Social Science Journal for Advanced Research *Peer Reviewed and Refereed Journal*
ISSN (Online): 2583-0074
Volume-4 Issue-1 || January 2024 || PP. 47-51 DOI: 10.5281/zenodo.10638528

An Econometric Analysis of Electricity Consumption from Renewable Energy in India

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Received: 22-12-2023	Revised: 08-01-2024	Accepted: 27-01-2024

ABSTRACT
In the wake of the oil crises of the 1970s, the world found itself at the crossroads, confronted by the vulnerability and volatility of over dependence on fossil fuels. These transformative events ignited a paradigm shift towards renewable energy sources, with solar energy emerging as a beacon of hope. Solar energy offered a viable means for achieving the elemental goal of greener, sustainable as well as economical and efficient energy resource for driving industrial growth. It provided an opportunity to reduce excessive reliance on imported oil, decrease carbon emissions, and thus create a more decentralized and resilient energy infrastructure. This study aims to verify the link between the progressive increase in solar energy consumption and the country's economic advancement. The study also focuses on the how the Indian Government has invested in and employed the potential of solar energy after 1990, i.e., after becoming a liberalized economy by adopting the LPG (Liberalization, Privatization and Globalization). In this context, the present paper determines the main driving forces of solar energy consumption in India during 2007–2022. The time series data of solar energy generation and domestic energy consumption are retrieved from Energy Statistics Data published by Ministry of Statistics and Program Implementation. The data has been analyzed by using the Compound Annual Growth Rate (CAGR) renewable energy generation as well as domestic electricity consumption. Furthermore, Simple Linear Regression technique has been used to measure the impact of REG on domestic electricity consumption.

Keywords: *consumption, renewable energy, electricity, compound annual growth rate*

JEL Classification: *D12, D16, E21, N75, Q43*

I. INTRODUCTION

For India's renewable energy industry, 2021 was a turning point in which important milestones were achieved even as the country recovered from the Covid-19 epidemic. After exceeding the 40% installed capacity target from the non-fossil sources in November 2021 alone, India managed to accomplish one of its Paris 2030 Nationally Determined Contributions (NDC) commitments nine years earlier. On August 12th, 2021, the nation crossed the benchmark of 100 GW installed renewable energy capacity (excluding big hydro). India is now ranked fourth in terms of installed RE capacity in the world(MNRE, 2022). Green energy alternatives are receiving more attention from economies that rely significantly on energy outsourced from fossil fuels. Green or sustainable energy sources are referred to as "green energy" in common parlance. Solar, wind, rain, and geothermal heat are all environmentally friendly forms of energy that can be employed. The use of green energy has several societal advantages. Prominent amongst these are, access to energy resources at lower costs, improved air quality and public health, and an increase in job creation and boost to the overall economic growth. Green energy conservation is widely acknowledged as being essential to lowering the carbon footprints in the efforts to contain Global warming. Significantly and alarmingly, two thirds of the world's energy production and consumption add to carbon footprints, thus endangering the planet. Utilising green energy has a substantial impact on lowering carbon emissions, (Saqib, 2022).With decades-long environmental changes, climate change and its effects have become a global phenomenon. Anthropogenic greenhouse gas (GHG) emissions are the key contributors and the cause of climate change. The burning of oil, coal, and natural gas results in the release of carbon dioxide, which is primarily what causes anthropogenic greenhouse gas emissions by raising air concentration and affecting future global climatic conditions (Blanco et al., 2014; Sarkodie et al., 2021). This grim backdrop calls for prompt transition to effective, efficient but cleaner and greener sources of energy in the form of green-energy.

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Although, the demand for a switch to sustainable and low-carbon energy sources is growing, clean energy solutions are still underdeveloped both in the emerging and the advanced economies. According to studies on the climate-led urban development debate by the Intergovernmental Panel on Climate Change, the change from a non-renewable source, such as fossil fuel energy sources, to a sustainable energy (renewables), such as wind, photovoltaic, and hydro energy, would foster economic growth in the emerging markets, (Bekun, 2022). In this league, the United Nations Sustainable Development Goal 7, which aims to achieve global access to clean, sustainable, and cheap energy by 2030, was designated as a priority for enhancing the quality of life in rural regions and expediting their energy transition. The stated intent in this regard is to not only focus on the electrification but also to provide access to clean fuels for cooking. However, understanding the fuels consumption of rural households and its evolution towards reaching a clean energy transition is complex due to the high dependence on different socioeconomic, behavioural, and geographic factors, subject as well to national policies (Dominguez et al., 2021). Set against this canvas, the present empirical study focuses on the relationships between renewable energy generation and its possible impact on domestic electricity consumption in the Indian context.

