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STATUS OF THE RENEWABLE ENERGY IN INDIA

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ABSTRACT----------
As India faces the dual challenges of rapid economic growth and rising energy demands, the shift towards renewable energy has emerged as a crucial strategy for sustainable development. This study examines the role of renewable energy in India's energy landscape and its impact on sustainable development. Renewable energy is essential for enhancing energy security, reducing environmental pollution, driving economic growth, and improving public health. By reviewing recent literature and analysing the progress in renewable energy adoption, this study highlights the significant advancements made in solar, wind, and bioenergy sectors. It also explores the benefits of renewable energy, including reduced greenhouse gas emissions, increased energy access, and alignment with global climate commitments. The findings emphasize the importance of continued investment, innovation, and supportive policies to maintain momentum and ensure a sustainable energy future for India. Further study used Average annual growth rate and graphs only.

KEY WORDS: *sustainable development, environmental, economic growth, greenhouse gas emissions*

INTRODUCTION

In recent years, the urgency for sustainable development has surged globally, driven by concerns over climate change, resource depletion, and environmental degradation. India, as one of the world's most populous and rapidly developing nations, faces unique challenges and opportunities in this context. The country's economic growth, coupled with its growing energy demands, necessitates a shift towards more sustainable energy solutions to ensure long-term prosperity and environmental health.

Renewable energy consumption has emerged as a critical component in India's strategy for sustainable development. With abundant resources such as solar, wind, and biomass, India is well-positioned to harness these renewable sources to meet its energy needs while mitigating the adverse impacts of conventional fossil fuels. This transition is not only crucial for reducing greenhouse gas emissions and combating climate change but also for fostering energy security, improving public health, and driving economic growth.

The Indian government has set ambitious targets for increasing the share of renewables in its energy mix, aligning with global climate commitments and national development goals. However, the impact of renewable energy consumption on sustainable development encompasses various dimensions, including technological, economic, social, and environmental factors.

This discussion aims to explore how renewable energy consumption influences sustainable development in India by examining its benefits, challenges, and the interplay between policy frameworks and real-world implementation. By understanding these dynamics, we can better assess the potential for renewable energy to contribute to a more sustainable and resilient future for India.

REVIEW OF LITERATURE

A.K. Nayak et al. (2020) conducted a study focused on the relationship between renewable energy and sustainable development, employing regression correlation analysis to examine this dynamic. Their findings indicated that renewable energy consumption has a positive impact on sustainable development. Based on these results, they suggested increasing investment in renewable energy technologies to further enhance sustainability outcomes. The study also highlighted the importance of supportive policies, technological innovation, and infrastructure development in maximizing the benefits of renewable energy. By investing in these areas, India can accelerate its

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transition to a more sustainable energy system, foster economic growth, and achieve its environmental goals more effectively.

M.A. Hossain et al. (2019) conducted a study titled "The Impact of Renewable Energy on Sustainable Development," utilizing factor analysis and cluster analysis to investigate the relationship between renewable energy adoption and various aspects of sustainability. Their findings revealed that increased renewable energy consumption significantly reduces greenhouse gas emissions, thereby contributing positively to environmental sustainability. The study suggested the implementation of robust policies to promote the adoption of renewable energy sources. Additionally, it emphasized the need for integrating renewable energy into national energy strategies, enhancing public awareness, and fostering innovation in renewable technologies. By adopting these measures, countries can not only mitigate climate change but also achieve broader sustainable development goals, such as improved air quality, energy security, and economic resilience.

Katarzyna Łukasiewicz et al (2022) : conducted a systematic literature review on sustainable energy development (SED), aiming to map out key trends and activities in the field. Their analysis, which combined both quantitative and qualitative methods, revealed a lack of a unified definition for SED, underscoring the need for a more cohesive framework. The study highlighted the most frequently cited articles, key contributing countries, and major subject areas in SED. The authors recommended increasing the use of renewable energy, improving energy efficiency, and reducing greenhouse gas emissions as essential steps toward advancing SED. Their proposed conceptual model offers a valuable starting point for future research and policy development in sustainable energy.

