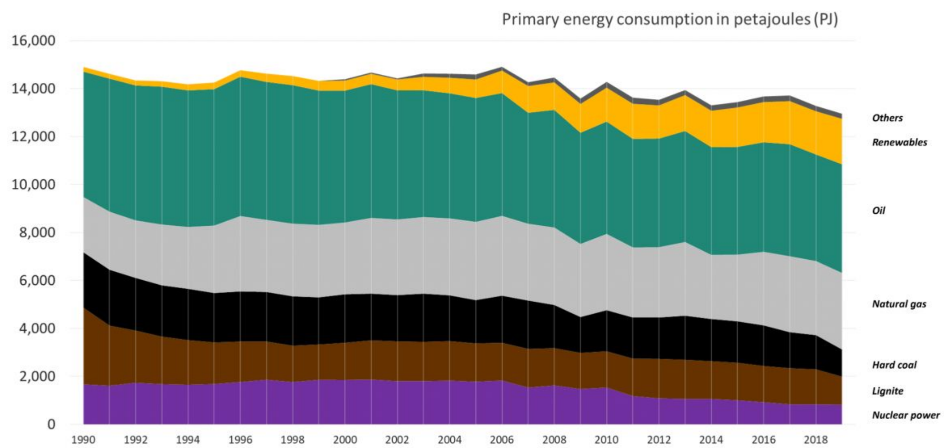

Figure 7: Germany Primary Energy Consumption 1990-2019

- Germany is the fifth-largest consumer of oil in the world. Oil consumption accounted for 34.3% of all energy use in 2018, and 23.7% of Germany's energy consumption came from gas.
- Germany is also the world's largest importer of natural gas. In 2016, Germany imported 49.8 billion cubic metres (bcm) of gas from Gazprom.
- Coal is the largest source of electricity in Germany. As of 2016, around 40% of the electricity in the country is generated from coal. Germany is also a major producer of coal. Lignite is extracted in the extreme western and eastern parts of the country, mainly in Nordrhein-Westfalen, Sachsen and Brandenburg.

5. ENERGY CONSUMPTION PATTERNS OF UK AND GERMANY

5.1 GENERAL PATTERN

Complete energy usage in Germany plummeted 6 percent between 2000 and 2016, down from about 344 Mtoe in 2016 to 322 Mtoe. Reading more in-depth, the downturn was driven through the time of the financial crisis (-5.32 percent), with 2014 becoming the lowest point attributed to the depression after the dramatic drop in 2009. The variability stayed constant between 2000 and 2007. The energy consumed by end-users rose minimally by 0.7 percent during 2000-2016, mostly influenced by the post-recession phase as evidenced from the graph.When we look at the energy consumption pattern sector wise both for Germany as well as UK, we see that the residential sector has the highest renewable energy consumption. In Germany, nearly 70% of the households are in the urban area.

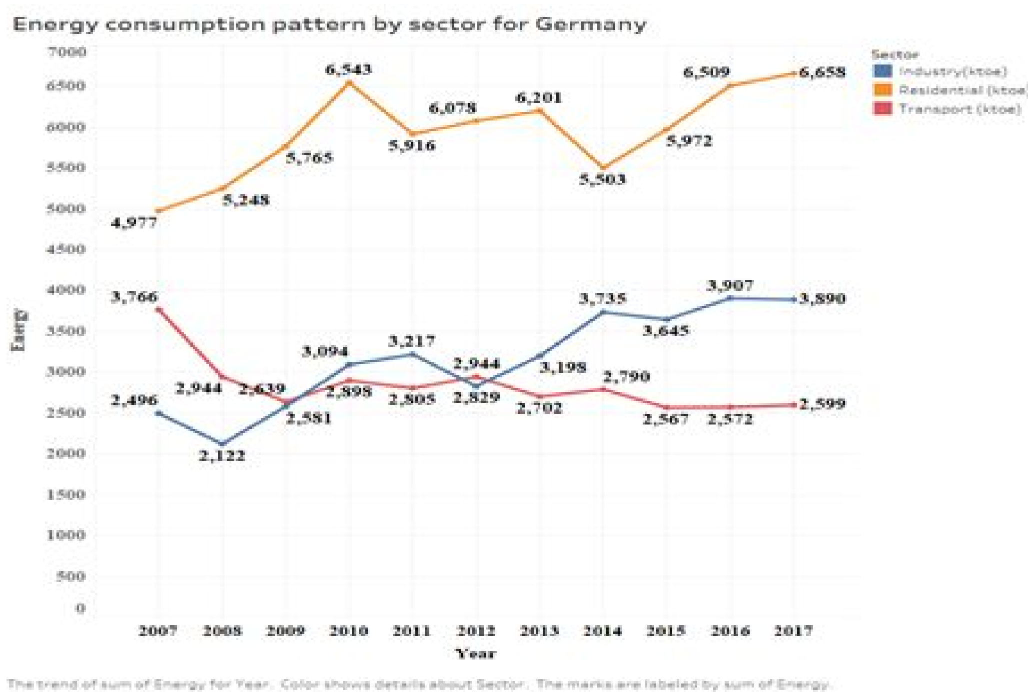

Figure 8: Energy Consumption Pattern, Germany

When we look at the energy consumption pattern sector wise both for Germany as well as the UK, we see that the residential sector has the highest renewable energy consumption.

