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The Trends and Progress of Renewable and Non-renewable Energy Consumption in India

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Abstract
This study investigates the trends and progress of renewable and non-renewable energy consumption in India from 1980 to 2021. It analyses the energy consumption pattern using statistical methods, including Least Squares for both renewable and non-renewable energy data. The results show a clear increase in renewable energy use, reflecting government efforts and growing awareness. However, non-renewable energy still forms a large part of India's energy mix. The Least Squares method reveals long-term trends, highlighting a gradual shift toward cleaner sources. This study provides valuable insights for future energy planning and supports the transition to a more sustainable energy system in India.

Keywords: *Energy Consumption pattern in India, Least Squares Renewable Energy Consumption, Least Squares Non-renewable Energy Consumption.*

I. INTRODUCTION

Energy is essential for human needs and plays a determining role in the development of the Economy. Due to rapid industrialization, urbanization, and high economic growth targets, energy demand has significantly increased during the last few decades. In 2022, India ranked fourth in the world in terms of energy consumption, at 31.963 (Quadrillion BTUs). In first place was China, which had the most significant energy use, valued at 165.158 BTUs. Second place was the United States with 97.907 BTUs.

India

India is a rapidly developing country with a growing economy and an increased demand for energy. Coal was the primary source of energy 16.432 (51.4), petroleum consumption was the second leading source 9.529 (29.80%), after renewable energy's highest consumption with 3.013 (9.43%) BTUs. Gas and oil are 2.468 (7.73%). Nuclear energy consumption was 0.521 (1.63%) Btu.

II. REVIEW OF LITERATURE

Ahmed et al. (2022) examine the link between energy consumption and greenhouse gas emissions in China, India, the USA, and Russia using advanced machine learning models. They predict future emissions trends and highlight that fossil fuel use, especially coal, petroleum, and natural gas, is the main driver of CO_2, methane, and N_2O emissions. The study shows rising emissions in China and India, while the USA and Russia show slight declines. Their findings stress the urgent need to adopt clean, sustainable practices to mitigate climate change.

Saine et al. (2022) highlight the importance of net-zero energy consumption buildings (nZECBs) in reducing Indians' energy demand and carbon emissions. The study outlines passive and active design strategies, renewable energy integration, and supportive government policies. It emphasises energy efficiency and sustainable construction as crucial for Indians' growing urban needs while also addressing technical and economic challenges in adopting nZECBs.

Franco et al. (2017) explore how rapid urbanisation in India is driving a surge in energy consumption and CO_2 emissions. The study highlights that cities are growing quickly, putting pressure on resources and energy infrastructure. Urban growth is linked to increased demand for electricity, fossil fuels, and transportation, all contributing to environmental stress. Their work provides a comprehensive view of the urban energy-emissions nexus and offers strategic solutions to effectively India's urban transition.

Kumar and Vimala (2016) analyse energy consumption trends in India, emphasizing its crucial role in economic development. They observe that energy demand is rapidly rising due to industrial growth, urbanization, and population increase. The study highlights a strong link between energy use and GDP growth and notes regional disparities and dependency on fossil. It suggests that improving energy efficiency and expanding renewable energy are essential to ensure sustainable growth and reduce environmental impact.

Wang and Li (2016) conducted a comparative analysis of energy consumption in China and India using the IPAT and LMDI models. They found that both countries' economic growth and income levels are the major drivers of rising energy demand. In China, technological progress has helped reduce energy intensity, and in India, energy efficiency and reduced environmental impact.

Kar and Gopakumar (2015) examine the rapid growth and potential of renewable energy in India, emphasizing its role in reducing import dependency and ensuring energy security. The study highlights government initiatives, policy support, and financial incentives promoting solar, wind, hydro, and biomass energy. Despite challenges like high costs, low efficiency, and financing risks, the authors argue that India is well-positioned to expand renewable energy with strategic planning and investment. Their findings suggest a bright future for green energy in achieving sustainable development.

