

Energy Consumption and Economic Growth Nexus in India

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Abstract:

This research investigates the intricate relationship between energy consumption and economic growth in India, aiming to understand how changes in energy usage impact economic development. The study delves into the causal link between renewable energy consumption and economic growth, considering factors such as capital and technology. Additionally, it explores the impact of energy consumption on agricultural economic growth, emphasizing the vital role of energy in the agricultural sector. The examination extends to assessing the relationship between electricity consumption and overall economic growth, along with sectoral growth across major Indian states, providing valuable regional insights for tailored energy strategies.

Furthermore, the research extends its purview to unravel the nuanced impact of energy consumption on agricultural economic growth. Recognizing the indispensable role of energy in the agricultural sector, the study accentuates the pivotal contribution of energy dynamics to the overall economic landscape. This emphasis underscores the significance of aligning energy policies with the unique needs and challenges of the agricultural domain, crucial for fostering balanced and sustainable economic growth.

Introduction:

The investigation into the energy consumption and economic growth nexus in India is paramount for understanding the intricate dynamics that shape the nation's developmental trajectory. With a focused research objective, this study aims to dissect the relationship between energy usage and economic growth, offering crucial insights into how changes in energy consumption impact India's economic development. The emphasis on renewable energy consumption adds a dimension of sustainability, exploring the causal link while considering critical factors like capital and technology. This nuanced analysis contributes to the formulation of green and sustainable policies, essential for India's long-term economic and environmental well-being.

The examination extends beyond the broader economic landscape, delving into the specific impact of energy consumption on agricultural economic growth. Recognizing the indispensable role of energy in the agricultural sector, the study underscores its pivotal contribution to overall economic prosperity. By addressing the reciprocal relationship between energy usage and agricultural development, the research provides a foundation for fostering balanced and inclusive growth, particularly significant in a country where agriculture plays a pivotal role in the economy.

Furthermore, the assessment of the relationship between electricity consumption and overall economic growth, coupled with sectoral growth across major Indian states, offers valuable regional insights. These

insights are essential for policymakers, enabling the tailoring of energy strategies to align with the unique economic landscapes of different states. In essence, this research endeavours to unravel the complex web of interactions between energy consumption and economic growth, paving the way for informed policy decisions that promote sustainable development in India.

Background:

The study on the energy consumption and economic growth nexus in India is driven by a crucial need to comprehend the intricate dynamics influencing the nation's developmental trajectory. The research objective centres on investigating how changes in energy consumption impact economic development, emphasizing the multifaceted nature of this relationship. The examination extends to the causal link between renewable energy consumption and economic growth, incorporating critical factors such as capital and technology. This not only deepens the understanding of the renewable energy-economic growth nexus but also contributes valuable insights into formulating sustainable development strategies.

The study's rationale underscores the significance of optimizing endogenous resources for sustained economic growth and effective global climate change mitigation. It advocates for a paradigm shift in policy, urging the integration of strategic, sustainable policies. Furthermore, the exploration of the impact of energy consumption on agricultural economic growth recognizes the indispensable role of energy in the agricultural sector. This aspect is crucial for fostering balanced and inclusive growth, particularly given the substantial economic contribution of agriculture in India.

Assessing the relationship between electricity consumption and overall economic growth, along with sectoral growth across major Indian states, provides regional insights essential for tailored energy strategies. The intricate regional variations in this relationship highlight the need for nuanced policy approaches that align with the unique economic landscapes of different states.

Research Objective:

- Investigate the relationship between energy consumption and economic growth in India, specifically focusing on how changes in energy usage impact economic development.
- Analyse the causal link between renewable energy consumption and economic growth in India, considering factors such as capital and technology.
- Examine the impact of energy consumption on agricultural economic growth in India, and vice versa, to understand the dynamics between energy usage and agricultural development.
- Assess the relationship between electricity consumption and overall economic growth, as well as sectoral growth, across major Indian states.

Rational of the study:

The study goals to provide complete information on the intricate relationship between energy consumption and economic growth in India. Investigating the impact of changes in energy usage on economic development is crucial for formulating effective rules and strategies.