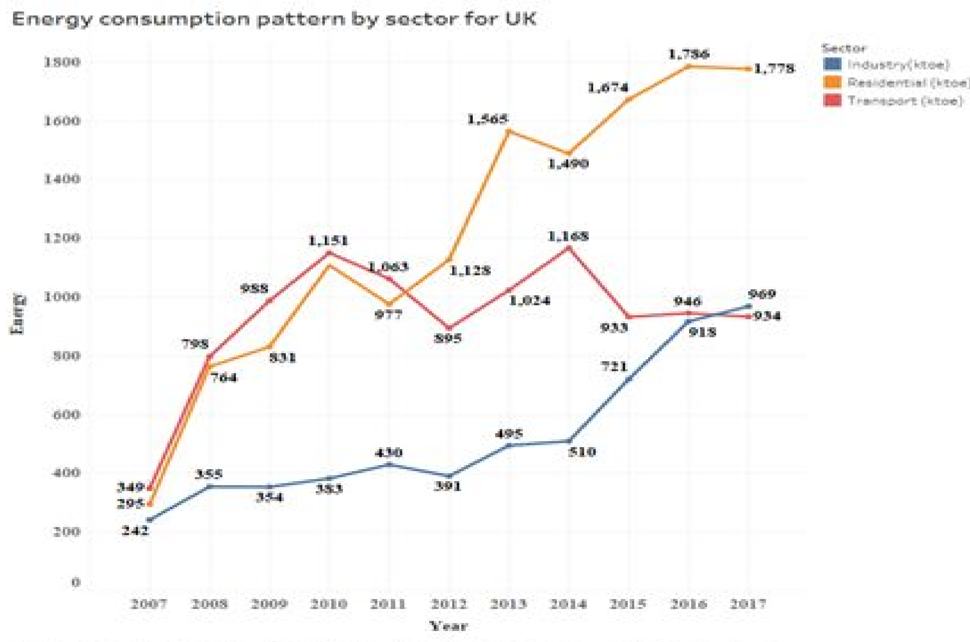

Figure 9: Energy Consumption Pattern, UK

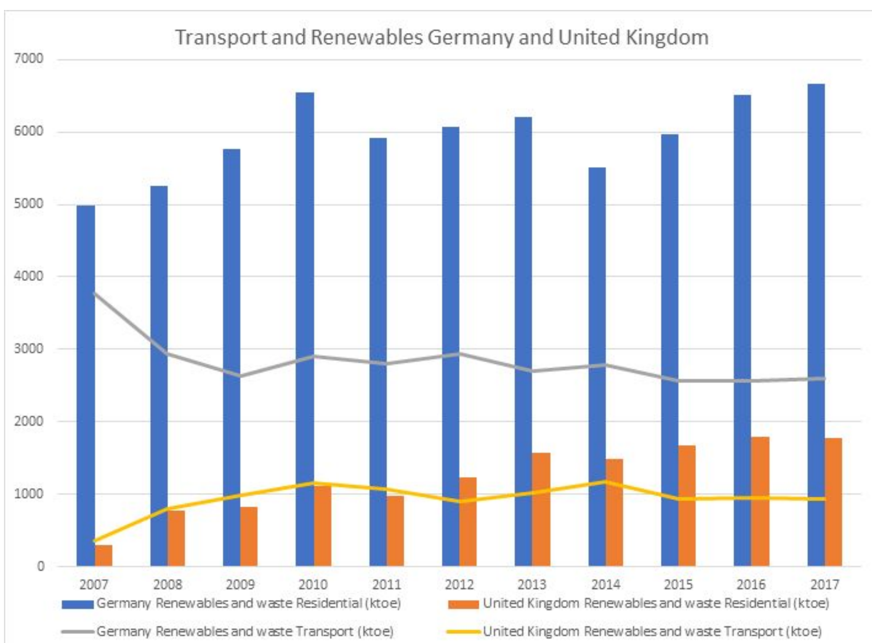

Figure 10: Comparison of residential energy consumption versus transportation energy consumption

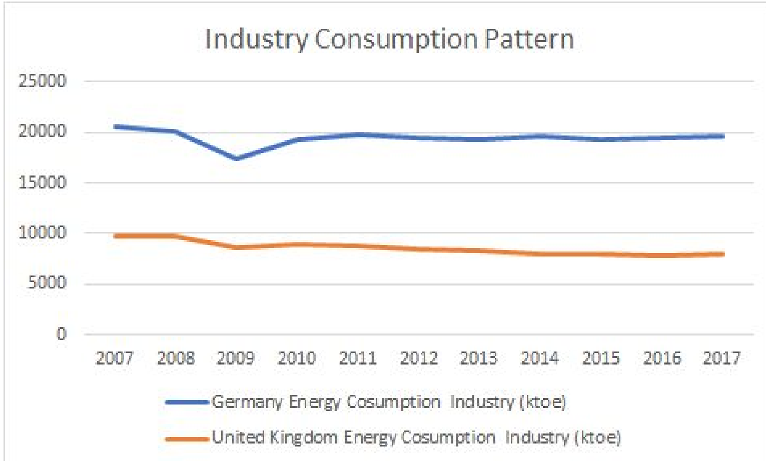

Figure 11: Industry Consumption Pattern

Transition to renewable energy in the transportation and industrial sectors has been slower.