S.S. Chauhal et al. (2018) conducted a study on the relationship between renewable energy consumption and sustainable development, utilizing time series analysis and cointegration analysis to explore this dynamic. Their findings indicated that increased renewable energy consumption significantly enhances energy security by diversifying energy sources and reducing dependence on fossil fuels. The study also highlighted the role of renewable energy in supporting long-term sustainability goals, such as reducing environmental impacts and promoting economic stability. The authors suggested encouraging public-private partnerships as a key strategy to advance renewable energy projects, enhance innovation, and mobilize additional resources. By fostering collaboration between government and industry, the study advocates for more effective and scalable renewable energy solutions to achieve broader sustainable development objectives.

S.K. Singh et al. (2020) conducted a study titled "Renewable Energy and Sustainable Development in India," employing regression and correlation analysis to examine the impact of renewable energy on sustainability in the Indian context. Their findings demonstrated that renewable energy consumption has a positive effect on sustainable development in India by contributing to environmental protection, energy security, and economic growth. The study emphasized the need to increase research and development (R&D) in renewable energy technologies to further enhance their benefits. Additionally, the authors suggested that investing in R&D could lead to technological advancements, cost reductions, and more efficient renewable energy solutions, ultimately supporting India’s efforts to achieve its sustainable development goals. Strengthening the R&D sector would also facilitate the development of innovative approaches to address challenges in the renewable energy sector, such as intermittency and storage.

In his 1996 study titled "Indian Scenario of Renewable Energy for Sustainable Development," Naidu B.S.K. examined the potential of renewable energy sources in India, with a particular focus on the electricity sector. The study highlights solar energy as a crucial component of India’s current and future energy landscape, estimating the country's solar energy potential at approximately 5 x 10^15 kWh per annum. In addition to solar power, the research explores various other renewable energy sources, including ocean thermal energy, sea wave power, tidal power, wind energy, and bioenergy. The paper concludes with a discussion of necessary policies and strategies to promote the increased adoption of these renewable energy sources, aiming to support sustainable development goals. The study underscores the importance of implementing supportive frameworks and incentives to enhance the use of renewable energies, thereby addressing energy security and environmental sustainability in India.

Gielen, D., Chawla, K., & Ghosh, A. (2017)**,** in their comprehensive study titled *"Renewable Energy Prospects for India,"* explore the projected growth of global energy demand and the critical role that individual nations will play in this expansion by 2030. The study forecasts that India's Total Final Energy Consumption (TFEC) is

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expected to nearly double between 2010 and 2030, underscoring the country's growing energy needs. The authors identify Brazil, India, China, and the United States as key players, collectively capable of contributing to half of the global renewable energy usage by 2030.

Twumasi, Y. (2017)**,** in his study titled *"Relationship between CO2 Emissions and Renewable Energy Production in the United States of America,"* examines the link between CO2 emissions and renewable energy production across the U.S. Utilizing Pearson's correlation coefficient, Twumasi seeks to determine whether a statistically significant relationship exists between these two variables. His analysis reveals that states with higher population densities tend to exhibit higher CO2 emissions, a trend that also correlates with higher GDP levels. However, the study does not establish a clear relationship between the production of renewable energy and the reduction of CO2 emissions. Interestingly, the findings indicate that there is no positive correlation between CO2 emissions and renewable energy generation in the U.S., suggesting that other factors may play a more dominant role in influencing emission levels.