By analyzing the causal link between renewable energy consumption and financial growth, the study seeks to contribute insights into sustainable improvement. considering factors like capital and technology in this

analysis provides depth to the knowledge of the renewable energy-economic growth nexus, assisting in the formulation of green and sustainable policies.

The examination of the impact of energy consumption on agricultural economic growth, and vice versa, addresses the critical role of energy in the agricultural sector. This understanding is essential for fostering balanced and inclusive growth, especially in a country wherein agriculture performs a huge economic role.

Assessing the connection between energy consumption and the overall economic boom, along with sectoral growth across major Indian states, presents valuable regional insights. This information is important for policymakers to tailor energy strategies that align with the specific economic landscapes of different states.

Literature Review:

The paper by Sharad Bhattacharya and Mousumi Bhattacharya explores the causal link between disaggregated energy consumption and economic growth in eight developed and eight emerging G20 countries. Employing Cointegration and Granger causality tests, the study reveals a primarily positive association, but feedback relationships in certain countries introduce complexity. Urging a significant policy shift, the findings emphasize the critical need to optimize endogenous resources for sustained economic growth and effective global climate change mitigation through strategic, sustainable policies.

Maneka Jayasinghe's research investigates India's complex nexus of energy consumption, CO2 emissions, GDP, and tourism from 1991 to 2018. Employing sophisticated frameworks like Autoregressive Distributed Lag and Vector Error Correction Models, the study extends Indian literature, shedding light on the positive contributions of energy consumption and tourism to CO2 emissions. The results emphasize a long-term unidirectional causality, urging a prioritized focus on sustainable tourism, energy usage, and economic growth for India's comprehensive economic development agenda.

Md Zulquar Nain, Wasim Ahmad, and Bandi Kamaiah delve into India's energy landscape, examining the intricate links between energy consumption, real GDP, and CO2 emissions from 1971 to 2011. Employing sophisticated methodologies, their study uncovers sectoral nuances in the long and short-run causal relationships. Notably, a short-run causality from electricity consumption to economic growth and CO2 emissions emerges, urging India to balance growth sustainability with CO2 control, considering sectoral disparities in energy-GDP relationships for effective policy formulation.

Burcak Polat conducts a comprehensive study addressing the contentious relationship between energy consumption and economic growth. Employing dynamic panel data analysis, the research spans 2002 to 2014, scrutinizing the impact of renewable and non-renewable energy consumption on developing and developed economies. Results indicate nuanced effects, revealing a positive correlation between non-renewable energy consumption and growth in developing nations, while such a connection is absent in developed countries, contributing valuable insights to the ongoing debate in the paper.

Aviral Tiwari's extensive study investigates the intricate dynamics among primary energy consumption, gross domestic product (GDP), and CO2 emissions in India from 1970 to 2007. Employing advanced methodologies like Granger's approach and dynamic analysis, the research reveals a lack of cointegration amidst structural breaks. Notably, static analysis indicates a unidirectional causality from GDP to energy consumption, emphasizing the pivotal role of GDP in influencing energy consumption patterns. The study advocates for energy reduction policies in India, highlighting GDP's substantial impact on primary energy consumption.

Mousumi Bhattacharya and Sharad Nath Bhattacharya delve into the escalating global energy demand, focusing on India and China. Employing a Vector Error Correction Model (VECM), their study reveals a long-term relationship between various energy forms and economic growth in both nations. In India, bidirectional causality between coal consumption and economic growth persists in both short and long runs, contrasting with a unidirectional causality from petroleum consumption to economic growth. Meanwhile, China exhibits a unidirectional causality from economic growth to coal consumption and from petroleum consumption to economic growth, emphasizing the intricate dynamics shaping energy and economic interdependencies.

Huajun Liu, Mingyu Lei, Naixin Zhang, and Guangjie Du conducted a groundbreaking study on the causality between energy consumption, carbon emissions, and economic growth. Utilizing multispectral convergent cross-mapping (CCM) and nonlinear dynamics, the research investigated China, India, and G7 countries. Results unveiled bidirectional links in China and India, while G7 countries displayed diverse relationships, including bidirectional, unidirectional, and neutral nexus. Notably, decoupling was observed in most G7 nations. This innovative approach offers crucial insights for policymakers to devise tailored strategies for sustainable economic growth and improved environmental quality.