Despite Germany's progress and plans to achieve emissions reductions in the power sector, the government recognizes that more progress is needed in other sectors, notably in heating and transport, in order to meet overall carbon reduction targets.

Transport, in particular, has been the biggest laggard on emissions reductions and the most significant impediment to Germany meeting its GHG targets. Moreover, Germany's heavy reliance on diesel vehicles in road transport has contributed to rising air pollution, especially nitrogen dioxide emissions. In addition to efficiency improvements in line with EU requirements as well as promoting EVs, the Climate Action Plan 2050 also identifies local public transport, rail, cycling, walking, and digitalization as playing important roles in achieving climate targets in the transport sector. The government launched a task force on emissions reduction in the transportation sector, called the National Platform Future of Mobility, to make recommendations on addressing transport sector emissions. Moreover, the government has decided to implement a carbon price on transport emissions, which would raise fuel prices and help motivate improvements in transport efficiency.

6. ECONOMETRIC DEMAND ANALYSIS

6.1 FACTOR DECOMPOSITION ANALYSIS

Decomposition method is used to analyze the impact of activity,intensity and structure of energy uses and the different components identified include activity effect, structural effect and intensity effect.

- Activity effect is the effect of changes in production without the impacts from structural and technological factors and refers to growth of the economy in terms of GDP.
- Structural effect on the other hand, describes the sectoral contribution to the total economy through indicating structural change of a sector in terms of energy consumption.
- The energy intensity effect measures the improvement in energy efficiency, changes in technology, fuel mix changes and other factors that are not related to activity or structure.A positive intensity means a higher energy consumption per GDP.A negative intensity implies an improvement in energy use per unit of GDP.

In general, the structural and activity effects for both the UK and Germany are not very pronounced and follow similar trends. However, intensity effects can be felt more in both the countries.Increasing gas prices might have led to people relying more on less efficient electrical sources for heat generation which might explain the increase in intensity in both Germany and the UK.In 2009, the European Union initiated the renewable energy directive. Following on the directive, both German and the United Kingdom installed solar and wind farms to increase their renewable energy source dependence. The period 2014-2015 might reflect the increasing inefficiencies in the newly adopted energy farms

