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# The Growth of Renewable Energy and Socio-Economic Analysis

**[*1]V Sumalatha**

[*1]Assistant Professor, Department of Statistics, Keshav Memorial Institute of Commerce and Sciences, Narayanaguda, Hyderabad, Telangana, India.

**Abstract**

This study examines trends and growth rates in renewable energy production across multiple countries using time series analysis and inferential statistical methods. The analysis is based on annual data covering renewable energy production, installed capacity, and key economic indicators, including gross domestic product (GDP), population, and electricity prices. To assess cross-country differences in renewable energy output, a one-way analysis of variance (ANOVA) is employed to test the null hypothesis that all countries exhibit equal mean renewable energy production against the alternative hypothesis that at least one country differs significantly. The results provide quantitative evidence of variability in renewable energy performance across countries, highlighting distinct production patterns and growth dynamics. These findings offer valuable insights for policymakers, researchers, and industry stakeholders by underscoring the need for country-specific strategies to promote and accelerate the global transition to renewable energy.

**Keywords:** Renewable energy, Time series analysis, One-way ANOVA, Cross-country comparison, Solar, Wind, Geothermal, Biomass, Hydro.

## 1. Introduction

Renewable energy (also called green energy) is energy made from renewable natural resources that are replenished on a human timescale. The most widely used renewable energy types are solar energy, wind power, and hydropower. Bioenergy and geothermal power are also significant in some countries Unlike non-renewable energy (coal, oil, natural gas) which will eventually run out and cause pollution, renewable sources are cleaner, sustainable, and help reduce dependence on fossil fuels. A large majority of worldwide newly installed electricity capacity is now renewable. Renewable energy sources, such as solar and wind power, have seen significant cost reductions over the past decade, making them more competitive with traditional fossil fuels. Renewable energy is the future of global energy systems essential for reducing greenhouse gas emissions. While challenges like cost and storage exist, advancements in technology are making renewables more efficient and affordable every year

## 2. Problem Statement

The Project aims to analyse the trends and growth patterns of renewable energy production across various countries & years and studying the relationship between production of renewable energy & electricity prices and also examining whether significant difference exist in the average renewable energy production across different countries.

## 3. Objectives

i). Analyse the trends in Renewable energy across years and countries

ii). To examine whether significant differences exist in the average renewable energy production across countries by applying one-way ANOVA

## 4. Methods and Materials

**i). Data Collection:** The Dataset is of Secondary datatype. The Dataset has been collected from the website Kaggle.com: "Global Renewable Energy & Indicators Dataset". Kaggle is a platform enables users to find and publish datasets. The dataset contains various Energy types across the world year-wise & it's production in (GWh).

**ii). Description of Data:** The Dataset contains yearly renewable energy types from 2000-2023. The original dataset includes 2000 rows representing various countries and years and having 150 columns including the following categories: Energy Type (Solar, Wind, Hydro, Geothermal, etc.), production (GWh), Installed capacity, Investments. The dataset is pre-processed selected some of the factors from the original dataset. After preprocessing the dataset, we have the following number of rows and columns: we have 992 rows and 8 columns. The Dataset consists of 8 columns (Features) such as Country, Year, Energy Type, Production, Installed Capacity, Population, GDP, Electricity Prices.

**iii). Percentage Change:** The percentage change method is a way to measure how much a variable (like production, sales, or revenue) has increased or decreased over time in

***Corresponding Author:** V Sumalatha

percentage terms. It helps in understanding the rate of growth rather than just the absolute increase. Concept: The percentage change compares the value of a variable in one period with its value in the previous period.

