**OBJECTIVE**

The main purpose of this project is to perform an analysis on wind energy consumption of various countries for the time-period of 1995 -2014, various plots were used to display the findings. In this report three statistical tests were performed, and a linear regression model was built to predict the wind energy consumption for Germany for the next 3 decades.

**Data Collection**

**Data Description:** The main dataset is collection of key metrics maintained in ‘Our World in Data’ (<https://ourworldindata.org/energy>) by Hannah Ritchie, Max Roser and Pablo Rosado. The dataset has information on energy consumption (primary energy, per capita, and growth rates), energy mix and other relevant metrics.

Dataset link: <https://www.kaggle.com/datasets/pralabhpoudel/world-energy-consumption>

The columns which were used for analysis in this report were:

* country: geographic location
* year: year of observation
* gdp\_per\_capita: per capita GDP of a country
* wind\_share\_energy: share of primary energy consumption that comes from wind

**1. PART 1: COMPARISON OF RENEWABLE ENERGY OF VARIOUS COUNTRIES**

**1.1. Comparison of Total Energy Consumption**

Chart, line chart

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It is evident from figure 1 that the total energy consumption is increasing for developing countries like China and India, whereas for developed countries like Germany, UK, and USA the total energy consumption is almost constant.

**1.2. Comparison of Renewable Energy**

Chart, scatter chart

Description automatically generated

As many countries are moving towards renewable energy, it is observed that Germany has the highest growth rate in renewable energy share over the years, when compared to countries like China, UK, and USA.

**1.3. Comparison of Germany’s Renewable Energy**

Chart, line chart

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In further analysis, the percentage of wind energy share for Germany is rapidly growing as compared to other sources of energy like solar and biofuel i.e., at the end of 2014, the %energy share of wind energy was 4.07, solar energy was 2.51, and biofuel energy was 0.91.

**1.4. Comparison of GDP**

Chart, line chart

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It is observed that all the countries have shown an increase in GDP for the two decades. But the growth rate GDP for developing countries like China and India is very high, whereas for developed countries like Germany, and UK the growth rate of GDP is very small.

In addition to this, another method of performance comparison needs to be evaluated for comparing renewable energy resources over the time period.

**1.5. Correlation of GDP per capita and %wind energy share for Germany**

Chart, line chart, scatter chart

Description automatically generated

**Person coefficient: 0.98**

**Kendall coefficient: 0.95**

It can be inferred from the plot that there is a strong correlation between share of %wind energy share and GDP for Germany. Thus, it is concluded that an increase in GDP is directly related to the increase in wind energy consumption for Germany.

**1.6. Part 1: Outcomes**

Energy Consumption for developing countries is increasing more rapidly as compared to some developed countries. Similarly, the GDP is also increasing more rapidly as compared to some developed countries. Therefore, we can say that there is correlation between energy consumption and GDP for developing countries.

Also, Germany is one of the leading countries in wind energy consumption, and there is a direct correlation between wind energy share and GDP.

**2. Statistical Analysis**

**2.1 Probability of % Wind Energy Share**

We wanted to find out, if a random observation is picked from our dataset what is the probability that (a) more than 2% wind energy share, (b) less than 1% wind energy share, and (c) less than 0.5% wind energy share.

Assuming that the world's % wind energy share is normally distributed with mean = 0.5541424, sd = 1.24989, we determine the following:

**X = R.V. of % Wind Energy Share**

**X ~ N (x; 𝜇 = 0.5541424, σ = 1.24989)**

(a) more than 2% wind energy share

[P(X >= 2)] = 0.124

(b) less than 1% wind energy share

[P(X<=1)] = 0.64

(c) less than 0.5% wind energy share

[P(X<=0.5)] = 0.483

Therefore, if a random observation is picked from our dataset there is a 48.3% chance that the %wind energy share is less than 0.5%.

**2.2. Hypothesis test for equality of proportions**

We then performed a two-sample proportion test for the hypothesis that there is a significant difference between proportion of Germany's % wind energy share > 1.5% and rest of the World’s % wind energy share between the year 1995 & 2015.

H0: Germany\_prop - World\_prop = 0 (There is no significant difference)

H1: Germany\_prop - World\_prop ≠ 0 (There is a significant difference)

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As p value is < 0.05, we reject the null hypothesis (H0: Germany\_prop - World\_prop = 0) and conclude that there is a significant difference (H1: Germany\_prop - World\_prop ≠ 0). Therefore the proportion of Germany's wind energy share > 1.5 is greater than proportion of rest of the World's wind energy share > 1.5.

