Data Engineering Advanced Project 1

Data Engineering-Batch of 2023

Comparative Analysis and Forecast of German, Norway and Indian Energy Market

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Date : 28/08/2022

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Abstract

As the amount of energy produced from renewable sources like solar and wind grows, forecasting becomes more crucial. Although forecasting ability is rising, forecasts are also being used in more effective ways [1]. There is a financial opportunity to integrate higher percentages of variable renewable energy sources in the power system by using electricity trading to balance generation and demand. It aims to measure the advantages of solar and wind forecasting for imbalanced energy markets [2]. In this study, the German energy market in 2020 and 2021 is analysed and contrasted with the energy markets of India and Norway. It particularly centred on determining the 2020–2021 Intraday Energy Spot Market Price and how the generation of solar and wind energy affected the price throughout this time. It focused also on the energy market of India recently in the year 2022 as per the data availability on Indian Energy Market.

Table of content

List of Tables and Figures

Introduction

Energy is a necessary component of both human and industrial existence. This is in the sense that a secure, sufficient, and accessible supply of energy is a critical requirement for modern society's sustainability and economic well-being [3]. Within the last decade, Germany's share of renewable electricity has more than doubled. While Germany is still far from achieving a sustainable electricity supply, relying heavily on coal (50%) and nuclear (28%), no other country has been as successful in rapidly expanding new capacity as Germany, particularly in the wind power sector[4]. The German renewable energy sector's success has positioned the country to lead and shape the global renewable energy market, as well as to set standards and serve as a global example of clean energy security [3]. Electricity scarcity in the day-ahead and intraday markets is reflected in publicly observable prices on power exchanges. Because traders can trade either on the exchange or bilaterally, the prices of unobserved bilateral trades will not deviate systematically from exchange prices. They will not trade in one market if they can make more money in another. Various modelling and forecasting approaches for electricity spot prices have been developed to assist producers, consumers, and traders in making decisions [5]. In comparison to the day-ahead pricing literature, no results from a fundamental modelling approach have been published for the German intraday market, and only a few explicit intraday price models exist [5]. Before forecasting we need to analyse on such trends. So, in this paper we will observe how the energy Market in Germany varies in year 2020 and 2021 with countries like Norway which tells us about the European market and then with Indian Market to see how the market is different with two different continents (The data for India was limited).

DATA SET

It is separated into three sections for easier comprehension, the first of which describes a data set on the German market. The second piece discusses data on the Norwegian market, and the third section discusses data on the Indian energy market.

German Energy Market Data Set

Germany's energy dataset is publicly accessible via smart.de. As a result, day-ahead market data and data on total load generation were obtained.

Three datasets are used in the in determine the results.

1. Data on wholesale prices, with 8785 rows and 18 columns.

   From 01.01.2020 to 31.12.2021, this dataset aids in understanding the cost of energy generation for each hour of the day.

   The features of the raw dataset with their corresponding description below:

Features	Description	Type
Date	Date(DD.MM.YYYY)	String
Time	Time (HH.MM.SS)	String
Countries (row 3 -18)	Price of Different countries in Europe, Starting from Germany to Norway is given in(€/MWh)	Float

Table 1. Features and their description of German Data 1

2. Predicted Generation of energy, with 35142 rows and 7 columns.

   This data set reveals the total MWh generation in Germany and distinguished it from the total solar and wind generation.

   The features of the raw dataset with their corresponding description below:

Features	Description	Type
DATE	Date(DD.MM.YYYY)	String
Time	Time (HH.MM.SS)	String
Total(MWh)	The total energy generation in Germany in a particular day.	Float
Wind Offshore(MWh)	The generation of wind energy offshore.	Float
Wind Onshore(Mwh)	The generation of wind energy onshore.	Float
Photovoltaic (Mwh)	The generation of solar energy.	Float

Other(Mwh)	Which includes the miscellaneous generation value.	Float

Table 2. Features and their description of German Data 2

Norway Energy Market Data Set

As the day ahead price value of energy generation in given by the previous dataset, this was taken into consideration from 01/01/2020 to 31/12/2021.

From ember-climate.org, an independent energy think tank that use data-driven insights to transition the world from coal to clean electricity, the information for Norway's anticipated energy generation was gathered.

The features of the raw dataset with their corresponding description below:

Features	Description	Type
Country or region	Norway	String
date	DATE(DD/MM/YY)	String
Variable	Different media of generation for e.g solar, biofuel, wind	String
generation_twh	The amount of generated energy which is given in tWh	Float

Table 3. Features and their description of Norway Data

Indian Energy Market Data Set

The Indian Day Ahead Energy Market was launched in November 2021, making the data available from 1 November 2021 to 31 July 2022. This data is not available in a single table but is instead broken down by month. It could be found on iexindia.com.

The features of the raw dataset with their corresponding description of one such table is shown below:

Features	Description	Type
Date | Hour Block	Date(DD/MM/YY) and hour (00-01)	String
Final Scheduled Volume (MWh) Total (MWh) | Solar (MWh) | Non-Solar (MWh) | Hydro (MWh)	The amount of generated energy which is given in MWh	Float
MCP (Rs/MWh)	Price for generation in Rupees per unit	Float
Weighted MCP (Rs/MWh)	Weighted Price for generation in Rupees per unit	Float

Table 4. Features and their description of Indian Data

Data Pre-Processing:

Data Cleaning

Each set of data was unique, various data pre-processing techniques were used.

The steps followed for each dataset will be given below:

1. Dropping of unnecessary columns and rows, as many of the data's columns belong to other countries with energy markets that are priced one day ahead. Finally rows which had Null values were removed.