Srivastava et al. (2012) explore the complex nature of energy access in rural India, revealing that poverty and energy use are deeply interconnected. They argue that measuring energy access based solely on basic consumption fails to reflect needs. Instead, access should be viewed as a service encompassing quality, affordability, availability, and efficiency. The study highlights those local factors, such as household size, fuel types, and regional resources, that must inform policy. Their findings emphasize the necessity for dynamic, service-oriented solutions rather than fixed benchmarks.

Sahu (2008) explores India's energy use from 1980 to 2005, highlighting a strong positive relationship between energy consumption and GDP. Using trend and regression analysis, he finds that total energy consumption rises as GDP, population, and per capita energy use increase. However, energy production lags behind consumption growth. His findings stress energy's critical role in economic development and the growing energy demand driven by economic and demographic factors.

III. DATA AND METHODOLOGY

Date and Sources

The present study is based on secondary data. To meet our objectives, we collected renewable and non-renewable energy consumption data from the US Energy Information Administration (EIA) 2022. The selection of the sample period is based purely on available data. Data on total energy consumption, renewable energy consumption, and non-renewable energy consumption from 1980 to 2021 has been collected for the last 42 years.

Table 1

Summary of Variables Utilized for Trends Analysis

Si. No	Variables Name	Units	Source
1.	Total Energy Consumption	(British Thermal Units per quadrillion)	US Energy Information Administration is the source (EIA, 2022).
2	1. Renewable Energy Consumption, including hydroelectricity, Wind, Solar, Biomass, and Waste)	(British Thermal Units per quadrillion)	US Energy Information Administration is the source (EIA, 2022).
	2. Non-renewable Energy Consumption 2.1 Coal Consumption 2.2 Natural Gas Consumption 2.3 Petroleum and Other Liquids Consumption	(British Thermal Units per quadrillion)	US Energy Information Administration is the source (EIA, 2022).

Source: Prepared by Author

Main Objective of this study: To study India's trends and progress in renewable and non-renewable energy consumption.

IV. EMPIRICAL FINDINGS AND DISCUSSION

4.1 Energy Consumption Trends in India

The energy consumption pattern in India from 1980 to 2021 shows significant shifts in both non-renewable and renewable energy use. Non-renewable sources, primarily coal, natural gas, and petroleum, were 36.38%, and natural gas was 1.59%, with renewable sources like hydro, wind, solar, biomass, and waste making up 12.99% of the total. Over time, while coal and petroleum remained the major contributors, natural gas usage increased, reaching 11.06% by 2010. However, the share of renewable energy remained relatively low but showed a gradual upward trend from 12.99% in 1980 to 9.58% in 2021, despite a dip during the late 1980s and 1990s.

Total energy consumption (in quadrillion BTUs) grew steadily from 3.719 in 1980 to 31.442 in 2021, reflecting rising energy demand due to population growth, industrialisation, and urbanisation. However, renewable energy's percentage share has not drastically increased; its actual consumption volume has grown significantly in absolute terms. The data highlights a slow but positive shift toward renewable sources. This trend signals progress in diversifying India's energy portfolio and supports the need for stronger policies and investment to accelerate the transition to sustainable energy.

Table No: 2

Non-renewable Energy and Renewable Consumption Trends in India (%)

