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An Overview Of Renewable Energy: Current Scenario, Prospects, Challenges, Employment & Investment Opportunities For Sustainable Development

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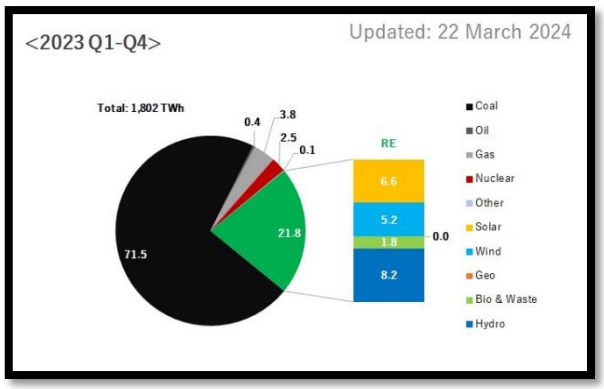
ABSTRACT:

The main goals of renewable energy deployment in India are to mitigate climate change, provide energy security, increase access to electricity and promote economic growth. The accessibility of modern, affordable, and dependable sustainable energy for everyone is one of the most crucial components of sustainable development. India is one of the most alluring and quickly expanding markets for renewable energy. To draw in international investment and boost the nation's renewable energy sector, the government has created legislation, initiatives, and a welcoming atmosphere. In the years to come, the country will see a large increase in employment due to the renewable energy sector. The several identified challenges of this sector here need to be solved. The possibilities and difficulties of renewable energy in India are discussed in this paper on the necessity of investments and regulation to achieve sustainable growth. This paper is based on secondary data and information that explains India's renewable energy, current scenario, and employment opportunities.

***Index Words*: Renewable, Deployment, Accessibility, Sustainable, Energy, Expanding, Initiatives, Atmosphere, Growth, Possibilities**

1. INTRODUCTION

The production of power from natural gas, coal, and oil accounts for one-third of global greenhouse gas emissions. Raising living conditions by providing cleaner and more reliable power is a critical requirement. The growing energy consumption in India is one pressing issue. An essential precondition for a country's economic growth is the expansion of energy supplies. The Ministry of Power's (MoP) National Energy Plan [NEP] has developed a 10-year comprehensive action plan to supply energy nationally and a second plan to ensure that power is delivered effectively and affordably, according to the 2017 World Resource Institute Report. India ranks fourth in terms of emissions, behind the United States (14.36%), China (26.83%), and the European Union (9.66%), and accounts for over 6.65% of global carbon emissions. Climate change may potentially disturb the planet's natural balance. Intended Nationally Determined Contributions (INDCs) have been submitted to the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement. The latter group has sought to limit global warming to well below 2°C. According to the World Energy Council, global power consumption is expected to peak in 2030. India stands as one of the world's largest coal consumers and relies heavily on expensive fossil fuel imports. Coal accounts for approximately 74% of the country's energy requirements. Data from the Centre for Monitoring Indian Economy indicates that India imported 171 million tons of coal during 2013-2014, 215 million tons in 2014-2015, 207 million tons in 2015-2016, 195 million tons in 2016-



2017, and 213 million tons in 2017-2018. Therefore, it is crucial to explore alternative methods of electricity generation. The country is poised for a rapid transition to renewable energy technologies to promote sustainable growth and mitigate the impacts of climate change. Renewable energy sources are vital in providing sustainable energy with reduced emissions. The potential of these technologies to meet electricity demands while significantly lowering emissions is widely acknowledged.

2. DISCUSSION

India has reached a significant milestone in its renewable energy journey, surpassing a total renewable energy capacity of 200 GW as of October 2024. This achievement aligns with the country's ambitious goal of attaining 500 GW from non-fossil sources by 2030. Currently, renewable energy accounts for over 46.3% of India's total electricity generation capacity, which has now reached 452.69 GW. The renewable energy mix includes solar power (92.12 GW), wind power (47.72 GW), large hydro (46.93 GW), small hydro (5.07 GW), and biopower (11.32 GW). When nuclear energy is factored in, the total non-fossil fuel capacity rises to 211.36 GW.