OBJECTIVE OF THE STUDY

- to understand the importance of the renewable energy in India .
- to analyse the status of renewable energy in India.
- **based on the objective 1. Renewable energy is of immense importance to India for several reasons:**

1. **Energy Security**: India heavily relies on imported fossil fuels, which exposes the country to price volatility and supply disruptions. Renewable energy, like solar and wind, can be produced domestically, reducing dependency on imports and enhancing energy security.
2. **Environmental Sustainability**: The use of fossil fuels contributes to air pollution and greenhouse gas emissions, leading to climate change. By shifting to renewable energy sources, India can significantly reduce its carbon footprint and mitigate the adverse effects of climate change.
3. **Economic Growth**: Investing in renewable energy infrastructure creates jobs and stimulates economic growth. It also encourages innovation and the development of new technologies, positioning India as a global leader in the renewable energy sector.
4. **Energy Access**: A significant portion of India's population, especially in rural areas, lacks access to reliable electricity. Renewable energy solutions, such as solar microgrids, can provide affordable and sustainable power to these regions, improving the quality of life.
5. **Global Commitments**: India is committed to international agreements like the Paris Agreement, which aims to limit global warming. Expanding renewable energy capacity is crucial for India to meet its climate targets and contribute to global efforts to combat climate change.
6. **Health Benefits**: Reducing reliance on fossil fuels will decrease air pollution, leading to better public health outcomes, particularly in urban areas where air quality is a major concern.

Totally renewable energy is key to India’s sustainable development, offering a pathway to energy security, economic growth, environmental protection, and improved public health.

- **Importance Renewable energy in sustainable development**

The 17 Sustainable Development Goals (SDGs) are a global plan to achieve a sustainable future by 2030. Adopted by all United Nations Member States in 2015, these goals address global challenges such as poverty, inequality, climate change, environmental degradation, peace, and justice. The SDGs aim to end poverty, eradicate hunger, promote good health and well-being, ensure quality education, achieve gender equality, ensure clean water and sanitation, provide affordable and clean energy, promote decent work and economic growth, build resilient infrastructure, reduce inequality, create sustainable cities and communities, ensure responsible consumption and production, combat climate change, conserve and sustainably use oceans, seas, and marine resources, protect terrestrial ecosystems, and promote peace, justice, and strong institutions. The SDGs also aim to strengthen global partnerships for sustainable development, enhancing international cooperation, mobilizing financial resources, promoting technology and knowledge sharing, and strengthening partnerships between governments, the private sector, and civil society. By achieving these goals, the world can work towards a more equitable and sustainable future for all.

- **Sources of energy region wise in India**

a comprehensive analysis of India's energy generation capacity across different regions, ownership sectors, and energy sources. As of the data provided, the total thermal capacity across India stands at 242,996.91 MW**,** with coal as the dominant contributor. The Western region leads in thermal energy production with 86,869.13 MW,

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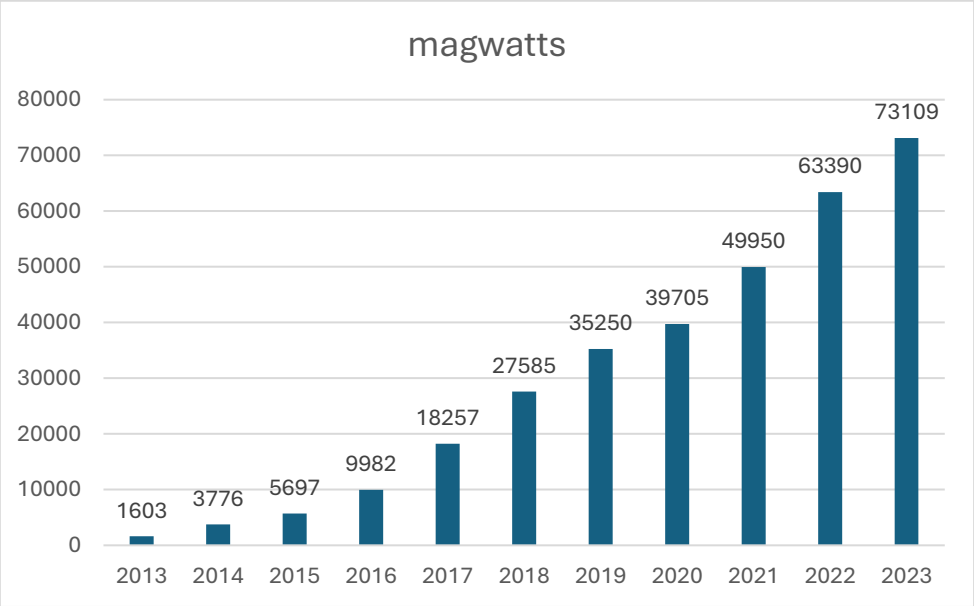
followed closely by the Southern region at 60,062.85 MW**.**In terms of nuclear capacity**,** India has a total of 8,180 MW, with the Southern and Western regions holding the largest shares, at 3,320 MW and 3,240 MW, respectively. The country's renewable energy sector shows significant potential, with a combined capacity of 195,012.81 MW**.** The Southern region is the frontrunner in renewable energy, with 55,363.29 MW in renewable energy sources (RES) and 11,827.48 MW in hydroelectric power. The Western region follows with 50,115.99 MW in RES and 7,562.5 MW in hydro.