It is expressed as a Percentage Change =

$$\frac{New\ value - old\ value}{old\ value} \text{X } 100$$

**Interpret the Results**
Positive % → Growth (increase).
Negative % → Decline (decrease).
Zero%→No growth

**iv). Moving Average**
Trend analysis using the Moving Average Method is a statistical technique used to smooth out short-term fluctuations in time series data and highlight the long-term trend. It is especially useful in analysing economic, business, and renewable energy production data Concept of Moving Average Method A moving average is an average of a fixed number of consecutive data points in a time series. As new data points come in, the average "moves forward," dropping the earliest value and including the latest one. This helps reduce random variations (noise) and makes the underlying trend clearer.

$$SMA_k = \frac{p_{n-k+1} + p_{n-k+2} + \cdots + p_n}{k} = \frac{1}{k}\sum_{i=n-k+1}^{n} p_i$$

**v). Anova**
One-way ANOVA (Analysis of Variance) is a statistical method used to determine whether there are significant differences between the means of three or more independent groups based on a single factor (independent variable).
Ex:- Null Hypothesis ($H_0$): All group means are equal. Alternative Hypothesis ($H_1$): At least one group mean is different.
It works by comparing: Between-group variance (differences caused by group factor). Within-group variance (random variation inside each group). The ratio of these variances gives the F-statistic, which tells us whether to reject $H_0$

| Source of Variation | Sum of Squares | Degrees of Freedom | Mean Squares (MS) | F |
|---|---|---|---|---|
| Within | $SS_w = \sum_{j=1}^{k}\sum_{j=1}^{l}(X-\bar{X}_j)^2$ | $df_w = k-1$ | $MS_w = \frac{SS_w}{df_w}$ | $F = \frac{MS_b}{MS_w}$ |
| Between | $SS_b = \sum_{j=1}^{k}(\bar{X}_j - \bar{X})^2$ | $df_b = n-k$ | $MS_b = \frac{SS_b}{df_b}$ | |
| Total | $SS_t = \sum_{j=1}^{n}(\bar{X}_j - \bar{X})^2$ | $df_t = n-1$ | | |

## 5. Results and Discussions

**i). India**
The chart for India reveals a dynamic energy production landscape. Solar and Wind energy show significant upward trends, indicating a strong push towards renewable energy sources. Hydro energy production appears relatively stable, while Geothermal and Biomass show more modest contributions or fluctuations. The consistent growth in solar and wind suggests India's commitment to expanding its renewable energy capacity, likely driven by policy support and decreasing technology costs.