The renewable energy sector has also contributed significantly to job creation, generating approximately 1.02 million jobs in 2023, predominantly in hydropower and solar photovoltaic technologies. India's commitment to tackling climate change is underscored by its enhanced Nationally Determined Contributions (NDCs) under the Paris Agreement, which target a 45% reduction in emission intensity and aim for 50% of cumulative electric power capacity from non-fossil sources by 2030. The leading states in renewable energy capacity include Rajasthan, Gujarat, Tamil Nadu, and Karnataka.

In 2023, India added approximately 13.5 GW of renewable energy capacity, solidifying its position as 4th globally in overall renewable energy installed capacity, as well as in wind power capacity, and 5th in solar power capacity. The introduction of the "Offshore Wind Energy Lease Rules, 2023" was a significant step in regulating the allocation of offshore wind sea blocks to developers. Furthermore, India established a definition for Green Hydrogen as part of the National Green Hydrogen Mission, aimed at creating production facilities with a capacity of 450,000 tonnes of Green Hydrogen. Under the revised targets for Components B and C of PM KUSUM, a total of 4.9 million pumps will be installed or solarized.

India has reached a remarkable milestone in its renewable energy journey, with its total renewable energy capacity exceeding 200 GW (gigawatts). This impressive growth is in line with the nation's ambitious goal of achieving 500 GW from non-fossil sources by 2030. According to the Central Electricity Authority, the total renewable energy-based electricity generation capacity now stands at 203.18 GW. This achievement underscores India's growing commitment to clean energy and its progress in building a greener future. India's total renewable energy installed capacity surged by an impressive 24.2 GW (13.5%) in just one year, reaching 203.18 GW in October 2024, up from 178.98 GW in October 2023. Additionally, when including nuclear energy, India's total non-fossil fuel capacity rose to 211.36 GW in 2024, compared to 186.46 GW in 2023.

This milestone reflects the result of years of dedicated efforts to harness India's natural resources. From sprawling solar parks to wind farms and hydroelectric projects, the country has steadily built a diverse renewable energy base. These initiatives have not only reduced reliance on fossil fuels but also strengthened the nation's energy security. When factoring in the 8,180 MW (megawatt) of nuclear capacity, the total non-fossil fuel-based power now accounts for almost half of the country's installed electricity generation capacity, signalling a strong move toward clean energy leadership on the global stage. India's total electricity generation capacity has reached 452.69 GW, with renewable energy contributing a significant portion of the overall power mix. As of October 2024, renewable energy-based electricity generation capacity stands at 203.18 GW, accounting for more than 46.3 percent of the country's total installed capacity. This marks a major shift in India's energy landscape, reflecting the country's growing reliance on cleaner, non-fossil fuel-based energy sources.

A variety of renewable energy resources contribute to this impressive figure. Solar power leads the way with 92.12 GW, playing a crucial role in India's efforts to harness its abundant sunlight. Wind power follows closely with 47.72 GW, driven by the vast potential of the coastal and inland wind corridors across the country. Hydroelectric power is another key contributor, with large hydro projects generating 46.93 GW and small hydro power adding 5.07 GW, offering a reliable and sustainable source of energy from India's rivers and water systems. Biopower, including biomass and biogas energy, adds another 11.32 GW to the renewable energy mix. These bioenergy projects are vital for utilizing agricultural waste and other organic materials to generate power, further diversifying India's clean energy sources. Together, these renewable resources are helping the country reduce its dependence on traditional fossil fuels, while driving progress toward a more sustainable and resilient energy future.

The use of renewable energy sources in meeting India's energy needs

India is a key player in the global energy transition. India's energy journey is important for the globe and itself because of its expanding population, increased energy demands, and notable economic growth. This highlights India's changing role in the global energy and climate arena, where reaching global climate targets depends on its emissions trajectory and developmental trajectory. India's shift to sustainable energy has been significantly shaped over the last ten years (2013–2023). In this period, India became the world's third-largest producer of renewable energy and the fourth-largest consumer of power.