II. REVIEW OF LITERATURE

Sarkhanov & Huseynli, 2022 - The study focused on the measurement of the effects of the renewable energy sector of Kazakhstan and Kyrgyzstan on the growth of economy. The authors used the data of renewable energy consumption and economic growth from 1996 to 2018. Simple Linear Regression (SLR) and its Multicollinearity and Normality Test Assumption were employed to estimate the results for both states. Positive relationship between economic growth and renewable energy consumption was determined.

Radmehr et al., 2022 – The study investigated the connection between the Ecological Footprint (EFP) and the Gross Domestic Product (GDP) as well as the consumption of Renewable Energy (REC). The study was based on the data of the G7 countries from 1990 to 2018. A panel simulation model with a generalised method of moments (GMM) was used for the overall tabulations. The authors discovered that the G7 nations' GDP, ecological footprint, and REC are inversely correlated. The findings of the study indicate that financial globalisation has had a negative and significant impact. Moreover, trade operations have a positive and significant impact on the REC and GDP of a country.

Lyeonov et al., 2019 - The study examined the connections between final Per Capita Energy Consumption (PICE), Renewable Energy (RE), greenhouse gas emissions, and the Gross Domestic Product (GDP) per capita (per person). Data from the European Union (EU) countries between 2008 and 2016 was used for the investigations. Pedroni Panel Cointegration Test, the Panel Unit Root Test, the Fully Modified Ordinary Least Square (FMOLS), and the Dynamic Ordinary Least Square (DOLS), and the Panel Cointegration techniques were enlisted for the analysis. The results established that the effects of GHG, PICE, and RE on the GDP of EU member states have the same effect on FMOLS and DOLD. Additionally, it obtained green investment (PICE) per unit change to increase GDP by 6.4%, reduce GHG emissions by 3.8%, and increase total energy consumption by 5.6%.

Ntanos et al., 2018- The study analysed the correlation between energy use and per-capita GDP in 25 European nations. The period of the study ranges from 2007 to 2016. Tools for evaluation included: Cluster Analysis, Descriptive Statistics, and the Autoregressive Distribution Lag (ARDL) model. In the long run, GDP was taken as the dependent variable on labour force, gross fixed capital formation, and consumption of renewable and non-renewable energy sources (RES). The findings of the study marked a strong relationship between GDP growth and REC.

III. METHODOLOGY

3.1 Data Source

Data for the present research were obtained from the Ministry of New and Renewable energy, and the Ministry of Power. The data for the study pertains to the time period from 2007 to 2022. It includes energy generation from renewable energy sources (Hydro, Nuclear, wind and solar), and domestic electricity consumption in Giga watt per hour (GWh).

3.2 Estimation Techniques

The Compound Annual Growth Rate (CAGR), Graphical Representation, and the Simple Linear Regression (SLR) techniques were used for the overall analysis.

CAGR is a measure of the average annual growth rate of an investment over a specified period, assuming that the profits are reinvested at the end of each year.

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$$CAGR = \left(\frac{EV}{BV}\right)^{\frac{1}{n}} - 1 \dots\dots\dots\dots\dots\dots\dots (1)$$

Where:

EV=Ending value
BV=Beginning value
n=Number of years

Regression is the work and way of connecting one thing with another. Statistical regression: It is defined as the dependency that emerges because of the relationship between two variables and the interaction of their values. If a single independent variable is used, it is called the Univariate Regression Analysis.
The equation for a simple Regression Model can be devised as-