Shahbaz et al. present a seminal study on CO₂ emissions, energy consumption, and economic growth in the Next 11 countries (1972–2013). Employing time-varying Granger causality, they unveil unique patterns: economic growth drives CO₂ emissions in Bangladesh and Egypt while causing energy consumption in the Philippines, Turkey, and Vietnam. A feedback effect is observed in South Korea, and unidirectional causality from economic growth to CO₂ emissions validates the Environmental Kuznets Curve hypothesis for Indonesia and Turkey. The study offers crucial insights for policymakers aiming at sustainable economic growth with minimal environmental impact.

Yang and Zhao conducted a pioneering study investigating the intricate temporal relationships among economic growth, energy consumption, and carbon emissions in India (1970–2008). Utilizing advanced out-of-sample Granger causality tests and directed acyclic graphs, the study unveils unprecedented contemporaneous causal patterns. Key findings include unidirectional causation from energy consumption to carbon emissions and economic growth, along with bidirectional causality between carbon emissions and economic growth. Notably, the study highlights trade openness as a crucial determinant influencing energy consumption and carbon emissions, providing valuable policy insights.

The study by Rudra Prakash Pradhan explores the interconnected relationship among transport infrastructure, energy consumption, and economic growth in India from 1970 to 2007. Utilizing cointegration and Granger causality tests, the research reveals a unidirectional causality from transport infrastructure to economic growth, economic growth to energy consumption, and transport infrastructure to energy consumption. Pradhan concludes by emphasizing the critical need for energy and transportation policies to acknowledge this nexus for sustaining economic growth.

Research Methodology

Qualitative research on the energy consumption and economic growth nexus in India involves an in-depth exploration of the subjective experiences and perceptions of key stakeholders. Utilizing a phenomenological approach, the study aims to understand the lived experiences of individuals and organizations influencing energy policies and economic development. In-depth interviews with policymakers, industry experts, environmentalists, and representatives from the energy sector will be conducted to gather rich, contextual insights.

Furthermore, content analysis of relevant documents, such as government reports and policies, will complement the interviews. This qualitative analysis seeks to identify underlying themes and patterns, providing a comprehensive understanding of the factors shaping the relationship between energy consumption and economic growth.

Discussion:

Over the last several decades, India's economy has grown significantly, ranking fifth in the world. From 1970–2021, fossil fuels accounted for about 90% of India's energy basket on average, and they were a major factor in the country's economic development. India has been heavily dependent on coal; in 2021, coal accounted for 56.7% of India's primary energy needs. India is currently the 0.33-highest CO₂ emitter in the world, typically due to its 211 GW coal-based power sector. India became responsible for 2.7 Giga tonnes of CO₂ emissions in 2021, or 7.5% of all emissions related to power worldwide.

The data provided in Table 3 highlights that the proportional increase in per capita energy consumption, in the period 1970-2021, concerning the increase in GDP per capita became more pronounced in India, which suggests that the need for economic growth in India over time has taken precedence over energy conservation efforts. As a result, this effort has increased greenhouse gas emissions and other pollutants, which is causing the environment to deteriorate. India's rating as the 8th-most polluted country in the world in the Annual World Air Quality Report by IQ Air on March 14th, 2023, reflects this trend.

India has made significant progress in the last ten years in lowering its energy consumption and dangerous emissions by utilizing cleaner energy sources and technologies. They have started to use more solar and wind power to generate electricity, as well as switching some transportation fuels to biofuels. By 2022, they had over 100 GW of renewable energy capacity, however, it still accounts for much less than 6% of total energy consumption. India has pledged to achieve zero net emissions by 2070 and to generate half of its transportation electricity from non-fossil fuels.

However, the percentage of renewable energy in the energy basket remains lower than 6 percent. India has submitted to the United Nations Framework Convention on Climate Change (UNFCCC) for attaining net zero through 2070 and meeting 50 percent of cumulative electric power capacity via non-fossil fuel sources by 2030. In the area of energy transition, decisive and forceful action will be required to achieve net zero by 2070.