2. The data did not contain any garbage values or missing values.

3. Some data, particularly those from India, were combined so that they only accurately represented a certain year.

4. All the data were distributed normally, it also indicates that no unique outliers which data to vary.

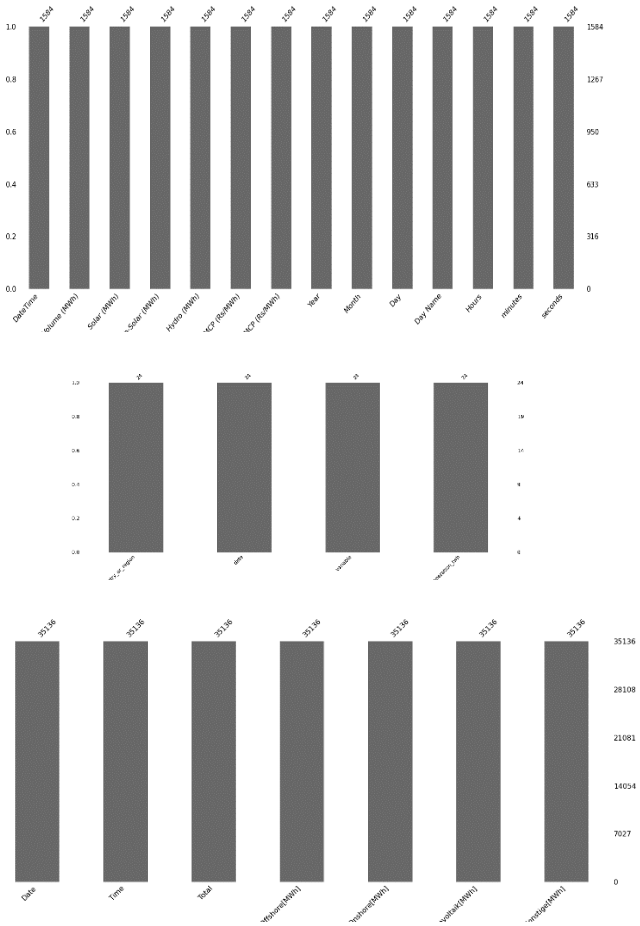
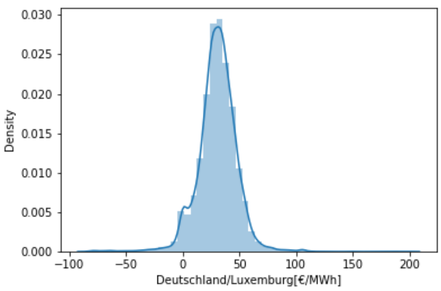
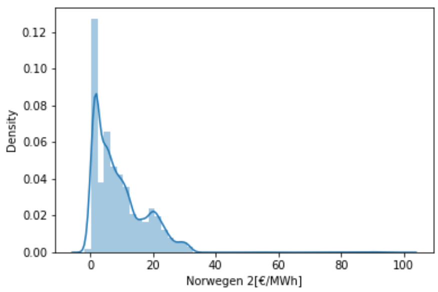


Fig.1 Bar chart showing each columns non null value(Missing Value)





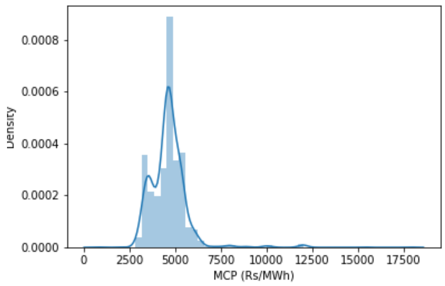


Fig.2 Graphs shows the datasets follows normal distibution

Data Transformation.

Due to the fact that all of the data are time series data, it is crucial to convert the date and time into date time objects. Additionally, because the data spans an entire year, it is essential to group the information according to the months. This is done to determine the average price value and forecast in a month,so that it can be compared in the future. In this dataset most of the values are floating point decimal as the features are measured in Mwh, €/MWh, Twh,Rs/Mwh .

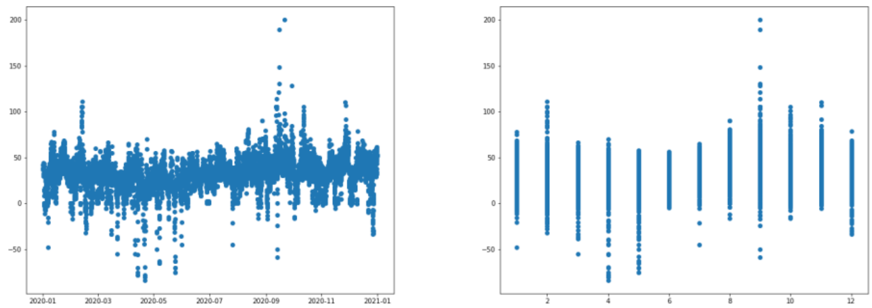


Fig.3 Graph showing before and After of grouping by month.

Dataset: Structure and Feature Interdependence

Outliers and Missing Value:

Most of the features which belongs to the price day ahead and predicted energy generation have outliers the variation and standard deviation of each column varies.But these outliers are the part of measurement of the quantity of these values, this does not affect our analysis as we have observed most of the features observes a normal distribution curve refer Fig.2. So taking the median values of each column could help maintain a balance between the data.There were no such missing value and it was handled in the pre- processing part.