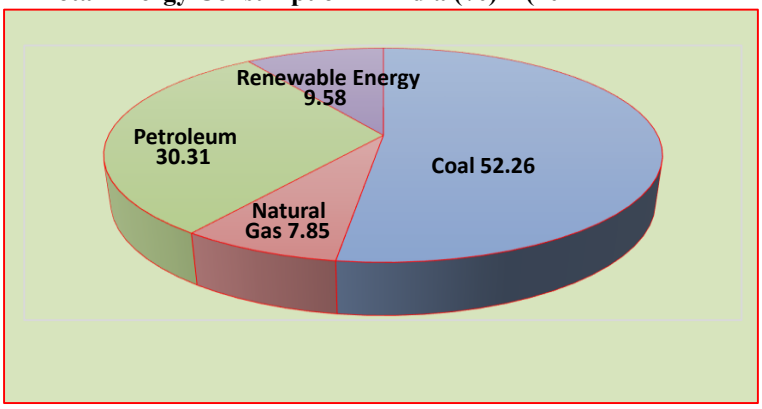
Sl. No	Year	Non-renewable energy Consumption (%)			"Renewable energy consumption (%)	Total Energy Consumption (%, Quadrillion British Thermal Units)
		Coal (%)	Natural Gas (%)	Petroleum and Other Liquids (%)	Hydroelectricity, Wind, Solar, Biomass and Waste Energy Consumption (%)	
1	**1980**	49.05	1.59	36.38	12.99	**100 (3.719)**
2	**1981**	49.14	1.77	36.67	12.42	**100 (4.170)**
3	**1982**	50.37	2.31	35.67	11.65	**100 (4.334)**
4	**1983**	50.32	2.61	35.58	11.49	**100 (4.559)**
5	**1984**	51.17	2.57	35.01	11.25	**100 (4.950)**
6	**1985**	50.81	2.93	36.12	10.14	**100 (5.196)**
7	**1986**	51.09	3.68	35.32	9.90	**100 (5.625)**
8	**1987**	52.16	4.42	35.06	8.35	**100 (5.901)**
9	**1988**	50.33	5.47	35.04	9.16	**100 (6.529)**
10	**1989**	50.58	5.26	34.77	9.39	**100 (6.902)**
11	**1990**	50.52	6.24	33.12	10.12	**100 (7.355)**
12	**1991**	51.32	6.69	32.13	9.85	**100 (7.724)**
13	**1992**	51.45	6.77	32.80	8.98	**100 (8.110)**
14	**1993**	51.64	7.27	32.38	8.72	**100 (8.420)**
15	**1994**	50.34	7.55	32.48	9.62	**100 (9.042)**
16	**1995**	50.05	7.55	34.15	8.26	**100 (9.567)**
17	**1996**	50.36	7.21	34.87	7.56	**100 (9.986)**
18	**1997**	50.03	7.07	34.93	7.96	**100 (10.475)**
19	**1998**	49.58	7.42	34.53	8.47	**100 (10.604)**
20	**1999**	49.19	6.90	35.83	8.09	**100 (11.279)**
21	**2000**	47.58	6.17	39.12	7.13	**100 (12.037)**
22	**2001**	48.34	6.01	38.61	7.04	**100 (12.199)**
23	**2002**	47.86	7.41	37.94	6.78	**100 (12.843)**
24	**2003**	47.68	7.55	37.82	6.95	**100 (13.271)**
25	**2004**	48.71	7.84	36.30	7.15	**100 (14.417)**
26	**2005**	48.92	8.65	34.36	8.06	**100 (15.240)**
27	**2006**	48.34	8.61	34.41	8.64	**100 (16.532)**
28	**2007**	49.26	8.71	34.13	7.91	**100 (17.778)**
29	**2008**	50.69	8.52	33.11	7.68	**100 (18.949)**
30	**2009**	52.09	9.71	31.08	7.12	**100 (20.618)**
31	**2010**	52.07	11.06	30.05	6.82	**100 (21.951)**
32	**2011**	52.36	10.58	29.31	7.75	**100 (22.772)**
33	**2012**	54.08	9.38	29.50	7.04	**100 (23.923)**
34	**2013**	54.99	8.04	29.03	7.95	**100 (24.590)**
35	**2014**	56.96	7.37	28.07	7.61	**100 (26.231)**
36	**2015**	56.27	6.99	29.80	6.94	**100 (26.742)**
37	**2016**	53.55	7.35	31.60	7.50	**100 (27.709)**
38	**2017**	53.24	7.38	31.45	7.93	**100 (28.898)**
39	**2018**	53.22	7.45	31.01	8.33	**100 (30.743)**
40	**2019**	52.29	7.50	31.36	8.85	**100 (31.293)**
41	**2020**	52.65	7.89	29.98	9.48	**100 (29.410)**
42	**2021**	52.26	7.85	30.31	9.58	**100 (31.442)**

Source: (EIA, 2022) Percentages Computed by Author based on Original Data.