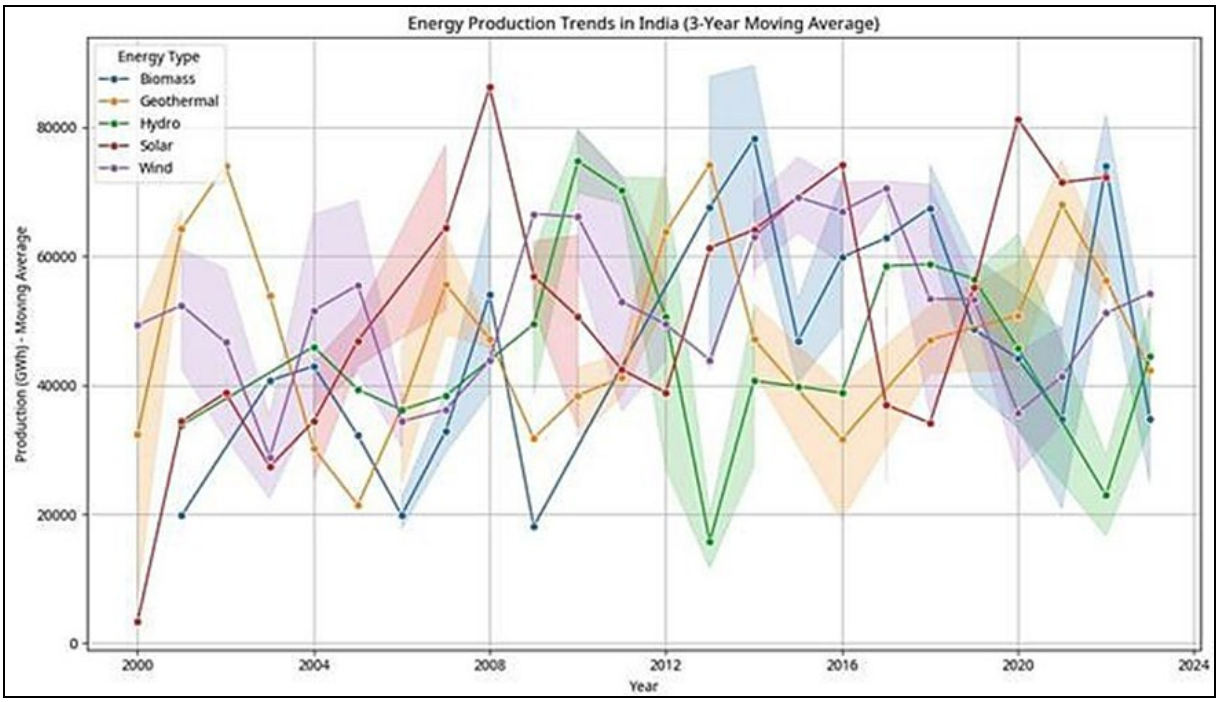


**Fig 1:** Energy Production Trends in India (3-Year Moving Average)

**ii). Russia**
In Russia, the energy production trends are distinct. Hydro energy appears to be a dominant and stable source, reflecting the country's extensive hydropower infrastructure. Other renewable sources like Solar, Wind, Geothermal, and Biomass show varying levels of development, with some exhibiting nascent growth. The overall pattern suggests a reliance on established energy sources, with gradual exploration of newer renewables.

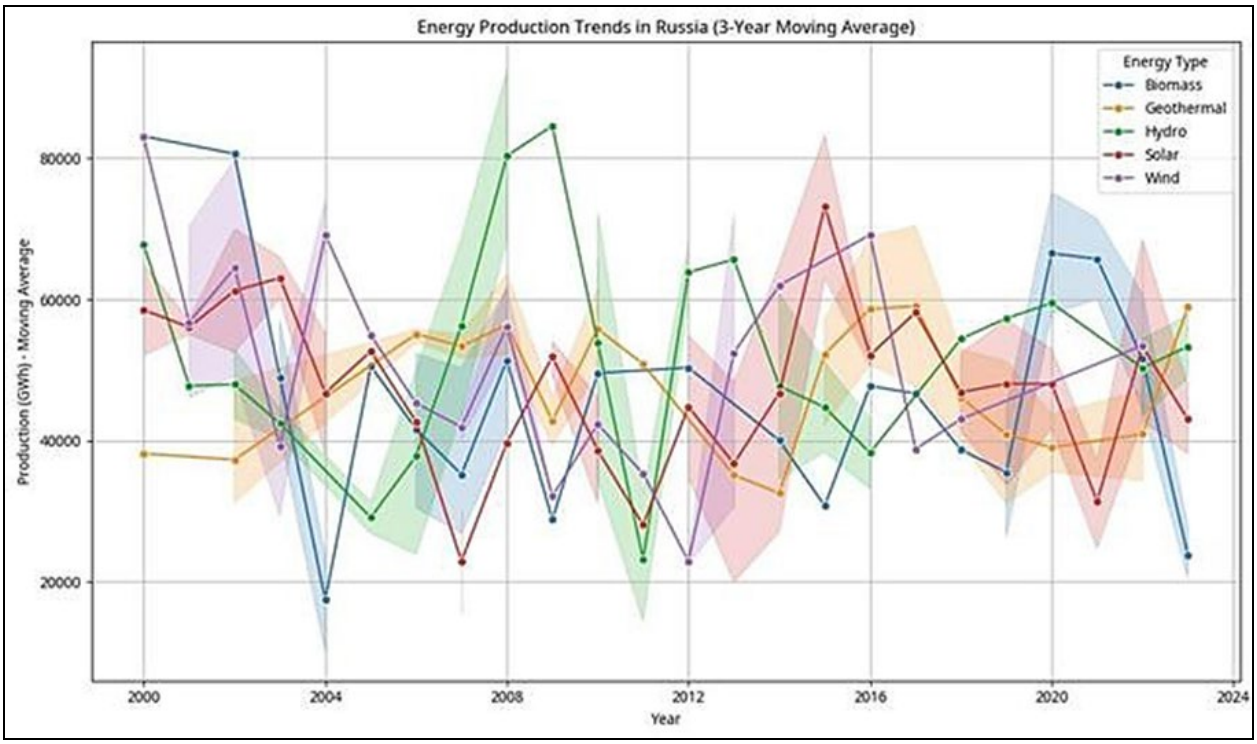


**Fig 2:** Energy Production Trends in Russia (3-Year Moving Average)

**iii). USA**

For the USA, the analysis indicates a diversified energy portfolio. Solar and Wind energy have experienced substantial growth over the years, aligning with global trends towards decarbonization and increased investment in clean energy technologies. Hydro and Biomass maintain a steady presence, contributing to the overall energy mix. Geothermal energy also shows a consistent, albeit smaller, contribution. The trends reflect a strategic shift towards a more sustainable and resilient energy system.