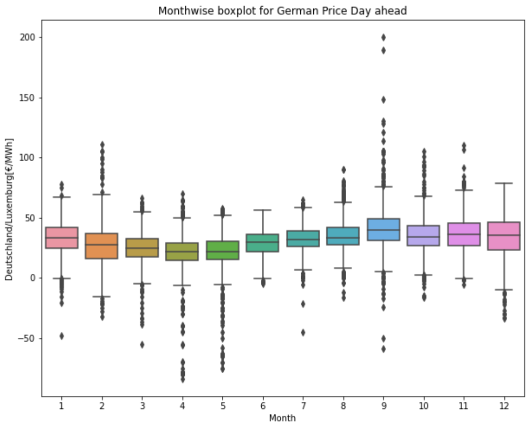


Fig.4 Outliers of German Dataset in the year 2020.

Correlation between different features.

Correlation is a way of understanding the strength of relationship between two variables or features in dataset. Correlation coefficients determine this strength by indicating a value between [-1, 1], where -1 indicates a strong negative relationship, while indicates no relationship and 1 indicates very strong positive relationship. Pearson correlation is one of the most widely used correlation methods and it indicates strength of linear relationship between 2 features[9].

It is crucial to determine whether any of the data utilized for this project are interdependent in any way that could influence future predictions. The Pearson correlation is used to this goal. One significant finding was that the wind and solar power in Germany are negatively correlated, proving that there is no interdependence of features among the data.

but please go to the data exploration section to see how the pricing varies with this generation for different countires.

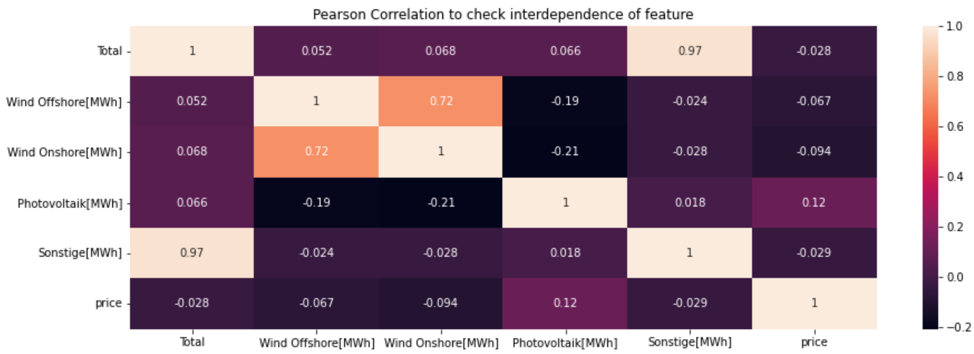


Fig.5 Heat Map showing the Pearson correlation between features

Data Exploration.

As this project compares the energy markets of Germany, Norway, and India but across a different time span, we start by talking about the German energy market before moving on to Norway and then India.

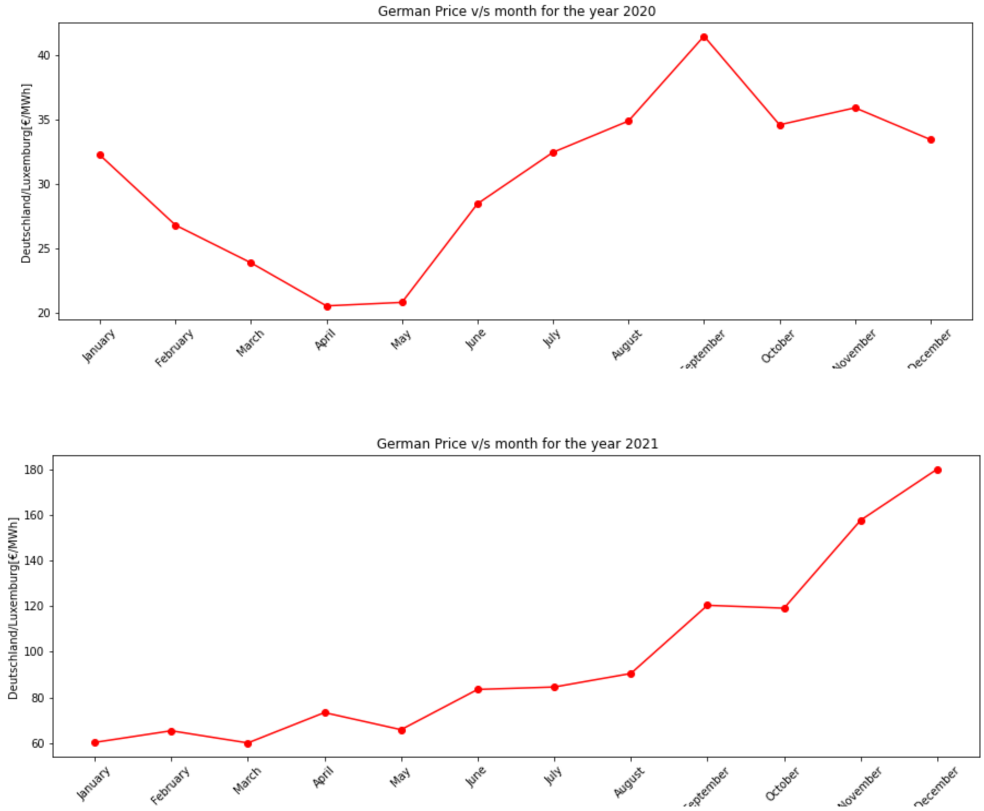


Fig.6 Graphs showing the Price varation in year 2020 and 2021

The two graphs up top represent the pricing day-ahead variation for the German Energy Market in 2020 and 2021. As you can see, prices rise during the winter season, which runs from September to January. This is mostly due to the fact that Germany's energy production depends heavily on solar and wind energy, both of which are scarce during this time. German residences and small businesses paid an average of 32.16 cents per kilowatt hour (ct/kWh) for energy in 2021, according to data by the German Association of Energy and Water Industries (BDEW).Over half of the cost was impacted by political factors including taxes, levies, and surcharges.[6]