The Northern region also contributes substantially with 11,580.51 MW in hydro and 379 MW in RES. The Eastern and Northeastern regions have comparatively smaller capacities, reflecting their lower energy demands and infrastructure development. The Islands have the smallest energy generation capacity, with a combined total of 2,942.98 MW in thermal, 1,944.01 MW in hydro, and 598.03 MW in RES.

Overall, the data highlights India's diverse and region-specific energy generation capacity, with a strong emphasis on expanding renewable energy sources to meet future demands while maintaining a significant base of thermal and nuclear power.

Based on the abjective 2 status of the renewable enrgy

1. Renewable energy Solar – Installed photovoltaic (PV) power and concentrated solar power (CSP)*

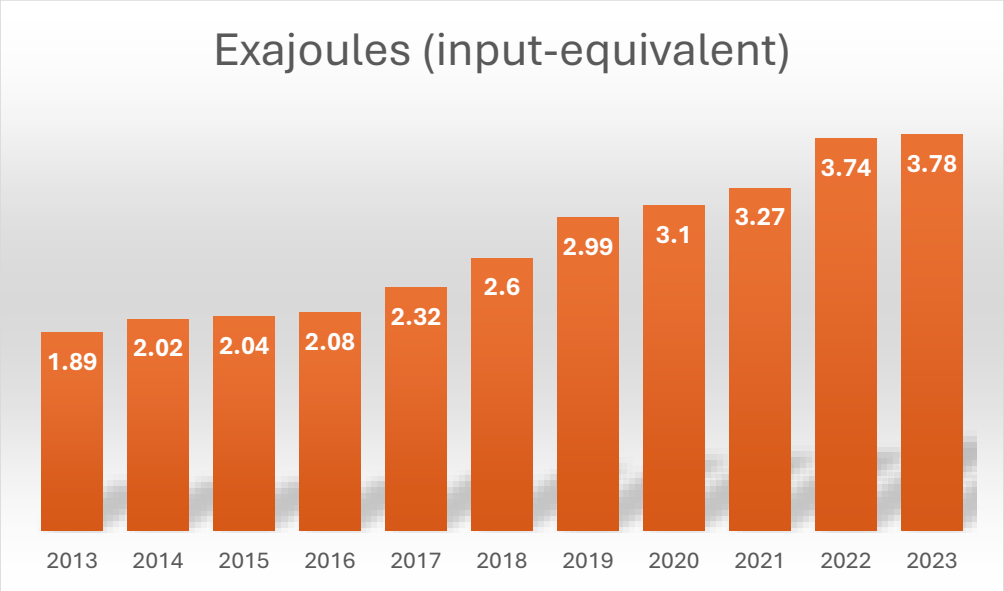


Sources: BP Energy outlook 2023

The graph illustrates the significant growth in India's installed renewable energy capacity from 2013 to 2023, measured in megawatts (MW). Starting from a modest 1,603 MW in 2013, the capacity steadily increased each year, reaching an impressive 73,109 MW by 2023. The data highlights a particularly rapid acceleration in growth after 2017, reflecting the impact of enhanced government initiatives, policy support, and increased investment in the renewable energy sector. The most substantial gains were observed between 2021 and 2023, where the capacity surged by over 33,000 MW. This trend demonstrates India's strong commitment to expanding its renewable energy infrastructure, driven by national goals and global climate commitments. The sharp rise in capacity not only signifies the progress made but also underscores the ongoing need for continued investment and innovation to sustain this momentum and ensure a sustainable energy future for the country.