India's energy sector is undergoing remarkable growth, reflecting the rapid increase in the country's population. Over the past decade—from 2013-14 to 2023-24—the primary energy supply has risen by 54.5 percent, escalating from 589 million tonnes of oil equivalent (Mtoe) to 910 Mtoe. Total electricity consumption, including captive usage, has doubled, increasing from 874 billion units (BU) to 1,543 BU during the same period, with an annual growth rate of 5.8 percent. Additionally, India's peak electricity demand surged by 79 percent, climbing from 136 GW to 243 GW between 2013-14 and 2023-24. Notably, on May 30, 2024, India reached an all-time high peak electricity demand of 250 GW. India has made impressive strides in tackling electricity shortages over the last decade by building a robust and sustainable power infrastructure. The country's installed electricity capacity has nearly doubled, soaring from 248 GW in 2013-14 to an impressive 442 GW in 2023-24 (CEA b, 2024). Significantly, renewable energy capacity has more than doubled as well, rising from 76 GW to 191 GW in this period. This remarkable growth has boosted the contribution of renewable energy to India's power generation mix, increasing its share from 18 percent to 21 percent in 2023-24.

Rooftop solar (RTS) has experienced extraordinary growth, achieving an astounding annual increase of 45 percent since 2017-18. It has surged from just 1.06 GW in 2017-18 to a remarkable 14.45 GW in 2024-25 (as of October 24). As a result of these advancements, peak demand shortages have plummeted from 4.5 percent to a mere 1.4 percent, and the overall electricity requirement shortage has been minimized to just 0.3 percent. This impressive progress underscores India's commitment to a cleaner and more reliable energy future. Peak demand shortages plummeted from 4.5 percent to 1.4 percent, and the overall electricity requirement shortage has been reduced to 0.3 percent. The industry sector in India is the largest consumer of both energy and electricity, accounting for 49.5 percent and 42 percent of the energy and electricity consumption share, respectively, in 2023-24. Over the past decade, there has been a significant transition towards cleaner fuels within the Industry Sector, marked by a decrease in coal's share of total energy consumption from 70 percent in 2013-14 to 63 percent in 2023-24. The implementation of energy efficiency initiatives has led to considerable energy savings in this sector, amounting to 25.81 Mtoe, and has contributed to a reduction in CO2 emissions by 110.95 MTCO2e per year. Notably, the Iron and Steel Sector has successfully met its emission intensity reduction targets, decreasing emission intensity from 3.1 T/TCS (tonnes of CO2 per tonne of crude steel) in 2005 to 2.5 T/TCS in 2020.

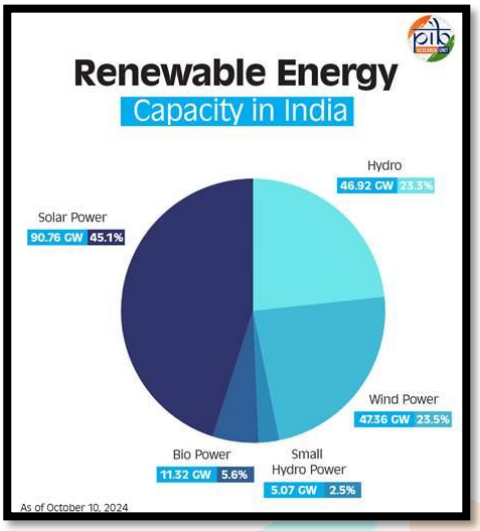
The transport sector is the second major energy consumer after the industry, accounting for 12 percent of the final energy consumption. The sector is indispensable for the country's socio-economic development, providing connectivity and integrating 1.4 billion people. The transport sector witnessed the highest demand growth in India's energy consumption basket, rising from 35 Mtoe to 72 Mtoe between 2013-14 and 2023-24. The increase continues to be propelled by growing vehicle usage in the road transport segment. Responsible for 87 percent of passenger and 60 percent of freight traffic, road transport accounted for over 77 percent of total transport-related energy consumption in 2023-24. In recent years, there has been a notable shift to Electric Vehicles (EVs), with EV ownership in new vehicle sales rising from 0.3 percent in 2016-17 to 7 percent in 2023-24. In the last decade, India registered 39.6 lakh electric vehicles, with 11.6 lakhs added between April 2024 and October 2024.