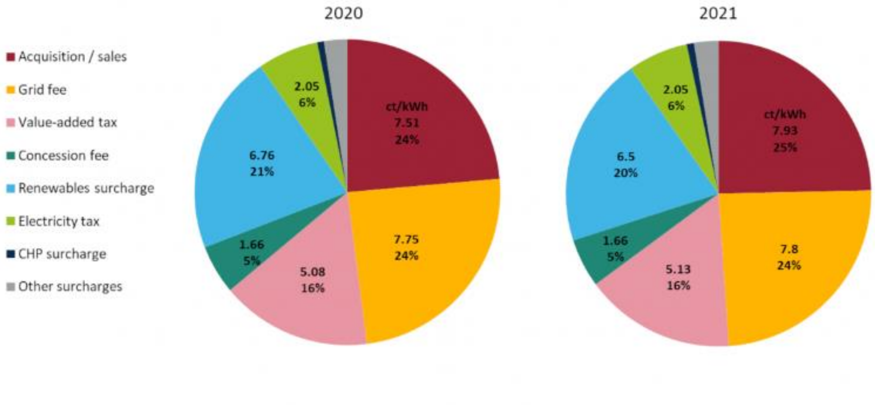


Fig.7 Composition of power price for German household using 3500 kWh per year in 2020 and 2021[6]

The graphs below will offer us an understanding of the relationship between the price of energy and total generation. We can see that when production is higher, prices fall, and vicversa.

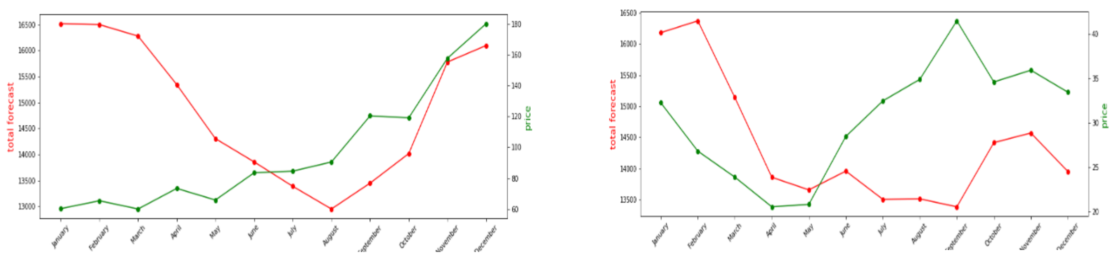
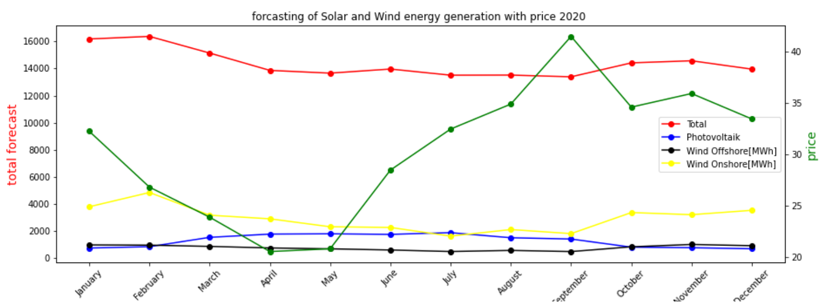


Fig.8 Graphs showing the interealtion between Price and Genretion of Enerfy in Germany per year 2020 and 2021

Germany has some of the highest electricity prices in Europe. The country's energy transition is still supported by the majority of consumers despite the high costs, which are partially caused by the requirement to support renewable energy sources [6]. The renewable energy especially from solar and wind is very less compared to the total energy production.



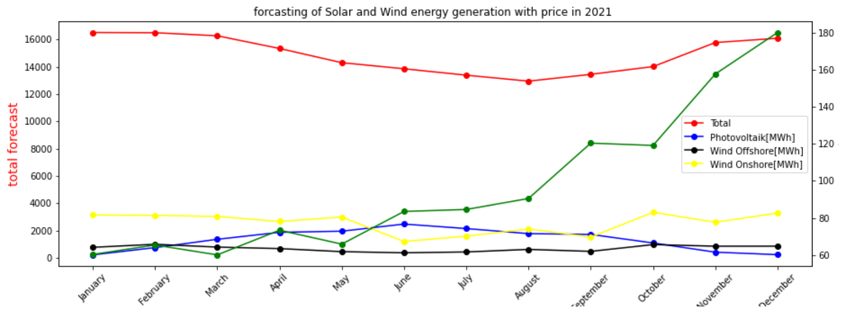


Fig.9 Graphs showing relation between renrewable energy and price of Germany per year 2020 and 2021

It's critical to understand when solar and wind energy production peaks each year so that we can compare it to market prices. The heatmaps below show us some of the notable months when solar and wind activity increase.