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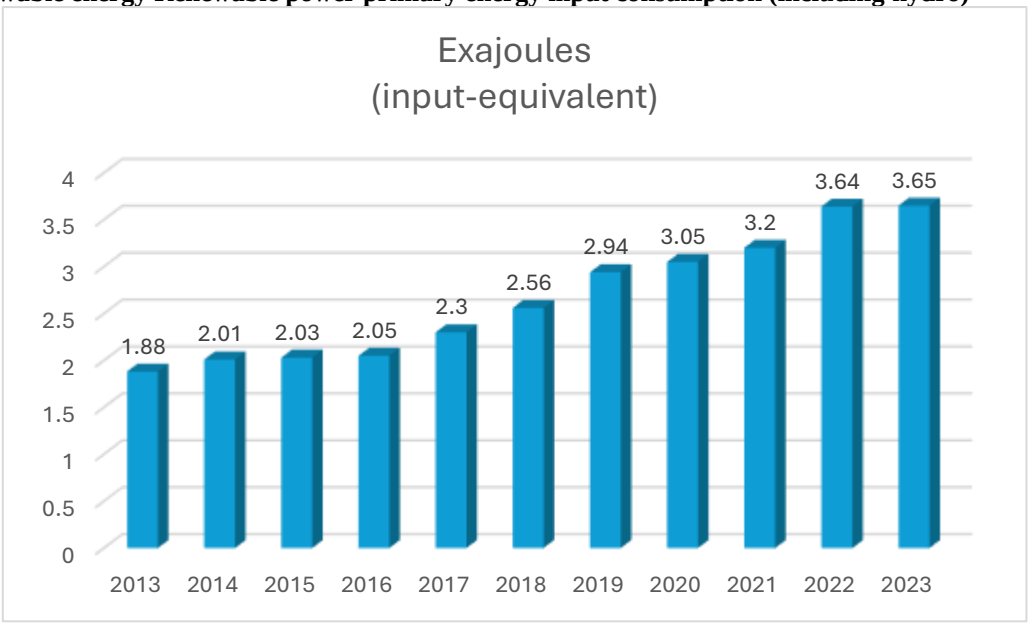
2. Renewable energy Combined renewable electricity and biofuels primary energy input consumption



Sources: BP Energy outlook 2023

The graph illustrates the steady growth in renewable energy consumption in India from 2013 to 2023, measured in exajoules. Starting at 1.89 exajoules in 2013, the consumption has gradually increased, reaching 3.78 exajoules by 2023. The early years from 2013 to 2016 show modest growth, with a significant rise beginning around 2017, followed by noticeable jumps in 2018 and 2021. These increases reflect India's expanding adoption of renewable energy, driven by policy initiatives, technological advancements, and growing investment in the sector. The consistent upward trend highlights India's commitment to enhancing energy security, reducing carbon emissions, and aligning with global climate goals, positioning renewable energy as a crucial part of the nation's energy strategy.