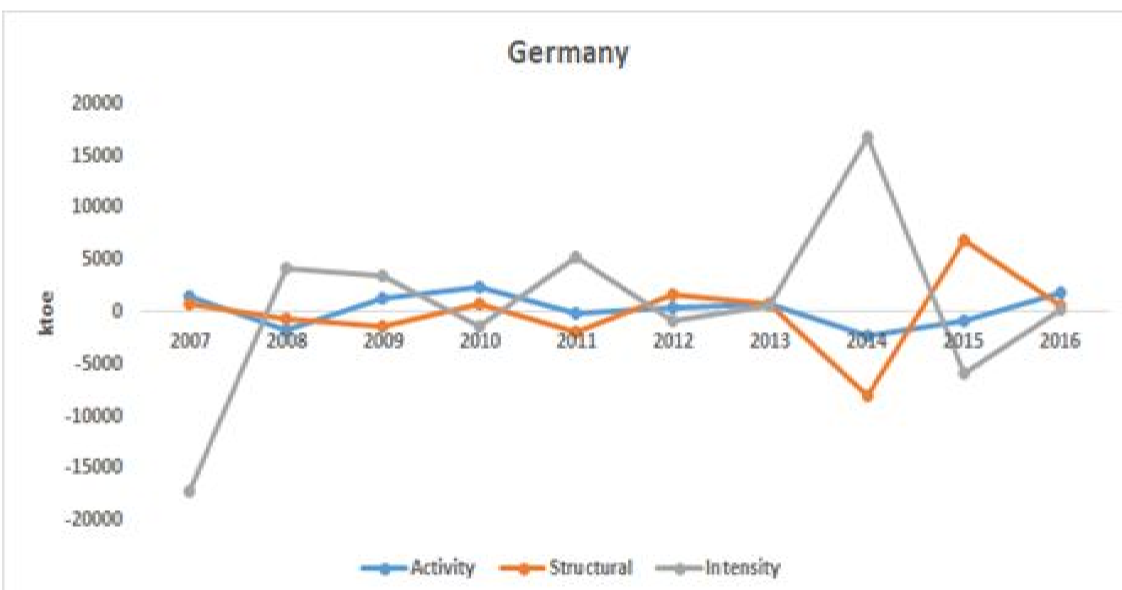

Figure 12: Decomposition Analysis, Germany

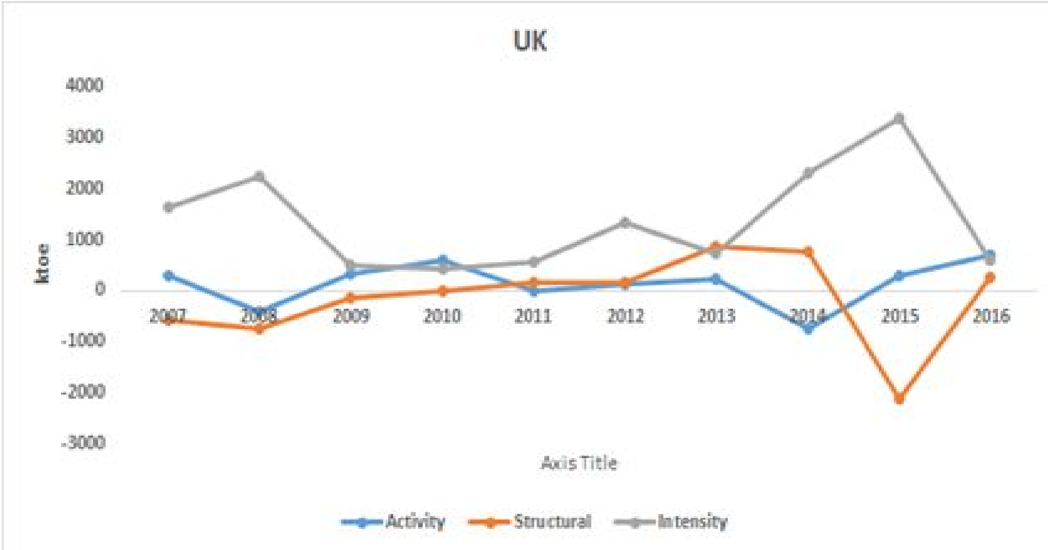

Figure 13: Decomposition Analysis, UK

Energy intensity was calculated by taking the ratio of total primary energy use (TPES) (all of the fuels and flows that a country uses to get energy) to GDP (the total money made in a country).

6.1.1 Jevons Paradox

Jevons paradox occurs when technological progress or government policy increases the efficiency with which a resource is used, but the rate of consumption of that resource rises due to increasing demand. The Jevons paradox is the most widely known paradox in environmental economics. However, governments and environmentalists generally assume that efficiency gains will lower resource consumption, ignoring the possibility of the paradox arising. One of the arguments in support of the Jevons Paradox is that improvement in efficiency or a technological improvement cannot guarantee reduction of fuel consumption.

The Jevons Paradox was first observed in England after Watt’s steam engine was invented. The engine greatly improved the efficiency of coal fired steam engines from the earlier design, but rather than reducing the fuel consumption, England's consumption of coal soared. Watt's innovations made coal a more cost-effective power source, leading to the increased use of the steam engine in a wide range of industries. This in turn increased total coal consumption, even as the amount of coal required for any application fell.

In the UK and Germany, when we analyze the Econometric Demand Analysis curve, we see that there is a spike in energy intensity in 2014. In 2014, the renewable energy obtained from offshore wind farms increased by 17 percent and onshore wind by 10 percent. In the second quarter of 2015, renewable electricity generation exceeded 25% and coal generation for the first time. The spike in energy intensity can be explained by the Jevons paradox. Due to investment and construction of increased number of wind farms, the demand for energy from the wind farms went up, leading to an increase in the energy intensity.

6.2 ENERGY INTENSITY COMPARISON

Energy intensity is a measure of the energy efficiency of the economy i.e. it is a measure of how much energy is required to translate into a unit of GDP. Energy intensity was calculated by taking the ratio of total primary energy use (TPES) (all of the fuels and flows that a country uses to get energy) to GDP (the total money made in a country).The energy intensity pattern of OECD countries in general and that of UK and Germany show similar increasing trends. For the UK it may be observed that the renewable energy intensity plateaued during 2015 to 2017 and for Germany it increased by only a small percentage. High energy intensity generally indicates a higher price or cost for converting energy into GDP. In the UK and Germany, when we analyze the Econometric Demand Analysis curve, we see that there is a spike in energy intensity in 2014. In 2014, the renewable energy obtained from offshore wind farms increased by 17 percent and onshore wind by 10 percent. In the second quarter of 2015, renewable electricity generation exceeded 25% and coal generation for the first time.The cost of production of renewable energy sources has risen to three times that in 2007.Taxes and policy costs accounted for as much as 30% of the industrial electricity prices in 2012.Higher generation costs compared to growth in GDP would account for higher intensities. Another issue has been the dependency of Germany on solar and wind energy which are intermittent. Short term energy imports are very expensive and could be contributing to the high energy cost.

The spike in energy intensity can be explained by the Jevons paradox. Due to investment and construction of increased number of wind farms, the demand for energy from the wind farms went up, leading to an increase in the energy intensity.