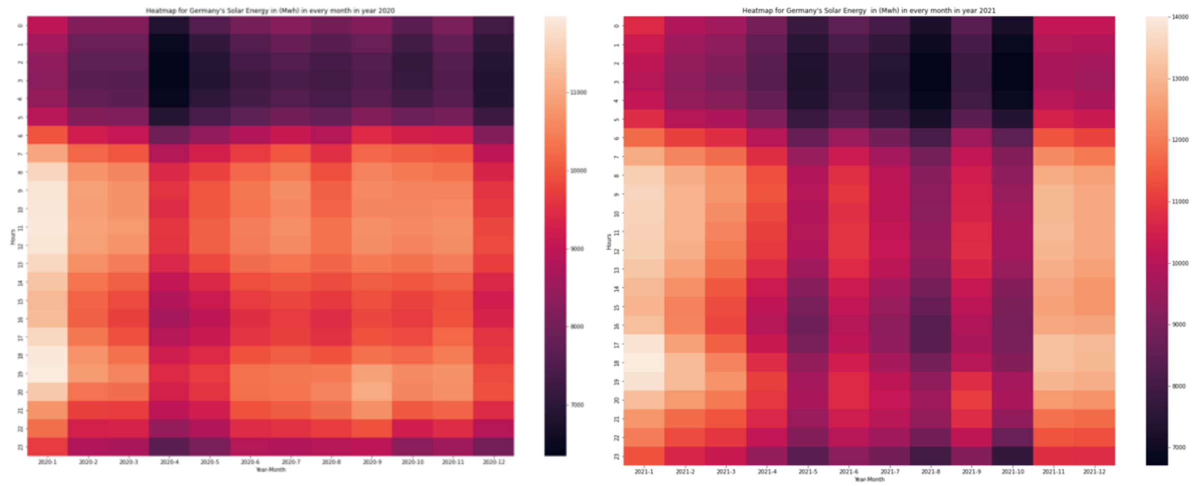


Figure.10 Headmap showing Solar energy in Germany per year 2020 and 2021

According to the heat map for the year 2020, solar production was at its highest between the hours of 7 and 8 pm and was generally modest during the rest of the year, with the exception of April and May. Comparing the production range for the months of April through October, we can see that Germany has the potential to have more solar energy in 2021. However, the generation was lower during these months than it was during the rest of 2021.

Similar to this, there is an offshore and onshore heatmap for wind energy production. It is obvious that, when comparing the two years, onshore wind contributes more to overall energy generation than offshore wind. Additionally, there is less wind generation onshore during the months of June through September. The wind generation in 2021 was lower than 2020, which may have contributed to the price increase.

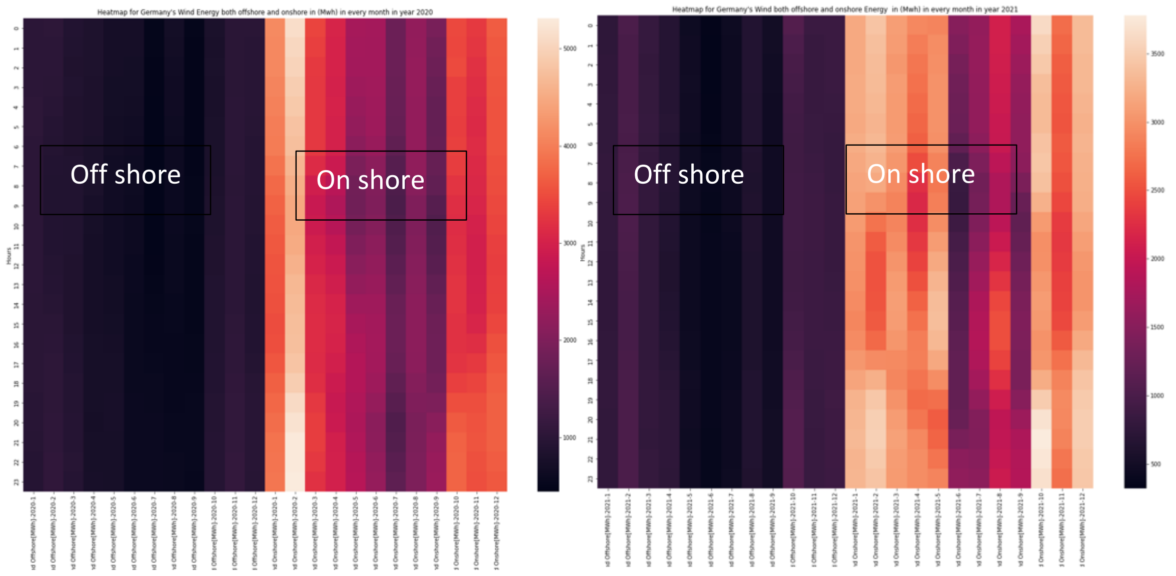
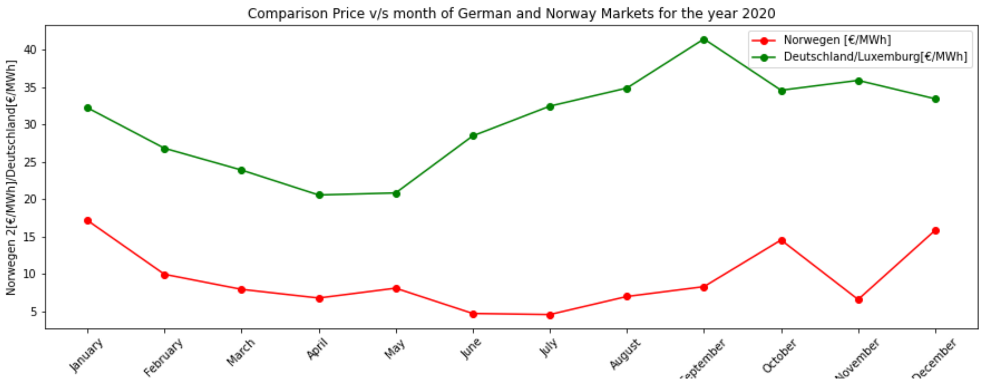


Figure.11 Headmap showing Wind energy (offshore and onshore) in Germany per year 2020 and 2021

We can infer from comparing the two Heatmaps that there will be less wind energy as sun energy increases.

Comparison of Energy Market between Norway and Germany.