Percentage share of Coal in Energy Basket (India)						
1970	1980	1990	2000	2010	2020	2021
57.19%	54.12%	55.46%	51.26%	53.62%	53.44	55.91
Percentage share of Natural Gas in Energy Basket (India)						
0.83%	0.93%	5.04%	6.80%	9.44%	6.85%	6.49
Percentage share of Renewables in Energy Basket (India)						
0%	0%	0.01%	0.27%	1.78%	4.99%	5.27%

Table-1: Share of Coal, Natural Gas and Renewables in Energy Basket (India)

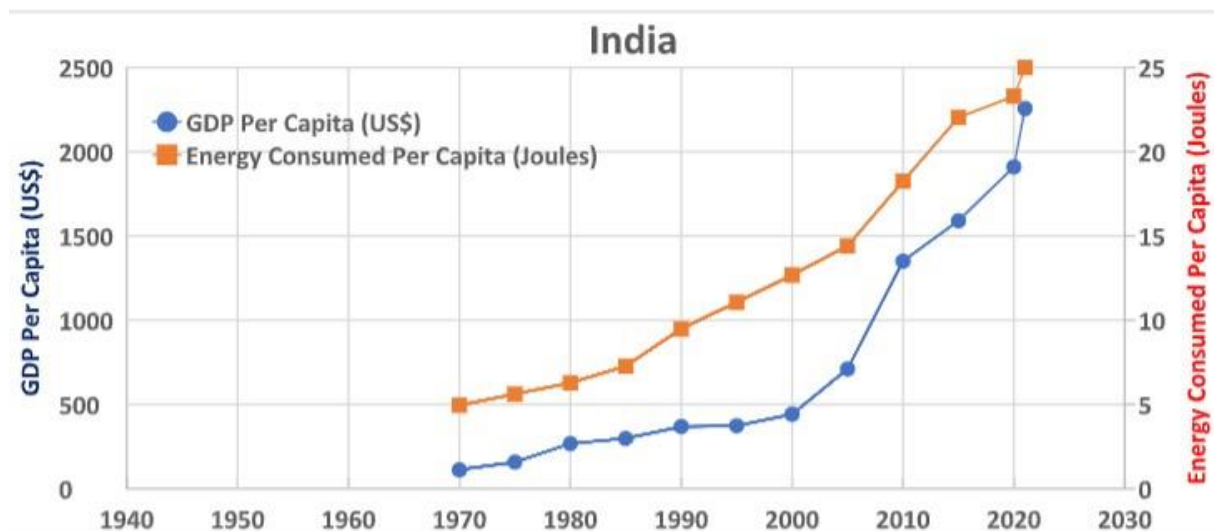
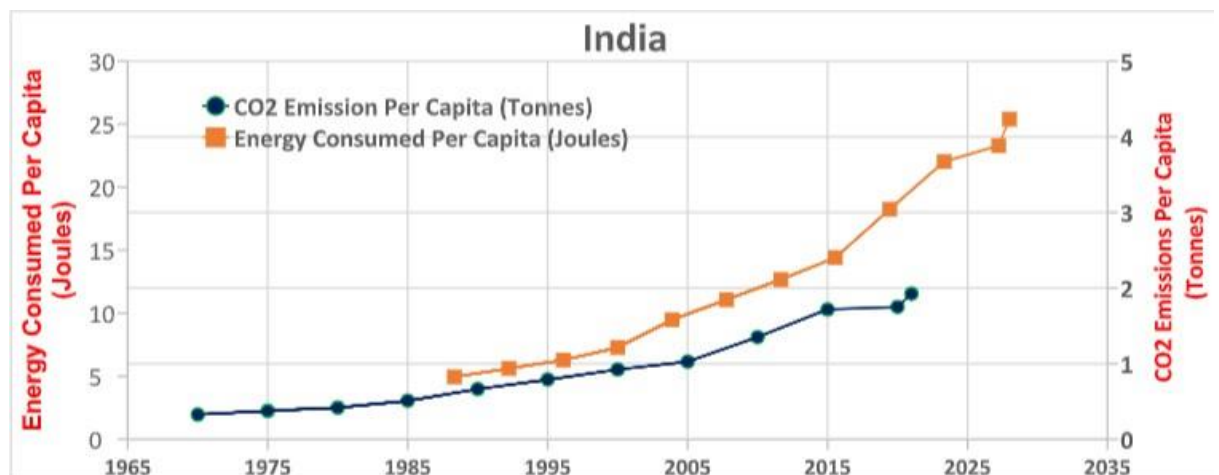