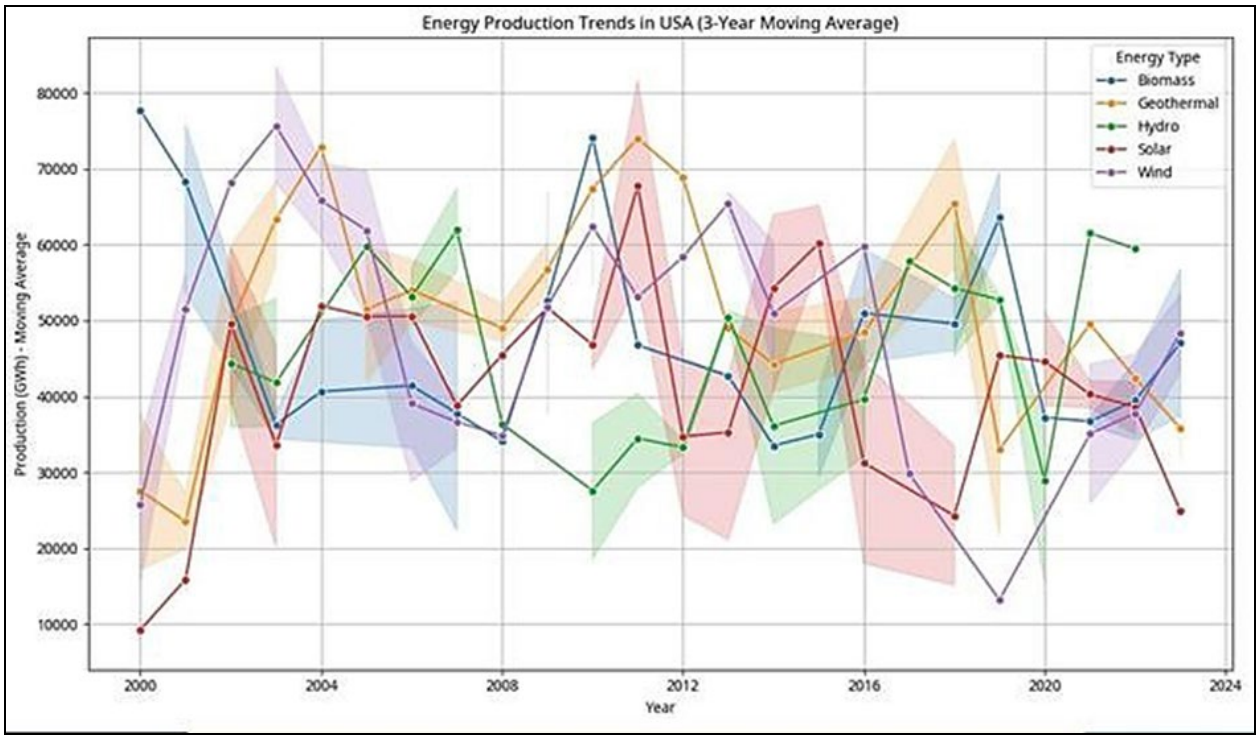


**Fig 3:** Energy Production Trends in USA (3-Year Moving Average)

**iv). China**

China's energy production trends are characterized by remarkable expansion, particularly in Solar and Wind power. The charts demonstrate an aggressive deployment of these renewable technologies, positioning China as a global leader in renewable energy capacity. Hydro energy also plays a crucial role, contributing significantly to the country's energy supply. Biomass and Geothermal show steady, though less pronounced, growth. This rapid growth underscores China's dual objectives of meeting escalating energy demand and addressing environmental concerns.