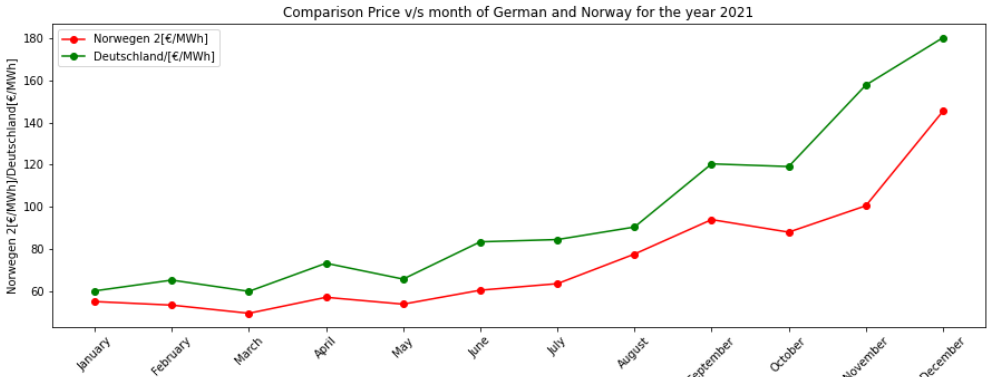


Figure.12 Graph showing Price of Germany v/s Norway per year 2020 and 2021

Although they follow the same trend, it is extremely obvious from the following numbers that Norway's prices are far lower than those in Germany. This is so because hydroelectric plants make up the majority of Norway's energy generation. Due to its location and nuclear fleet, France has typically served as the grid's greatest exporter up until 2020 point. But Norway surpassed France in the second half of 2020 to take the lead in Europe[7].

Germany produced 126TWh of wind energy in 2019, according to the International Energy Agency. Germany exported more power than any other nation in 2020 on windy days, when the country exports its extra energy.On calm days, however, Germany must import a large quantity of power due to the unpredictable nature of the wind. As a result, France, which benefits from scale in its largely nuclear-based energy market, was the world's largest net exporter in 2019[7].

This altered in the second half of 2020, as it does with many other things. Hydroelectric power accounts for almost all of Norway's domestic energy. The nation experienced above-average precipitation in 2020, and finally the reservoirs rose to their highest level since 2015.As a result, Norway's electricity cost decreased, making it a desirable power choice for associated nations [7].

Comparison of Energy Market between Germany and India.

The Indian Energy Exchange launched the Indian Day Ahead energy market on October 27/10/2021, so data prior to that is not available. Importing data from October 2021 to June 2022 was not flexible, so each month's data was loaded and combined together. For more information, see the data preprocessing section.

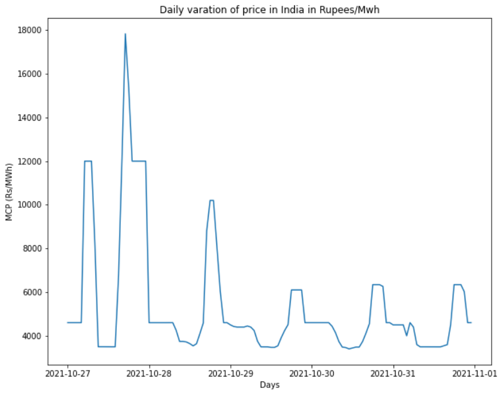


Figure.13 Graph showing Price varaition in India in a month(October 2021)

Due to rising incomes and rising living standards, India is now the world's third-largest energy consumer [8]. Most of the energy comes from coal,oil,gas,thermal,nuclear and hydro.Eventhough the renewable energy contibution to energy is parse it said that, Solar power is on track to surpass coal's share of the Indian power generation mix within two decades under the STEPS scenario, and even sooner under the Sustainable Development Scenario. Solar currently accounts for less than 4% of India's electricity generation, while coal accounts for nearly 70% for the time being [8].

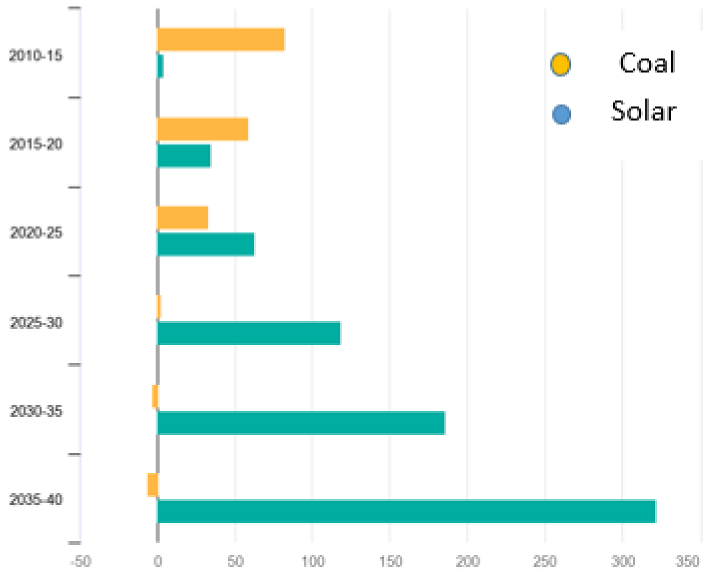


Fig.14 Changes in coal and solar capacity in India in the Stated Policies Scenario, 2010-2040[8]

Before comparing the energy markets of Germany and India, consider how energy generation and prices in India have changed over time. As shown in the graph below, as generation increases, so does the price decreases, and vice versa. We can't compare the generation and price trends because the data is so limited, but there was a price drop in November 2021 and a huge price increase in April 2022.