Chart 1, in the case of India, shows that a rise in GDP per capita has always resulted in a rise in energy consumption per capita.



In India, Chart 2 clearly illustrates a direct link between growing per capita energy consumption and the subsequent rise in per capita CO2 emissions over the years. This stems from the fact that around 90% of

India's power consumption from 1970 to 2021 came from fossil fuels, leading to increased CO₂ emissions. Slower growth in CO₂ emissions, during the 2015-2020 period, shows the adoption of renewable energy sources and low-carbon fuels to combat CO₂ emissions. The significant increase observed in 2021 can be attributed to the reopening of economies following the Covid-19 pandemic.

Effective Correlation: economy, energy & environment

The increase in GDP over the years observed through an increase in energy consumption and CO₂ emissions supports the conventional hypothesis to some extent for countries.

According to the theory, India's economic boom increases energy consumption, which in turn causes more beneficial carbon emissions and ensuing environmental damage.

India's Employment and Economic Growth Challenges:

Like its neighbours in South Asia, India has a young population that might contribute to further economic growth. The need to create jobs, however, is a significant obstacle for policymakers considering this demographic advantage. According to World Bank projections, there will be a huge increase in South Asia's working-age population between 2020 and 2050, with India playing a major role in driving global growth.

The critical nexus between job creation and economic development in India and South Asia extends beyond regional boundaries. Despite the potential, India grapples with mounting unemployment, sparking youth-led protests. Concurrently, factors such as heightened enrolment in education and a shift of young individuals away from agriculture contribute to the swelling ranks of the unemployed.

Intriguingly, despite agriculture employing nearly 43.5% of India's workforce, the sector faces challenges like low productivity and inadequate public investment, driving rural youth to seek alternatives due to perceived "disguised unemployment."

The question arises: Can the allure of non-agricultural opportunities adequately absorb the surging labour supply in India? Regrettably, the answer leans towards the negative. Research based on official employment statistics from 2012-18 underscores a marked increase in unemployment rates, particularly among men. The insufficient creation of new jobs has led to the withdrawal of women from the labour market, with only 23.0% employed in 2018, down from 42.8% in 2005. This shift has seen a rise in the proportion of women reporting engagement in domestic duties.

In the wake of the COVID-19 pandemic, India faced a severe economic downturn, witnessing a negative GDP growth rate of -7.3% in 2020. This crisis hit the informal sector hard, leaving millions of workers without a source of income. The heart of India's employment challenge lies in the stunted job creation within the manufacturing sector. From 2012 to 2020, the manufacturing workforce experienced a decline, emphasizing the need for targeted interventions.

Addressing this crisis demands comprehensive measures. A prevailing sentiment in policy circles advocates for a revaluation of labour laws, deeming them overly restrictive. The argument posits that easing constraints on firing and reducing wages could incentivize employers to expand operations, fostering job creation.

Examining India's vast workforce of 471.0 million reveals a stark reality: only 12.3% are regular workers with some form of social security and legal labour protection. The majority, constituting casual workers and petty producers, navigate precarious informality. The COVID19 lockdown in March 2020 showcased the plight of poor migrant workers undertaking arduous journeys back to their villages, emphasizing the vulnerabilities of informal labour.

Controversially, some state governments responded to the crisis by increasing daily working hours from eight to twelve. Simultaneously, the Union government initiated the amalgamation of 29 labour laws into four codes, a move met with concerns about the potential weakening of labour's position.