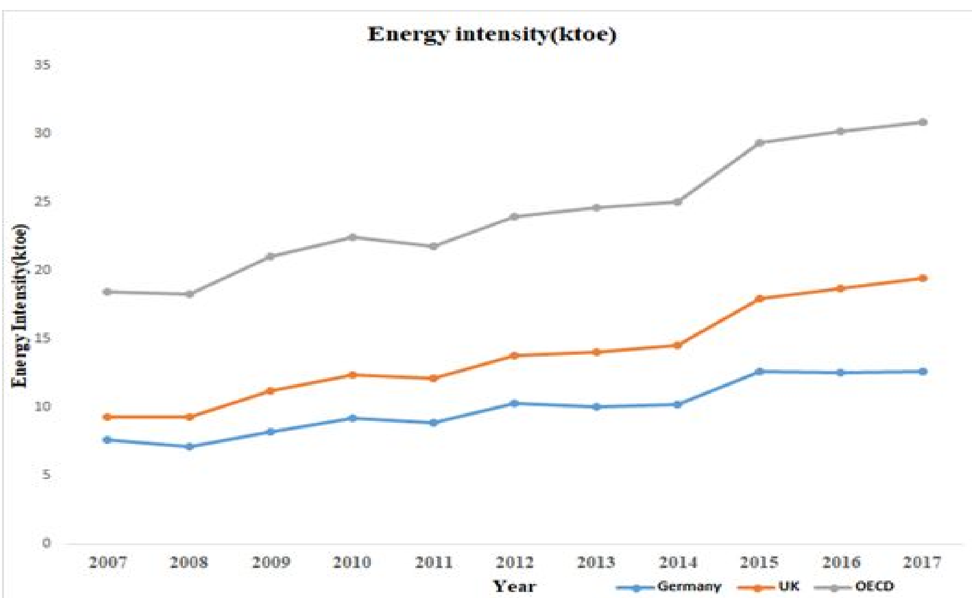

Figure 14: Energy Intensity

6.3 PRICE ELASTICITY OF ENERGY SUPPLY AND DEMAND

The price elasticity of demand is defined as the ratio between percentage change in energy quantity and the proportional percentage change in price. Economists use this concept of price elasticity of demand to describe how the quantity demanded changes in response to a price change.

When the absolute value of the ratio is <1, it is termed as inelastic and when >1, it is termed as elastic. The price elasticity of demand has been calculated using the midpoint method.

A high elasticity means that, for a smaller percentage increase in price, there is a larger percentage change in quantity. The price elasticity of energy supply shows an interesting pattern . A positive elasticity is observed during 2008 to 2013 while a negative one from thereon for both Germany and the UK. An inelastic condition where a price change does not affect consumption. This is intuitive for these countries which are strong proponents of renewable energy and enforce the use of renewable energy despite higher energy costs imposed on consumers. This trend is observable in all the major sectors including residential, transportation and industrial where despite increased cost of renewable power, power consumption does not come down. The long term price elasticity seems to be predominantly positive, a trend that is generally expected. Over a short period of time the quantities of energy supplied and demanded are slow to react to changes in price.

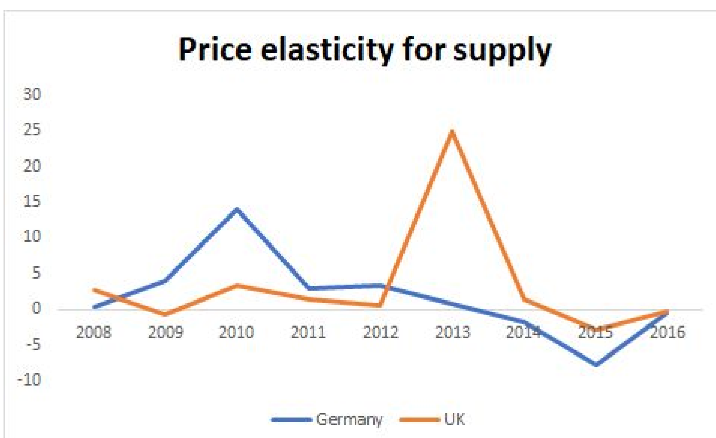

Figure 15: Price elasticity of energy supply

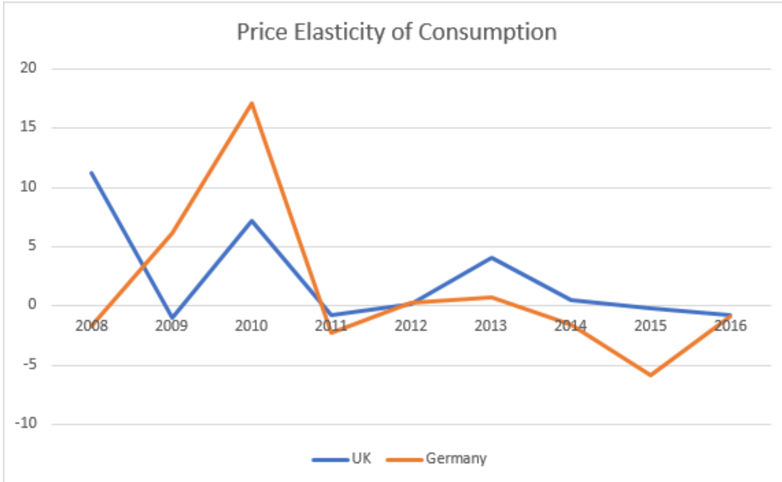

Figure 16: Price elasticity of consumption

7. POLICY EVALUATION

7.1 EMISSIONS

After the econometric analyses of renewable energy data were calculated, historical data of carbon emissions and power generation was compared to determine the effectiveness of each country's renewable energy policies. 10-year data was compiled for renewables, coal, natural gas, and oil energy sources, as well as CO2 emissions. These data are summarized in Figures 17 and 18, which represent Germany and the UK, respectively.