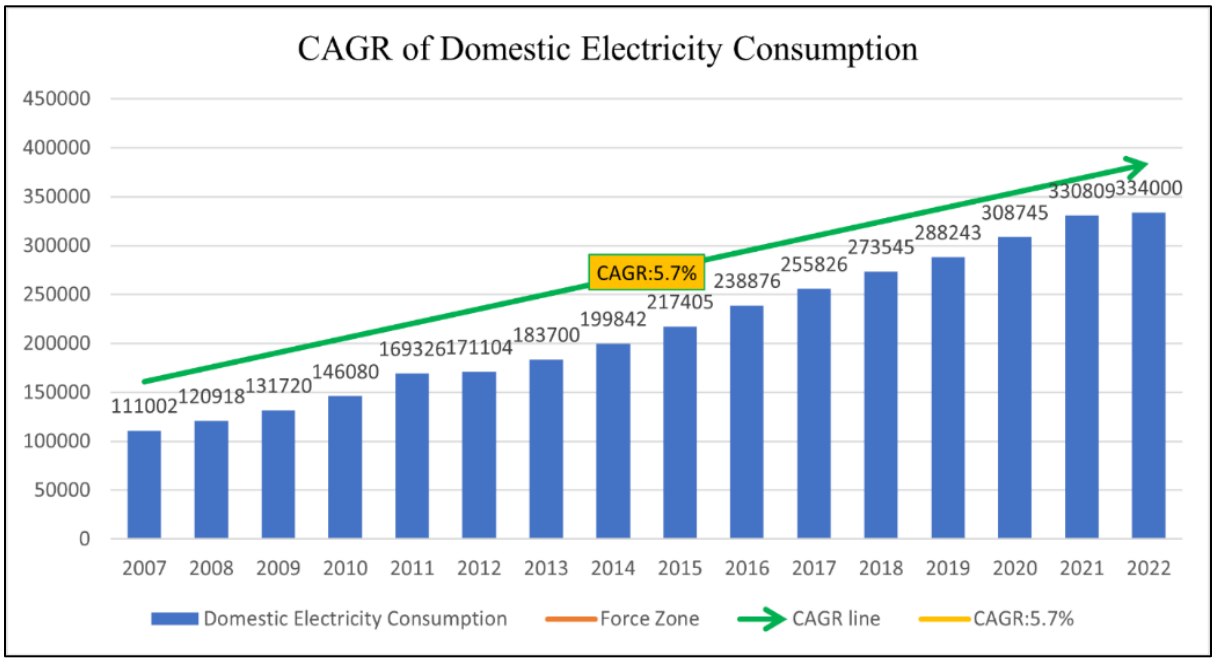
$$y = \alpha_0 + \beta_1 X + \varepsilon \dots\dots\dots\dots (2)$$

Where:

Y: The dependent variable is X Independent variable.
α0: It is a constant value and is the value of Y when X = 0.
β1: It is the regression coefficient. It expresses the change that will occur in the dependent variable in response to 1 unit change in the independent variable.
ε; It is the random error term. It is assumed that the dependent variable contains a certain error. There is no error in the argument.

IV. ANALYSIS AND RESULT

Graph: 1 CAGR of Domestic Electricity Consumption



Source: Ministry of New Renewable Resources, Estimated by Author

The result of the CAGR calculation is 0.057 or 5.7%. This means that the domestic electricity consumption experienced an average annual growth rate of 5.7% over the period of sixteen-years. It indicates that if the domestic electricity consumption continued to grow at the same rate of 5.7% every year, the domestic electricity consumption would have reached an ending value of 3,34,000 GWh from its beginning value of 1,11,002 GWh after sixteen years. It's important to note that CAGR assumes steady growth over the entire period, which may not always reflect the actual performance of the domestic electricity consumption. Additionally, CAGR does not consider the volatility or fluctuations that may have occurred within the

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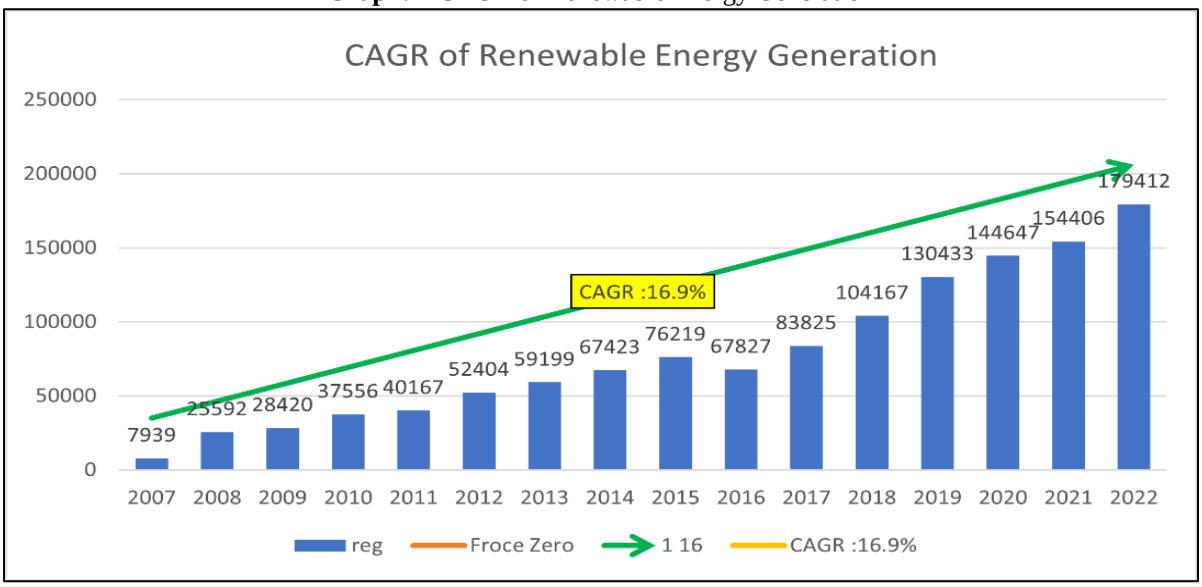
period. Therefore, it's essential to consider other factors and conduct a comprehensive analysis when evaluating domestic electricity consumption.