3. Renewable energy Renewable power primary energy input consumption (including hydro)



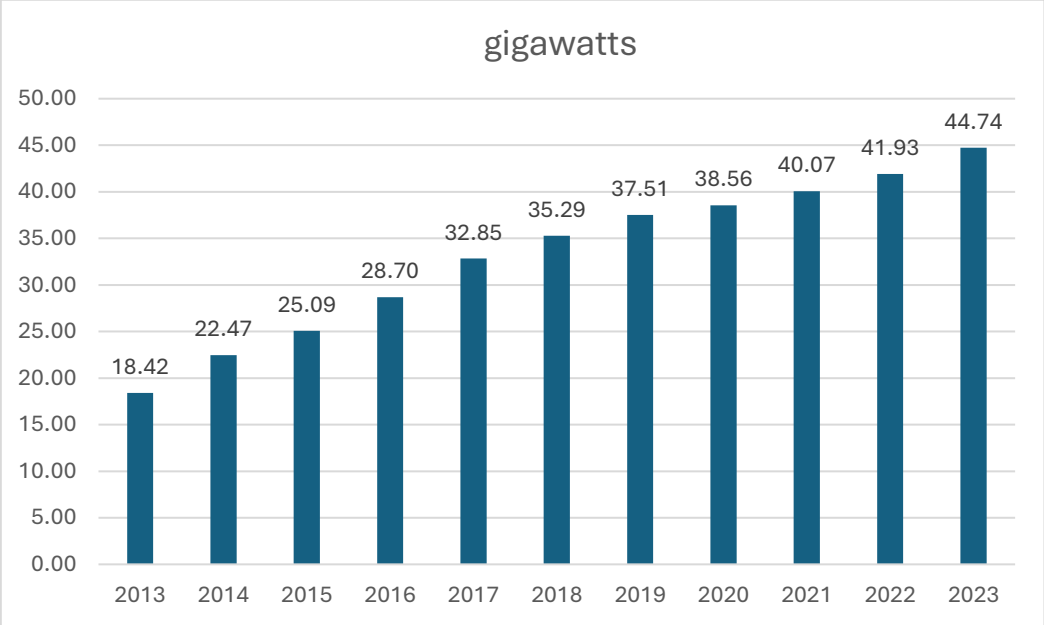
Sources: BP Energy outlook 2023

The graph illustrates the consistent and significant increase in renewable energy consumption in India from 2013 to 2023, measured in exajoules. Starting at 1.88 exajoules in 2013, consumption has steadily risen, reflecting

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India's growing commitment to renewable energy sources. The growth was relatively modest in the early years, with a gradual rise until 2016. However, from 2017 onwards, the pace of growth accelerated, with consumption reaching 3.65 exajoules by 2023. This sharp increase, particularly noticeable in the years 2018-2019 and 2021-2022, underscores India's strategic focus on expanding its renewable energy capacity. The data highlights the country's efforts to enhance energy security, reduce carbon emissions, and meet international climate goals, positioning renewable energy as a cornerstone of its energy policy.

4. Renewable energy Wind – Installed wind turbine capacity



Sources: BP Energy outlook 2023

Over the decade from 2013 to 2023, the installed capacity of wind turbines has shown impressive and consistent growth, increasing from 18.42 gigawatts (GW) to 44.74 GW. This nearly two-and-a-half-fold rise highlights a strong commitment to expanding renewable energy infrastructure. The annual growth rate averages around 2.66 GW, with a noticeable acceleration in recent years, particularly after 2016. This suggests not only a steady increase in wind power adoption but also an intensifying momentum driven by advancements in technology and supportive policies. The expansion of wind capacity reflects broader energy transition trends, emphasizing a shift away from fossil fuels towards more sustainable sources. This growth is significant for reducing greenhouse gas emissions, advancing climate goals, and fostering economic development within the renewable energy sector. Looking ahead, if current trends persist, wind energy will continue to play a crucial role in the global energy landscape, contributing to a cleaner and more sustainable future.