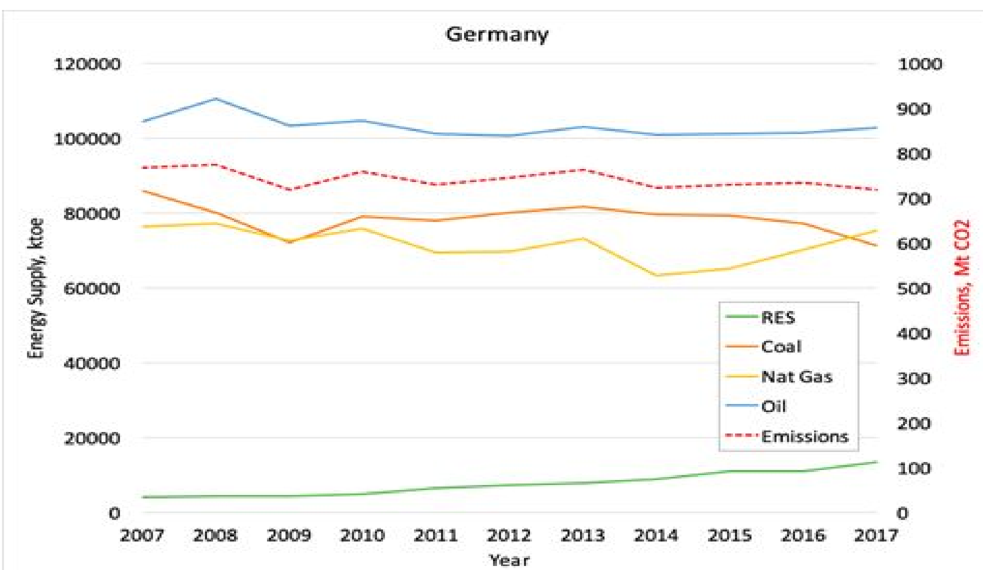

Figure 17: Germany emissions and energy generation by source

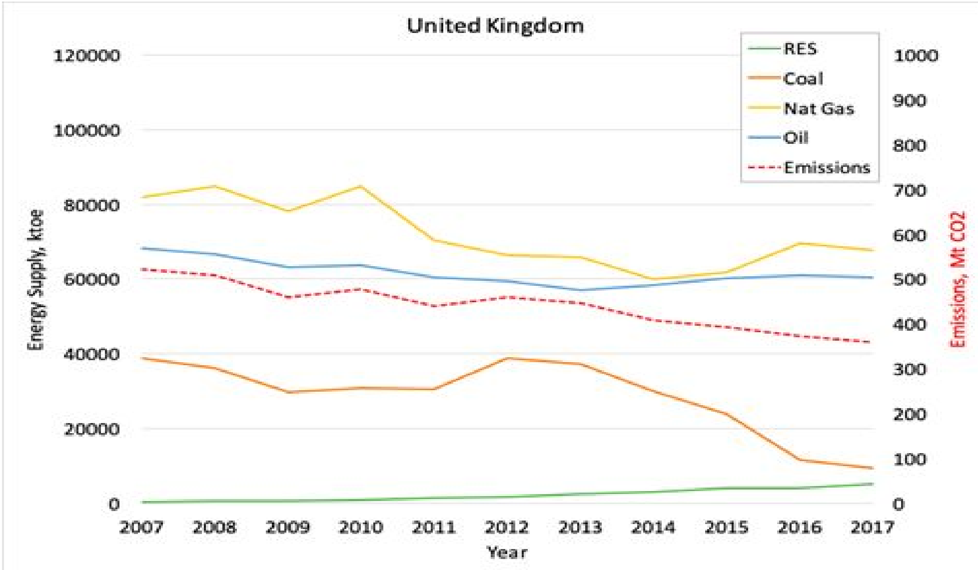

Figure 18: UK emissions and energy generation by source

Figures 17 and 18 demonstrate the results of each country's policy approach over the last 10 years. As shown in Figure 17, Germany's renewable energy generation increased steadily over the 10 year period. Carbon-based energy sources remained relatively constant over the same time period, and as a result, emissions reductions were minimal. A significantly different observation can be made for the UK's policy approach. As shown in Figure 18, the UK's utilization of renewables also increased steadily over the 10 year period. Unlike Germany, however, the UK saw a significant decrease in carbon-based energy generation, particularly coal. There was a much more substantial decrease in CO2 emissions in the UK compared to Germany, which may imply that their energy policy has been more effective. To analyze the impact of various energy sources on emissions, the correlations between each source and the result of emissions were calculated and summarized in Table 1. Correlations may range from (+1,-1) where a positive correlation means that a decrease in production from that energy source would cause a decrease in carbon emissions or vice versa. Conversely, a negative correlation suggests that an increase in production of that energy source would result in a decrease in emissions or vice versa. A strong correlation is indicated by a value close to +1 or -1 and a weak correlation is indicated by a value closer to 0.