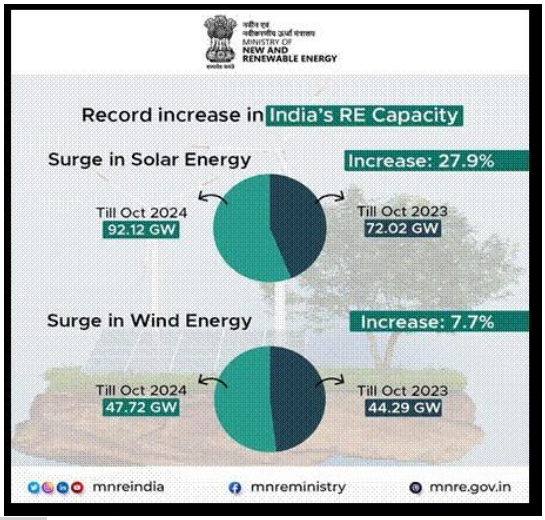
The building sector is the second major electricity consumer after the industry, accounting for 32 percent of the total electricity consumption in India. Improving living standards and a massive electrification drive led to a significant increase in electricity consumption in residential buildings. From 2013-14 to 2023-24, electricity consumption increased from 200 BUs to 375 BUs, taking India's second-highest share (after Industry) for category-wise electricity consumption. The Pradhan Mantri Ujjwala Yojana (PMUY) scheme led to an exponential rise in the use of Liquid Petroleum Gas (LPG) for cleaner cooking, increasing its share of residential consumption from 69 percent in 2013-14 to 99 percent in 2023-24, as of 01st December 2024, 10.33 crore s were released nationwide.

India is an agriculture-based country with agriculture providing livelihood to almost 45.76 percent of the population in the country. Solar energy for irrigation is paving a sustainable and economical path for growing agricultural activities in India. Oil consumption in the farm sector has been steadily declining, with electricity serving as the primary energy source, accounting for 97 percent of total energy use in 2023-24. The

number of energized pump sets has increased from 189 Lakhs in 2012-13 to 272 Lakhs in 2022-23, reflecting an annual growth rate of 4 percent. Meanwhile, solar pump adoption grew substantially during the same period, rising from 11,626 to 5.27 Lakhs, marking a 45-fold increase.

Estimated renewable energy potential in India





Source: https://npp.gov.in/dashBoard/cp-map-dashboard

Gross installed capacity of renewable energy in India.

India's total electricity generation capacity has reached 452.69 GW, with renewable energy contributing a significant portion of the overall power mix. As of October 2024, renewable energy-based electricity generation capacity stands at 201.45 GW, accounting for 46.3 percent of the country's total installed capacity. This marks a major shift in India's energy landscape, reflecting the country's growing reliance on cleaner, non-fossil fuel-based energy sources.

A variety of renewable energy resources contribute to this impressive figure. Solar power leads the way with 90.76 GW, playing a crucial role in India's efforts to harness its abundant sunlight. Wind power follows closely with 47.36 GW, driven by the vast potential of the coastal and inland wind corridors across the country. Hydroelectric power is another key contributor, with large hydro projects generating 46.92 GW and small hydropower adding 5.07 GW, offering a reliable and sustainable source of energy from India's rivers and water systems. Biopower, including biomass and biogas energy, adds another 11.32 GW to the renewable energy mix. These bioenergy projects are vital for utilizing agricultural waste and other organic materials to generate power, further diversifying India's clean energy sources. These renewable resources are helping the country reduce its dependence on traditional fossil fuels while driving progress toward a more sustainable and resilient energy future.

With its total renewable energy capacity surpassing 200 GW (gigawatt), India has achieved a major milestone in its renewable energy path. The nation's ambitious renewable energy goal of 500 GW from non-fossil sources by 2030 aligns with this impressive. The CEA reports that 203.18 GW of power can now be generated using renewable energy. India's increasing dedication to renewable energy and its advancements in creating a more environmentally friendly future are highlighted by this accomplishment. In just one year, India's installed capacity for renewable energy increased by an astounding 24.2 GW (13.5%), from 178.98 GW in October 2023 to 203.18 GW in October 2024. Furthermore, India's total non-fossil fuel capacity increased to 211.36 GW in 2024 from 186.46 GW in 2023 when nuclear energy was included.