In the 2020s, India's total energy consumption dropped from 31.293 to 29.410 quadrillion BTUs due to the COVID-19 pandemic. Lockdowns and reduced industrial activity led to lower demand across all energy sources.

Both non-renewable and renewable consumption slowed, showing the pandemic's strong impact on the energy sector and highlighting the need for resilient, flexible energy systems.

Pia chart - 1
Total Energy Consumption in India (%) – (2021



Source: Author Computed based on Original Data (EIA) - 2022

The pie chart -1 illustrates India's energy consumption pattern for the year 2021. It shows a heavy reliance on non-renewable sources, with coal being the dominant contributor at 52.26%. Petroleum follows with 30.31%, and natural gas accounts for 7.85%. In contrast, renewable energy sources such as hydro, wind, solar, and biomass contribute only 9.58% of the total energy mix. This highlights a strong dependence on fossil fuels, especially coal and petroleum. Although renewable energy has gradually increased over the years, its share remains limited. The data emphasises the urgent need to boost clean energy initiatives to achieve a sustainable energy future.

Table No: 3 Method: (1)
Least Squares (Renewable Energy Consumption)

The dependent variable: LREC				
Approach: Least Squares				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	-0.903871	0.034873	-25.91883	0.0000
T	0.044117	0.001413	31.22340	0.0000
R-squared	0.960587	*Mean dependent var*		0.044638
Adjusted R-squared	0.959602	*SD dependent var*		0.552208
SE of regression	0.110990	*Akaike info criterion*		-1.512309
Sum squared resid	0.492749	*Schwarz criterion*		-1.429563
Log-likelihood	33.75849	*Hannan-Quinn criteria.*		-1.481979
F-statistic	974.9008	*Durbin-Watson stat*		0.508979
Prob (F-statistic)	0.000000			

- Renewable Energy consumption is growing at 0.044 percent every year. The link between the dependent variable LREC and the independent variable T was modeled using least squares regression analysis.

- With T having a coefficient of 0.044117, an increase of about 0.0441 units can be expected in LREC for every unit rise in T. P-values of 0.0000 indicate that both coefficients are statistically significant. The model accounts for almost 96.06% of the variability in LREC, according to the R-squared value of 0.960587. This illustrates the degree of fit between the regression line and the data.

- The least squares regression model for the variable LREC based on time (T) provides a highly significant and precise representation of the relationship. The positive coefficient for T indicates a positive trend over time. • The high R-squared value indicates that the model can explain significant variability in LREC.

Table 4 Method: (2)
Least Squares (Renewable Energy Consumption)

Dependent Variable: LREC				
Approach: Least Squares				
Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***Prob.***
C	-0.724222	0.039499	-18.33512	0.0000
T	0.019619	0.004237	4.630713	0.0000
T2	0.000570	9.55E-05	5.962816	0.0000
R-squared	0.979383	*Mean dependent var*		0.044638
Adjusted R-squared	0.978326	*SD dependent var*		0.552208
SE of regression	0.081297	*Akaike info criterion*		-2.112668
Sum squared resid	0.257758	*Schwarz criterion*		-1.988549
Log-likelihood	47.36602	*Hannan-Quinn criteria.*		-2.067173
F-statistic	926.3263	*Durbin-Watson stat*		0.948827
Prob(F-statistic)	0.000000			

- Renewable energy Consumption is accelerating at 0.0006 percent every year. T2 (Squared term of Time): The coefficient for T2 is 0.000570, suggesting a quadratic effect on LREC. As T increases, the rate of change in LREC is influenced by both the linear and quadratic terms. All coefficients are statistically significant (p-values = 0.0000).