Germany				UK			
Coal	Nat Gas	Oil	RES	Coal	Nat Gas	Oil	RES
0.730	0.599	0.686	-0.588	0.860	0.733	0.671	-0.941

Table 1: Correlation between energy sources and emissions

As shown in Table 1, carbon-based energy sources showed a positive correlation to CO2 emissions, whereas renewables showed a negative correlation. In both countries, a decrease in coal-fired energy production showed the strongest correlation to emissions reductions. An interesting result of this analysis is that stronger correlations were observed in the UK than Germany. In particular, the correlation between increased renewables and reduced emissions was much stronger in the UK compared to in Germany. Looking back to the importation analysis, one explanation of this discrepancy is that the UK imports a significant portion of their renewable energy. This means that they have much more control over the supply of renewable energy and are not forced to account for factors such as intermittency and heavily as Germany, who produces much of their renewable energy within their own borders.

7.2 RELIABILITY AND RESILIENCY

A key factor in the implementation of renewable energy resources is their impact on the power grid. Unlike conventional power sources, most RES are non-dispatchable. This means that their power production cannot be controlled in the same way as a coal, nuclear, or natural gas power plant. One issue that arises from this lack of control is the "duck curve", which shows the output of conventional power sources over a 24 hour period. Figure 19 presents an example of the duck curve, and it can be seen that over time, power generation from conventional sources has dropped significantly during the daytime. Analysis of wind patterns show that speeds are generally higher during the day, then drop off quickly in the evening. As more renewables are introduced, they represent a higher portion of power supply during daytime hours. Thus, the night time power dropoff becomes much more impactful. The duck curve shows this impact as conventional power sources much quickly ramp up power generation to ensure power demand is met. These fast ramp rates result in substantial decreases in plant efficiency.

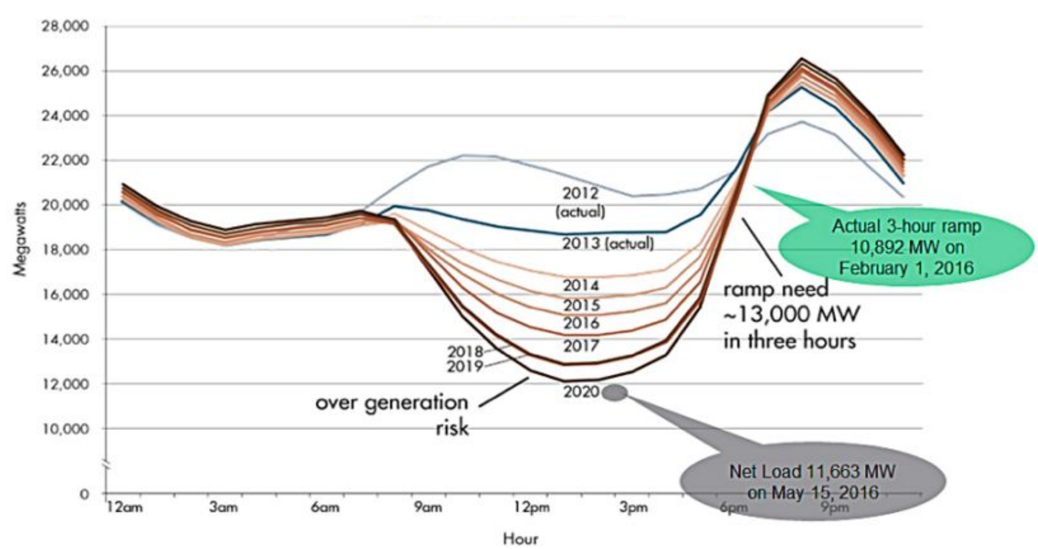

Figure 19: The "duck curve", conventional power generation over a 24 hour period [CAISO, 2016]

Additionally, since there is no way to control wind speed or weather patterns, the output of wind and solar power can be extremely volatile. This pattern is exemplified in Figure 20, which shows normalized power generation from wind and solar sources over time. Areas such as those circled in green are occasions when wind speed varied drastically over a short period of time. As a result, the power output from these resources increased and decreased rapidly.