Chart, box and whisker chart

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Figure 6 describes the quartile range, minimum values and maximum values for the countries comparing their medians of % wind energy share. For Germany, it is observed that the median of % wind energy share is 1.86, whereas for rest of the World it is observed that the median of % wind energy share is 0.0515.

**2.3. Hypothesis test for equality of means**

We then performed a two-sample t-test for the hypothesis that there is a significant difference between the mean of mean of %wind energy share of Germany and Rest of the World the best, when the population variances are unknown.

H0: Mean\_Germany – Mean\_World = 0

H1: Mean\_Germany – Mean\_World ≠ 0

Text

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As p value is < 0.05, we reject the null hypothesis (H0: Mean\_Germany – Mean\_World = 0) and conclude that there is a significant difference (H1: Mean\_Germany – Mean\_World ≠ 0). We found that mean of %wind energy share of Germany is greater than Rest of the World.

Chart, bar chart

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**2.4. Part 2: Outcomes**

It clear from the above statistical tests that Germany’s wind energy usage is much higher than rest of the world’s wind energy usage.

**3. Part 3: Prediction Analytics**

Building a linear regression model for predicting wind energy share for next 30 years for Germany using the existing data with the help of Linear Regression Model.

**3.1 Assumptions for Linear Regression**

Linear regression is a useful statistical method we can use to understand the relationship between two variables, x and y. However, before we conduct linear regression, we must first make sure that four assumptions are met:

* **Linear relationship:** There exists a linear relationship between the independent variable, x, and the dependent variable, y.
* **Independence:**The residuals are independent. There is no correlation between consecutive residuals in time series data.
* **Homoscedasticity:**The residuals have constant variance at every level of x.
* **Normality:**The residuals of the model are normally distributed.

**3.2 Linear Regression Model**

Creating a linear regression model to predict % Wind energy Share for Germany for the years 2021-2050, using the existing data.

Chart, line chart

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![A screenshot of a computer

Description automatically generated with medium confidence]()

Model Summary

**Chart, diagram

Description automatically generated3.3 Diagnostic Plots**

**1. Residuals vs Fitted:** Used to check the linear relationship assumptions. A horizontal line, without distinct patterns is an indication for a linear relationship, what is good.

**2. Normal Q-Q:** The QQ plot of residuals can be used to visually check the normality assumption. The normal probability plot of residuals should approximately follow a straight line. In our example, all the points fall approximately along this reference line, so we can assume normality.

**3. Scale-Location (or Spread-Location):** Used to check the homogeneity of variance of the residuals (homoscedasticity). The horizontal line with equally spread points is a good indication of homoscedasticity. This is not the case in our example, where we have a heteroscedasticity problem.

**4. Residuals vs Leverage:** Used to identify influential cases, that is extreme values that might influence the regression results when included or excluded from the analysis. This plot will be described further in the next sections.

**3.4 Prediction using the model**

The following equation was obtained using Linear regression model:

Y = -455.655 + (0.228\*X)

**%Wind energy share = -455.655 + (0.228\*year)**

The Predicted values are:



**Conclusion**

After the analysis of various parameters, we can say that the Energy Consumption for developing countries is increasing more rapidly as compared to some developed countries. Similarly, the GDP is also increasing more rapidly as compared to some developed countries. Therefore, we can say that there is correlation between energy consumption and GDP for developing countries. Germany is one of the leading countries in wind energy consumption, and there is a strong positive correlation between wind energy share and GDP.

A two-sample proportion hypothesis test was performed to find out whether there is a significant difference between proportion of Germany's % wind energy share > 1.5% and rest of the World’s % wind energy share between the year 1995 & 2015. We found that proportion of Germany's wind energy share > 1.5 is greater than proportion of rest of the World's wind energy share > 1.5. Similarly, a two-sample t-test was performed for the hypothesis that there is a significant difference between the mean of mean of %wind energy share of Germany and Rest of the World the best, when the population variances are unknown. We found that mean of %wind energy share of Germany is greater than Rest of the World.

Lastly, a linear regression model was built to predict % Wind energy Share for Germany for the years 2021-2050, using the existing data.

**References**

1. <https://ourworldindata.org/energy>
2. <https://www.kaggle.com/datasets/pralabhpoudel/world-energy-consumption>
3. <https://sustainabledevelopment.un.org/index.php?page=view&type=99&nr=24&men=1449>
4. <https://en.wikipedia.org/wiki/Renewable_energy_in_Germany>
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