- 926.3263 is the F-statistic, and the model's overall statistical significance is shown by the p-value of 0.0000. The least squares regression model for the variable LREC based on time

- (T) and its squared term T2 provide a highly significant and precise representation of the relationship. The positive coefficients for T and T2 indicate a positive trend with a potential quadratic effect over time.

Table 5 Method: (1)
Least Squares (Non-renewable Energy Consumption)

The Dependent Variable: LTNREC				
Approach: Least Squares				
Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***Prob.***
C	1.251353	0.019580	63.91129	0.0000
T	0.054002	0.000793	68.07263	0.0000
R-squared	0.991442	*Mean dependent var*		2.412388
Adjusted R-squared	0.991228	*SD dependent var*		0.665336
SE of regression	0.062315	*Akaike info criterion*		-2.666773
Sum squared resid	0.155328	*Schwarz criterion*		-2.584027
Log-likelihood	58.00223	*Hannan-Quinn criteria.*		-2.636443
F-statistic	4633.882	*Durbin-Watson stat*		0.244923
Prob(F-statistic)	0.000000			

- Non-renewable energy consumption is growing by 0.054 percent. Intercept (C): The intercept is 1.251353, indicating the estimated starting point for LTNREC when T is zero. T (Time): The coefficient for T is 0.054002, suggesting that LTNREC is expected to increase by approximately 0.054 units for each unit increase in T. All coefficients are highly statistically significant, with p-values of 0.0000.

Table-6 Method: (2)
Least Squares (Non-renewable Energy Consumption)

The Dependent Variable: LTNREC				
Approach: Least Squares				
Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***Prob.***
C	1.146917	0.021436	53.50470	0.0000
T	0.068243	0.002299	29.68061	0.0000
T2	-0.000331	5.19E-05	-6.387386	0.0000
R-squared	0.995817	*Mean dependent var*		2.412388
Adjusted R-squared	0.995603	*SD dependent var*		0.665336
SE of regression	0.044119	*Akaike info criterion*		-3.335099
Sum squared resid	0.075913	*Schwarz criterion*		-3.210980
Log-likelihood	73.03709	*Hannan-Quinn criteria.*		-3.289605
F-statistic	4642.621	*Durbin-Watson stat*		0.423266
Prob(F-statistic)	0.000000			

TNREC decreased in India over the study period compared to REC, with the former declining at 0.0003 percent annually. This study's conclusions imply that India saw significant changes in both its non-renewable and renewable energy consumption over the research period. It is decided to accept the alternative hypothesis and reject the null hypothesis.

V. Conclusion

The Trends and Progress of Renewable and Non-renewable Energy Consumption in India. The results show a clear increase in renewable energy use, reflecting government efforts and growing awareness. However, non-renewable energy still forms a large part of India's energy mix. The Least Squares method reveals long-term trends, highlighting a gradual shift toward cleaner sources. This study provides valuable insights for future energy planning and supports the transition to a more sustainable energy system in India.

In the 2020s, India's total energy consumption dropped from 31.293 to 29.410 quadrillion BTUs due to the COVID-19 pandemic. Lockdowns and reduced industrial activity led to lower demand across all energy sources. Both non-renewable and renewable consumption slowed, showing the pandemic's strong impact on the energy sector and highlighting the need for resilient, flexible energy systems.

Renewable Energy consumption is growing at 0.044 percent every year. The link between the dependent variable LREC and the independent variable T was modelled using the least squares regression analysis. Renewable energy Consumption accelerates at 0.0006 percent every year, while non-renewable energy consumption grows by 0.054 percent. TNREC decreased in India over the study period compared to REC, with the former declining at 0.0003 percent annually. This study's conclusions imply that India saw significant changes in both its non-renewable and renewable energy consumption over the study period.

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