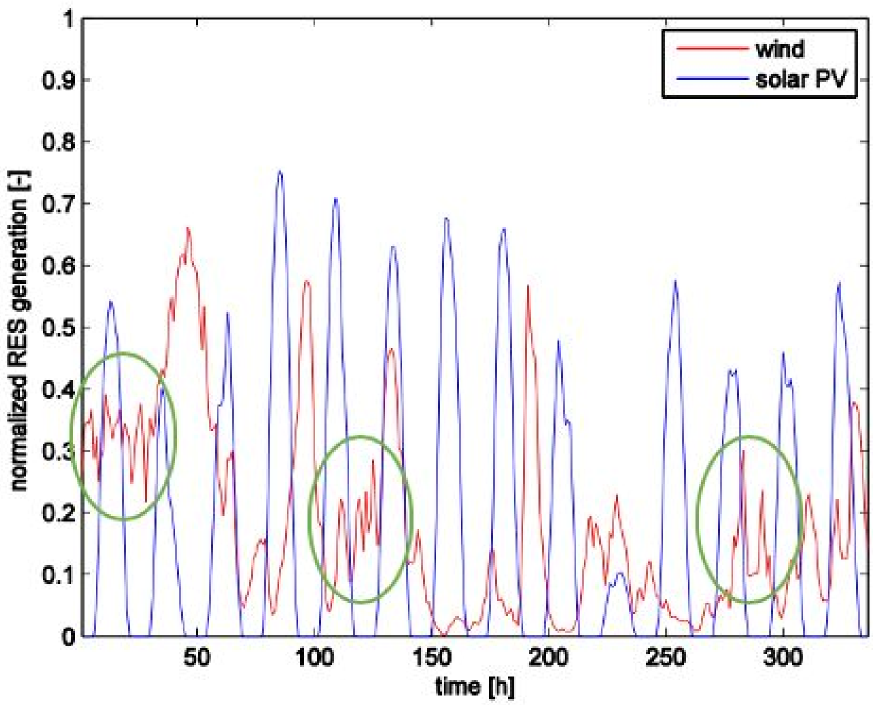

Figure 20: Wind and solar power generation over time [Delarue, 2015]

Obviously, power demand does not follow these same volatile patterns, which can create significant issues in reliability and resiliency of the power grid. To avoid adverse impacts of unpredictable power dropoff, conventional power plants, namely natural gas, must “fill in the gaps” by rapidly increasing and decreasing power output. This pattern, known as load following or peaking, has several substantial techno-economic impacts. Similar to highway fuel efficiency in a car, conventional power plants are designed to operate most efficiently at a single setpoint. Thus, the load following pattern of “accelerating and decelerating” decreases plant efficiency. Not only does this cause increased emissions, but it also makes the plant more expensive to run. The end result is that this intermittency of renewable energy causes emissions and energy prices to increase.

These factors may explain several patterns from the analyses presented in this paper. One such pattern is that the energy intensity of renewables has increased over time, which may be influenced by the increased cost of load following. In fact, Germany has some of the highest electricity prices in Europe [Rapier, 2015]. Another pattern that may be explained by these phenomena is the relatively stagnant emissions reductions in Germany, despite their rapid expansion of RES. Decreased efficiency caused by peaking and load following has likely caused emissions from conventional power sources to increase, leading to a less significant correlation between RES implementation and emissions reduction.

8. DISCUSSION

- With respect to renewable energy consumption. In general, with more efficient renewable energy-based sources in place, it is expected that the overall consumption of energy would come down making the system altogether more efficient. However, it is found that the opposite happens to neutralize the positive effects of the more energy-efficient system, an economic paradox called Jervor's paradox.
- In the econometric analysis performed some spikes in energy consumption were observed especially in 2014-2015 in both the countries and in general the consumption patterns show an increasing trend. In general, with more efficient renewable energy-based sources in place, it is expected that the overall consumption of energy would come down making the system altogether more efficient. However, it is found that the opposite happens to neutralize the positive effects of the more energy-efficient system, an economic paradox called Jevons paradox, the most widely known paradox in environmental economics. Another interesting fact that may be observed about Germany is that due to the implementation of Energiewende the average household had to pay more than double for power in 2017 as compared to 2000. Despite this fact the energy consumption in the residential sector grew. Similar patterns apply to the UK as well and we feel that it can also be accounted for by the Jevons paradox.
- When looking at energy intensity trends, the renewable energy intensity for both the UK and Germany has been increasing over the years from 2007 to 2017 though overall energy intensity trends are on declining trend for the European Union as understood from literature. New investments in wind farms ,biomass plants and similar renewable energy resources imply a higher renewable energy generation cost and a greater increase in energy generation cost compared to increase in GDP implies a higher energy intensity. Since both countries are renewable energy proponents such a trend is expected.Additionally as in the case of Germany, an over reliance on intermittent solar and wind energy causes more expensive short term energy imports.

9. CONCLUSION

This project has presented a comparison of Germany and the United Kingdom's energy policies through research and techno-economic analyses. Both countries are global leaders in renewable energy and emissions goals, but they have taken different policy approaches in attempt to reach these goals. Germany has focused primarily on the rapid expansion of renewable energy resources, while the UK has taken a more holistic approach of emissions reduction through reduced use of carbon-based power, reduced consumption, and improved efficiency. 10-year historical data highlights the differences in each country's energy production, consumption, and importation patterns. Both countries rapidly expanded renewable energy sources over the 2007 to 2017 time period, but energy consumption also increased substantially. An increasing trend in renewable energy intensities was observed, which suggests that policy choices, namely RES introduction, have resulted in increased cost of energy production. Overall, the UK has been more successful in their goal to reduce emissions than Germany, whose emissions have remained relatively constant. It can be concluded that impacts of increased RES such as intermittency have caused volatility in the power grid, leading to issues with reliability and resiliency, as well as price increases. These factors are a significant barrier to the emissions goals set by each country. Based on the analyses presented in this project, neither country will meet those goals with the current policy approach. In order to progress, Germany and the United Kingdom must update their energy policies to account for the issues revealed by this study.

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