The inadequate discussion on mainstream platforms about the impact of poor wages on aggregate demand and economic growth is a critical oversight. A consumption-expenditure survey reveals a stark wealth gap: the poorest 50% contribute a mere 13.4% to overall spending on durable goods in urban India, while the richest 5% command a disproportionate 64%.

To overcome economic and employment challenges, there is a growing realization that demand must be diversified by enhancing consumption and investment for the poor. Proposals include establishing industries linked to food processing or affordable housing in rural areas, with potential multiplier effects. Investments in health, education, roads, rural infrastructure, and public transport are imperative for holistic development.

India's burgeoning youth population presents an untapped source of demand that could reinvigorate the global economy. However, this requires policies counter to mainstream economic thinking. Real improvements for India's working classes necessitate substantial government spending to enhance skills, incomes, and purchasing power. Prioritizing health and education, coupled with investments in critical infrastructure, is vital for sustainable human development.

Economic Growth's Role in India: Energy and economic growth are inextricably linked. Energy is a vital stimulant for a nation's economic development; hence they are mutually reliant. When one looks at the differences in economic growth amongst the states of India, one finds that certain areas—such as the industrially developed Gujarat and Maharashtra, or the agriculturally prosperous Haryana and Punjab—are growing faster than others, like Jharkhand, Chhattisgarh, and Bihar. The main cause of these differences is the disparity in infrastructural development. Notably, one essential element of this equation is energy infrastructure. Essentially, the relationship between energy and economic growth suggests that the success of one is inevitably linked to the success of the other.

Energy and Economic Development in India

Since the 2000s, India has experienced a significant surge in energy consumption, more than doubling over the years and ranking third globally in gross power generation. Despite this, per capita energy consumption remains notably low, even trailing behind Africa. The fact that 250 million people lack access to electricity poses a serious obstacle to India's aspirational \$5 trillion economy. The government has started several electricity projects to close this gap, frequently using the public-private partnership approach.

These endeavours aim to enhance the accessibility and affordability of energy across the nation. Noteworthy energy sources in India include:

1. **Coal:** Historically dominant, coal and petroleum products contribute substantially to India's energy mix. Import dependency, environmental pollution, and non-renewability underscore the need for reduced reliance on these sources, prompting government efforts.
2. **Water:** Hydrothermal power plants use the kinetic energy of high-speed water to drive mills, providing energy to the economic and residential sectors.
3. **Nuclear:** Nuclear fission power facilities, with their massive power-producing potential, play a critical part in India's energy mix. Nuclear fission is the process of dividing massive nuclei into smaller ones at high speeds to generate power.
4. **Wind and Solar:** Emphasizing sustainability, India taps into abundant wind and solar resources as renewable energy alternatives. Their perpetual availability positions them as long-term solutions to meet energy demands.

Role of Energy in India

During the 1950s, nearly 44% of the country's power was consumed by the transportation sector, making it the most energy-demanding sector. Following closely, the industrial sector also had substantial energy requirements. At that time, household energy demand was relatively limited.

Fast forward to the present day, the share of power consumption by the transportation sector has dwindled to below 5%, with industries now claiming the highest percentage of energy usage. Concurrently, households have witnessed a significant increase in their share of energy consumption.

The indispensable role of energy in India's agricultural sector remains unquestionable. Energy is integral to various farming activities, encompassing irrigation, storage, and the operation of farm machinery. In the success of the green revolution, energy stands as an unsung hero, contributing significantly to agricultural advancements.

The energy sector's effect on India's economic expansion

The world we live in is changing quickly, and rising energy use has raised questions about overusing resources and the potential environmental consequences. India, a growing country, has seen a noticeable increase in its electricity usage. When compared to other countries, the nation's energy industry is more diversified, although output is still dominated by traditional sources like coal and water-based thermal power plants. The worldwide situation, in which energy supplies are running out at an alarming rate, is reflected in this pattern.

India, the world's third-largest energy user, faces pressing challenges such as an expanding population and rising energy consumption. Strategic goals include things like boosting domestic energy production, encouraging alternative energy sources, and lowering energy imports. In the international climate talks in 2021, India committed to building 500 GW of non-fossil power capacity by 2030 and attaining net-zero greenhouse gas emissions by 2070.