FINDINGS

1. **Significant Growth in Renewable Energy Capacity**
   India has seen remarkable growth in renewable energy capacity over the past decade, particularly in solar and wind energy. Solar capacity surged from 1,603 MW in 2013 to 73,109 MW in 2023. Wind capacity also grew substantially, nearly doubling from 18.42 GW to 44.74 GW during the same period.
2. **Increased Renewable Energy Consumption**
   Renewable energy consumption, including solar, wind, and biofuels, has shown a steady increase, reaching 3.78 exajoules by 2023 from 1.89 exajoules in 2013. This growth reflects the country's commitment to enhancing energy security and reducing carbon emissions.
3. **Diverse Energy Sources by Region**
   India's energy generation capacity varies significantly across regions. The Southern region leads in both renewable energy and hydroelectric power, while the Western region follows closely. The Northern region contributes significantly to hydro power, and other regions have relatively smaller capacities.
4. **Government Initiatives and Policy Support**
   The rapid acceleration in renewable energy capacity since 2017 can be attributed to enhanced government initiatives, supportive policies, and increased investments in the sector.

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5. **Environmental and Health Benefits**
   The transition to renewable energy is crucial for reducing greenhouse gas emissions, improving air quality, and mitigating the adverse effects of climate change. This shift also has positive implications for public health, particularly in urban areas affected by air pollution.
6. **Economic Growth and Energy Security**
   Investment in renewable energy infrastructure has spurred job creation, technological innovation, and economic growth. It also reduces dependence on imported fossil fuels, thereby enhancing energy security.

SUGGESTIONS

1. **Continued Investment and Innovation:**
   To sustain growth and enhance the effectiveness of renewable energy, continued investment in research and development is essential. Innovations in energy storage, grid integration, and efficiency improvements will be crucial for managing intermittent energy supplies and maximizing renewable energy benefits.
2. **Supportive Policy Framework:**
   Strengthening and expanding supportive policies at both national and regional levels will be vital. This includes incentives for renewable energy adoption, subsidies for technology development, and regulations that encourage private sector participation and public-private partnerships.
3. **Infrastructure Development:**
   Focus on improving infrastructure to support renewable energy integration into the national grid. Investments in transmission and distribution networks, as well as smart grid technologies, will help manage the increased capacity and ensure reliable energy delivery.
4. **Addressing Regional Disparities:**
   Develop region-specific strategies to balance energy generation capacities and address disparities. This includes targeting investments in underdeveloped regions to promote equitable growth and enhance energy access across the country.
5. **Enhancing Public Awareness and Participation:**
   Increase public awareness about the benefits of renewable energy and encourage community participation in renewable energy projects. This will help build public support and drive grassroots initiatives for sustainable energy solutions.
6. **Strengthening International Collaboration:**
   Engage in international partnerships to share knowledge, technology, and best practices. Collaboration with other countries can provide access to advanced technologies, funding opportunities, and expertise in renewable energy development.

By addressing these areas, India can continue to advance its renewable energy sector, achieve its climate goals, and foster a sustainable and resilient energy future.

CONCLUSION

The transition towards renewable energy in India represents a pivotal strategy for addressing the country's growing energy demands while ensuring sustainable development. The significant growth in renewable energy capacity—from solar and wind to bioenergy—demonstrates India's commitment to reducing dependence on fossil fuels and mitigating climate change. This transition is crucial for enhancing energy security, promoting environmental sustainability, fostering economic growth, and improving public health.

The data from the past decade underscores the substantial progress made in expanding renewable energy infrastructure. With solar capacity surging from 1,603 MW in 2013 to 73,109 MW in 2023 and wind turbine capacity nearly doubling, India's renewable energy sector has shown remarkable growth. The steady rise in renewable energy consumption reflects the country's ongoing efforts to align with global climate goals and reduce carbon emissions.

Despite these advancements, continued investment, innovation, and supportive policies are essential to sustain this momentum. Addressing challenges such as intermittent energy supply, storage solutions, and infrastructure development will be crucial for maximizing the benefits of renewable energy. Moreover, fostering public-private partnerships and enhancing research and development will play a vital role in advancing renewable technologies and achieving India's sustainable development objectives.

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In finally, renewable energy is not only a key component of India's energy strategy but also a critical driver of sustainable development. By capitalizing on its renewable resources and implementing effective policies, India can achieve its climate targets, ensure energy security, and contribute to a more sustainable and resilient future.

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