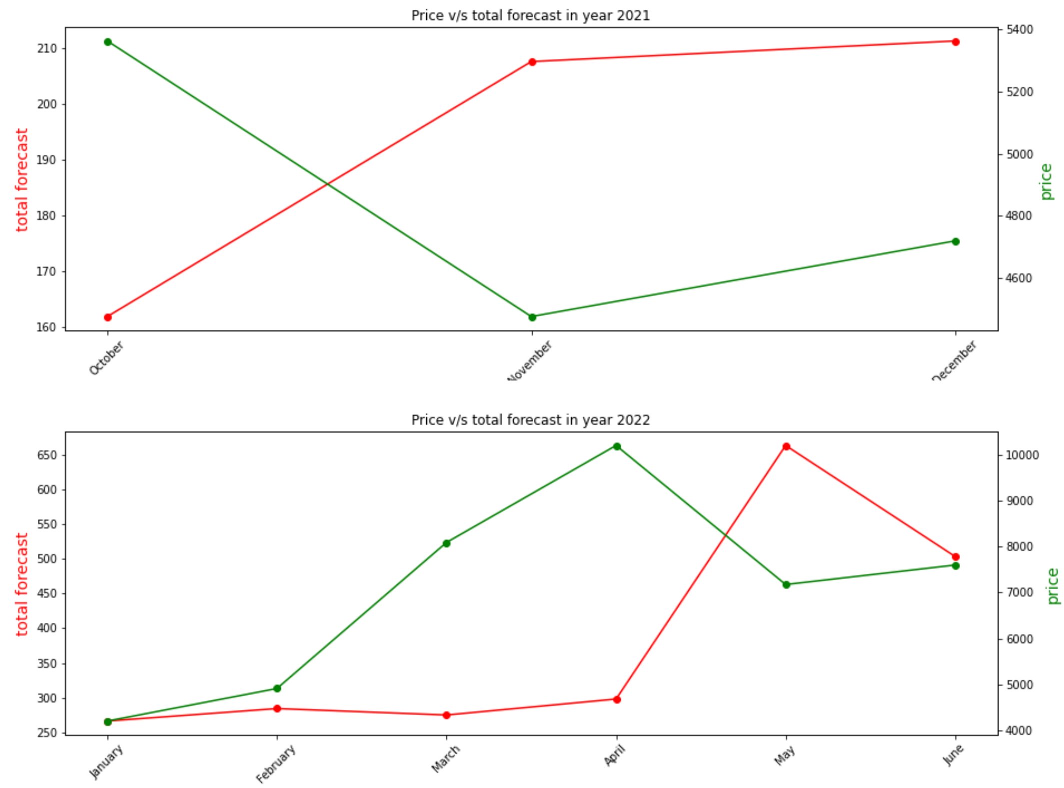


Fig.15 Price v/s Generation in India per year 2021 and 2022(limited data)

The solar energy produced or generated is very low in contrast to Germany, as illustrated by the heat map in Fig.15.and the figure below, which show the contribution of solar generation in India.As we can see that solar generation inIndia is very less compared to Germany and the total price trading dosenot depened upo the renewable energy produced in India, rather it comes from other conventional sources such as coal, thermal etc.