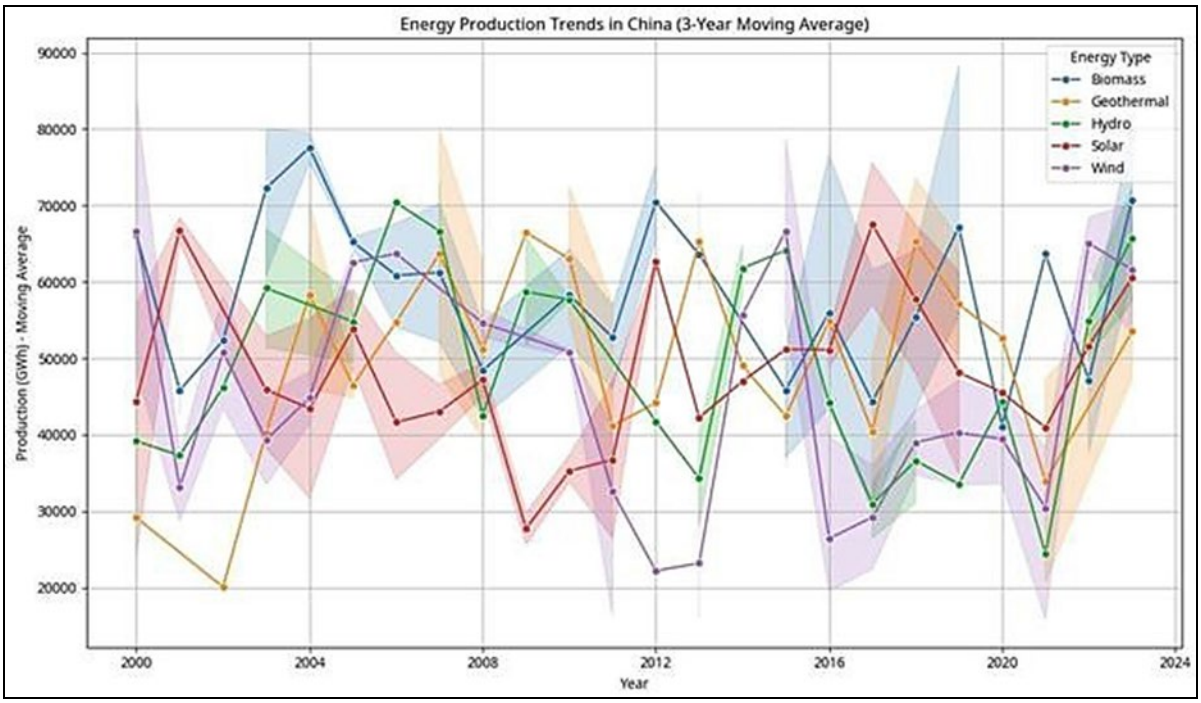


**Fig 4:** Energy production in China (3-Year Moving Average)

**Hypotheses**

**Null Hypothesis ($H_0$):** All countries have the same mean renewable production.

**Alternative Hypothesis ($H_1$):** At least one country differs in its mean renewable production.

The Output of ANOVA Analysis is

**F-Statistic:** 0.8408

**P – Value:** 0.471

Since the p-value (0.4716) is greater than the conventional significance level of 0.05, we fail to reject the null hypothesis ($H_0$).

Based on the calculated p-value: If P-value < 0.05: We reject the null hypothesis. This means that there is sufficient evidence to conclude that the average renewable production differs significantly among the countries. If P-value >= 0.05: We fail to reject the null hypothesis. This means that there is not enough evidence to conclude that the average renewable production differs significantly among the countries.

## 6. Conclusion

This research examined the annual production growth patterns for different renewable energy types across multiple countries. From this analysis we can conclude that solar energy demonstrates the highest growth rates across all countries analysing the trend patterns reveals that consistent growth in production and capacity and in many regions. By examining the relation between production of renewable energy sources and electricity prices across different countries it can be concluded that there is generally a very weak or no significant linear relationship between electricity production & electricity prices in India, Russia, USA and China during the observed time period. While India showed a statistically significant but weak positive correlation, the other countries exhibited negligible or non-significant relationships.

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