The growth of India's energy sector faced challenges during the global COVID-19 pandemic, resulting in restricted economic activity. Noteworthy governmental endeavours, such as the Jawaharlal Nehru National Solar Mission, rooftop scheme, and solar park scheme, have consistently propelled the energy sector's

expansion. As of December 2022, India's total power consumption reached 121.19 billion units. Acknowledging the critical role of energy in human survival and machinery operation, India is actively exploring alternatives to primary energy sources, emphasizing efficiency and sustainability.

In any economy, the energy sector stands out as a pivotal factor with the potential to ensure sustained economic growth and development. The well-being and prosperity of a nation are intricately linked to the sector's growth, prompting India to address challenges like securing safe, affordable, and continuous energy sources for both the population and industries. This commitment aims to ensure that available resources sustainably meet energy requirements with minimal long-term negative impacts.

Key Insights into India's Energy Landscape

1. India stands prominently among the top three global leaders in driving the growth of renewable energy.
2. Globally, India secures the 3rd position in total additions to renewable power capacity.
3. The country holds the 3rd largest position worldwide in adopting new solar photovoltaic (PV) capacity.
4. India's primary energy consumption, fuelled mainly by coal, oil, natural gas, and biomass, ranks as the third largest globally.
5. In 2022, the industrial sector in India accounted for a significant 42% of the total energy consumption.
6. The Micro, Small, and Medium Enterprises (MSME) sector demonstrates the potential to contribute around 20-25% to industrial energy consumption in 2022.
7. According to the Bureau of Energy Efficiency (BEE) national strategy plan, the industrial sector aims for a substantial 60% energy-saving potential by 2030.

India's Energy Sector Performance

India holds the 4th position worldwide in terms of installed renewable energy capacity, encompassing large hydro, wind, and solar power capacities. With a targeted expansion, India aims to reach a remarkable 500 GW of renewable energy capacity by 2030. The aftermath of the 2020 COVID outbreak resulted in decreased consumption of bioenergy and other renewable sources compared to the preceding year. Despite this setback, the forecast indicates an expected Compound Annual Growth Rate (CAGR) of 10.10% in the Indian renewable energy market between 2022 and 2027. This positive trajectory is attributed to government policies, growing environmental concerns, and enticing incentives, including tax benefits for solar panel installations. Notably, the solar energy segment is poised for significant growth during this forecast period, fuelled by escalating investments in the sector. The Ministry of New and Renewable Energy (MNRE) has outlined an ambitious target of achieving 500 GW in renewable energy capacity by 2030, providing a foundation for future market growth and expansion. These initiatives underscore the pivotal role of government plans orchestrated by MNRE in driving the upward trajectory of India's renewable energy sector.

Renewable Energy and Economic Development

To enhance economic and social progress, it is imperative to prioritize renewable energy. The government's vision of achieving carbon neutrality in India by 2070 underscores the crucial role of renewable energy in this endeavour. The commitment to reducing the carbon footprint aligns with the broader goal of fostering sustainable development.

In the 2022 Budget, the government articulated its intent to meet 50% of the nation's energy needs through renewable sources. This ambitious target, if realized, holds the potential to substantially diminish our reliance on coal and petroleum products. Consequently, such a shift would contribute to mitigating our trade deficit, marking a positive indicator for overall economic growth.

Conclusion:

This comprehensive research elucidates the intricate relationship between energy consumption and economic growth in India. The study unveils the causal link between renewable energy consumption and economic development, considering factors such as capital and technology. Notably, it extends its focus to the agricultural sector, recognizing the pivotal role of energy in fostering balanced and inclusive growth, particularly in a country where agriculture plays a substantial economic role.

The assessment of the relationship between electricity consumption and overall economic growth, coupled with sectoral growth across major Indian states, provides valuable regional insights. These insights are imperative for policymakers to tailor energy strategies that align with the unique economic landscapes of different states. The research underscores the significance of aligning energy policies with the specific needs and challenges of the agricultural domain, crucial for fostering balanced and sustainable economic growth.

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