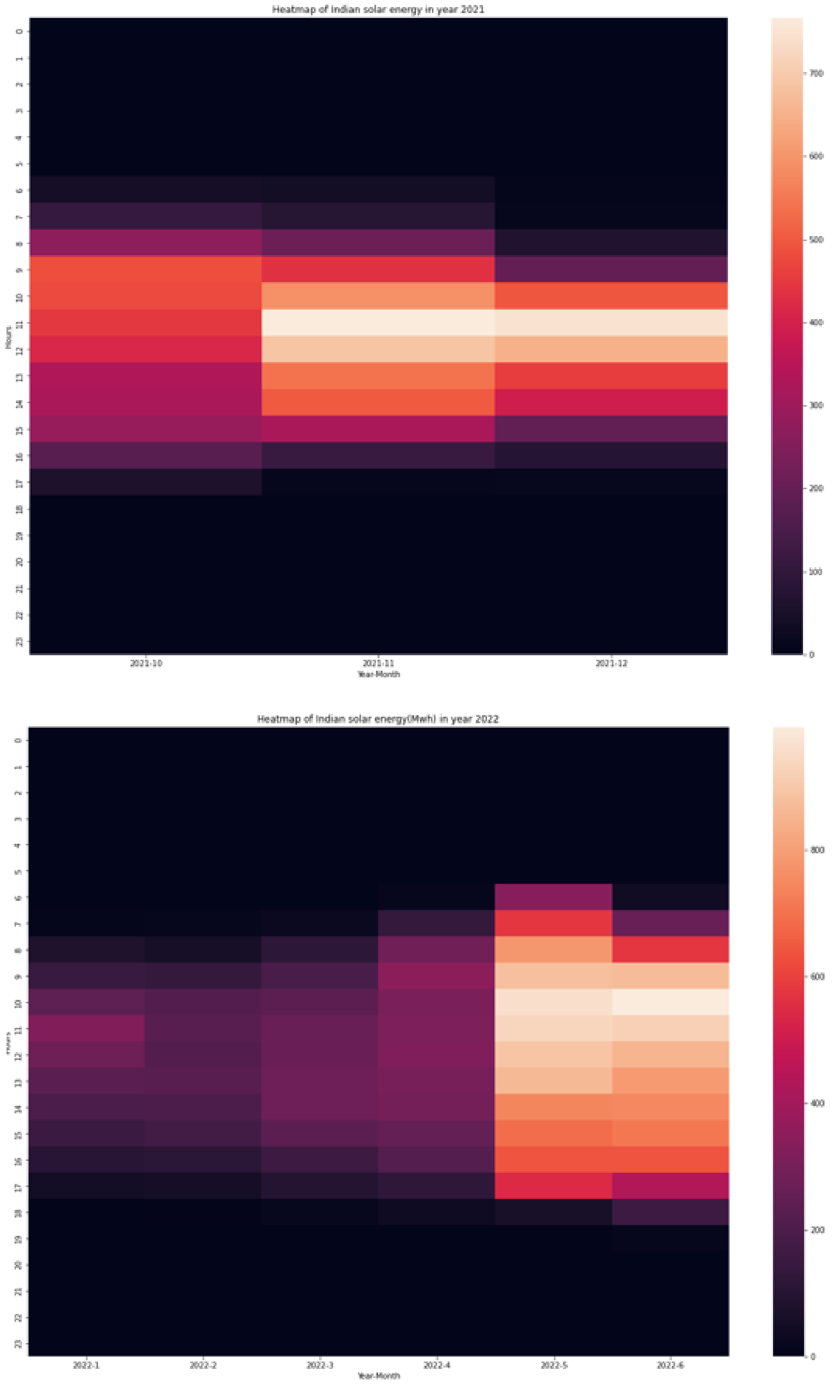


Fig.16 Heat map of Solar energy in India per year 2021 and 2022(limited data)

Before comparing both energy markets, it is important to compare them on the same scale, so Indian Rupees/Mwh were converted to German Euro using the most recent values. When comparing two different prices in the energy market, it is difficult to reach a proper conclusion because many factors depend and vary, for example, India's energy generation differs from Germany's generation. India's reliance on renewable energy is far lower than Germany's. However, based on the given time period, we can say that the German price per Meghawhatt hour is 178.75 €/MWh, while the Indian price is 70 (€/MWh. These figures are approximations that are calculated throughout the process and not be accurate as it is caluclated with approximate values.

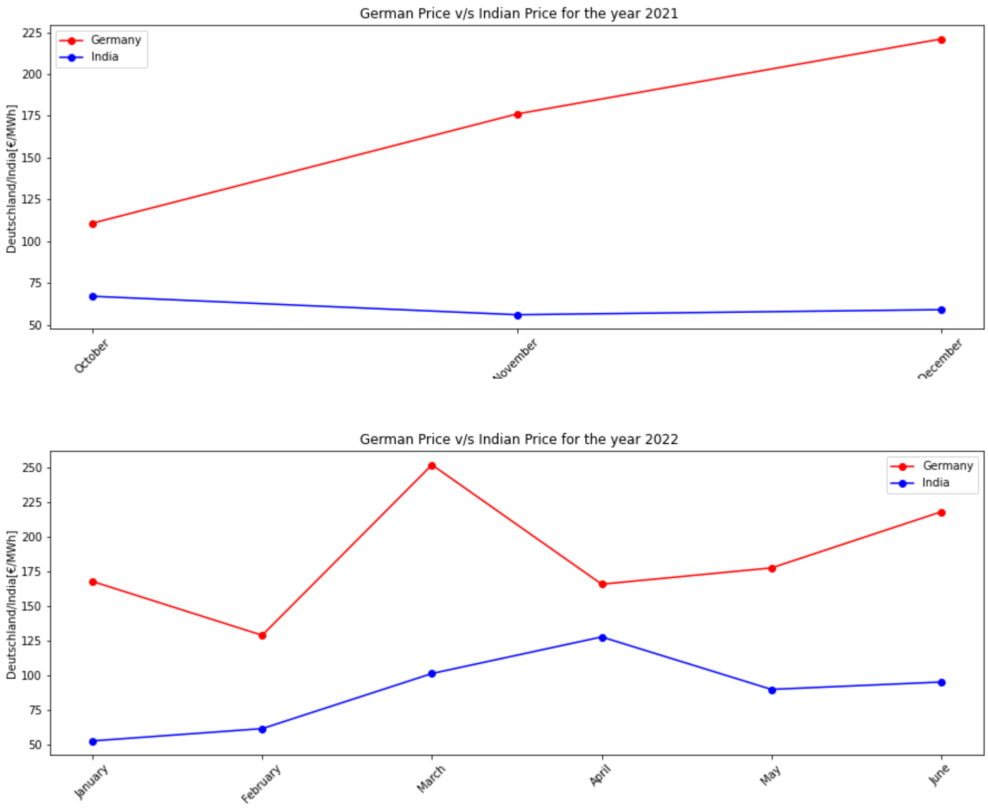


Fig. 17 Graph showing the varation of German and Indian price per year 2021 and 2022(limited data)

Conclusion.

The goal of this project was to comprehend a comparative analysis of the German market with those of Norway and India. In this process, wesaw how renewable energy generation has influenced the rise of the German energy market. We also looked at which months saw an increase in renewable energy generation, such as solar and wind. When compared to the Norwegian market, we can see that energy production in Norway is less expensive than in Germany. The energy price trends in India and Germany were also compared, where we averaged the prices to make a numerical calculation, despite the fact that India's data was limited.

Future Scope

Using a multiple linear regression model, the we can investigates the impact of intraday price determinants in Germany and explains how intraday supply side shocks can have varying price effects. In a contour diagram, we could show the causal relationship between German intraday prices and unforeseen intraday changes in the residual load [5].

Appendix

Dataset chosen for the above project can be downloaded using the below links.

https://www.smard.de/home - German Data

https://ember-climate.org/about/ - Norway Data

https://www.iexindia.com/ - Indian Data

Complete code implementation for the above project is available on Github, which can be accessed through the link below:

https://github.com/jeevasam30/Advacedproject1/

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