Graph: 2 CAGR of Renewable Energy Generation



Source: Ministry of New Renewable Resources, Estimated by Author

The result of the CAGR calculation is 0.169 or 16.9%. This means that the renewable energy generation experienced an average annual growth rate of 16.9% over the sixteen-year period. It indicates that if the renewable energy generation continued to grow at the same rate of 16.9% every year, the renewable energy generation would have reached an ending value of 179412 GWh from its beginning value of 7939GWh after sixteen years.
A simple regression model was created to measure the factors affecting domestic electricity consumption as follows:

$$\textit{Domestic Electricity Consumption}(y) = \alpha_0 + \beta_1 \textit{ renewable energy generation}(X) + \varepsilon \ldots\ldots\ldots (3)$$

It can be shown that there is a substantial association between these series based on the data in Table 3. The model's ability to explain the one GWh increase in generation of renewable energy causes an increase in the domestic energy consumption by 1.437 GWh. In this context, the constant value implies that if the renewable energy generation is zero, then the domestic electricity consumption is 104428.79 GWh in India. The R2 coefficient's value of 0.946 indicates that the 94% of the total variation in dependent variable is explained by the model. At a 95% confidence level, the model is deemed to produce meaningful findings.

Table 3: Linear Regression Analysis Results

Domestic Energy Consumption	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Renewable Energy Generation	1.437	.091	15.73	0	1.241	1.633	***
Constant	104428.79	8471.328	12.33	0	86259.6	122597.98	***

Mean dependent var	217571.313	SD dependent var	74772.850
R-squared	0.946	Number of obs	16
F-test	247.510	Prob > F	0.000
Akaike crit. (AIC)	360.645	Bayesian crit. (BIC)	362.191

*** $p<.01$, ** $p<.05$, * $p<.1$

Source: Estimated by the Author

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Notably, Economic expansion and renewable energy generation are positively correlated with domestic electricity consumption.

V. CONCLUSION

Harnessing Renewable Energy sources so as to cater to the ever-increasing demand for cleaner fuels at affordable costs with zero-carbon emissions is a compelling need for all countries across the globe. Moreover, availability of cleaner and green energy resources not only fuels the industrial momentum but also reaps higher economic dividends for the countries. The stated objective was empirically analyzed in this investigation. Significantly, the study determined a positive relationship between renewable energy generation and domestic electricity consumption. The Compound Annual Growth Rate of domestic electricity consumption is 5.7%, and the renewable energy generation is 16.9% for sixteen years continuously. By employing the Simple Linear Regression Model, it was determined that 1.43 Units change of domestic electricity consumption can be affected from merely one Unit change of Renewable Energy generation. Thus, Renewable Energy can be insourced as a significant contributor in providing sustained, affordable and cleaner electricity for domestic consumption. This would not only aid in better quality of life with access to healthier and economical access to energy but would be a catalyst in furthering the overall economic growth of the country.

However, the present investigation considers only two variables for analysis which could be a key limitation of this study. A more expansive empirical study can include other aspects like ceteris paribus. India is located on the tropical belt. The country is privileged with ubiquitously available solar energy that needs to be tapped to light up Nation's homes, industries and propel Green Economy revolution in the country. More investments in the solar energy research and development (R&D) initiatives would ensure that India becomes a top solar energy generation nation in the world. Hence, the core findings of the study also seek to garner the attention of the policymakers to insist on mechanisms that connect the Indian rural and urban households with RE in the efforts to meet the Nation's target of Zero- Carbon emissions. The extension of the National Solar mission for residential use of solar PV is the much-needed leap that the nation needs to take in this league.

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