Power At a Glance		Updated on 12.06.2023 Source: OM SECTION
Total installed capacity (as on 31.05.2023) Source: Central Electricity Authority (CEA)		
INSTALLED GENERATION CAPACITY SECTOR-WISE AS ON 31.05.2023		
Sector	MW	% of Total
Central Sector	1,00,055	24.0%
State Sector	1,05,726	25.3%
Private Sector	2,11,887	50.7%
Total	4,17,688	

Years of devoted work to utilize India's natural riches have culminated in this milestone. The nation has gradually developed a varied renewable energy base with wind farms, hydroelectric projects, and expansive solar parks. In addition to lowering dependency on fossil fuels, these efforts have improved the country's energy security. Nearly half of the nation's installed electricity generation capacity is currently derived from non-fossil fuel-based power, including the 8,180 MW (megawatt) of nuclear capacity. This represents a significant step toward the nation's leadership in clean energy on the international scene. India has 452.69 GW of total electricity-producing capacity, and a sizable amount of the power comes from renewable sources. More than 46.3 percent of the nation's installed capacity is made up of 203.18 GW of power generated by renewable energy as of October 2024. As India's reliance on cleaner, non-fossil fuel-based energy sources grows, this represents a significant change in the country's energy landscape. This remarkable number is a result of numerous renewable energy sources. With 92.12 GW, solar power tops the field and is essential to India's attempts to capture its plentiful sunshine. With 47.72 GW, wind power comes in second, propelled by the enormous potential of the nation's inland and coastal wind corridors. Another significant contributor is hydroelectric power, which provides a dependable and sustainable source of energy from India's rivers and water systems. Large hydro projects generate 46.93 GW, while minor hydro projects produce 5.07 GW.

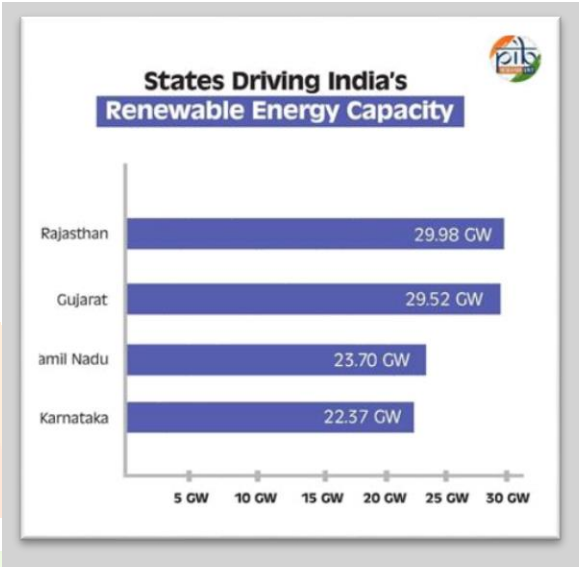
INSTALLED GENERATION CAPACITY (FUELWISE)As on 31.05.2023

Category	Installed Generation Capacity (MW)	% of share in Total
Fossil Fuel		
Coal	205,235	49.1%
Lignite	6,620	1.6%
Gas	24824	6.0%
Diesel	589	0.1%
Total Fossil Fuel	2,37,269	56.8%
Non-Fossil Fuel RES (Inc. Hydro)	173,619	41.4%
Hydro	46,850	11.2%
Wind, Solar, other RE	125,692	30.2%
Wind	42,868	10.3%
Solar	67,078	16.1%
BM Power /Cogen	102,48	2.5%
Waste to Energy	554	0.1%
Small Hydro Power	4944	1.2%
Nuclear	6,780	1.6%
Total Non-Fossil Fuel	179,322	43.0%
Total Installed Capacity (Fossil fuel & Non-Fossil Fuel)	4,17,668	100%

An additional 11.32 GW is added to the mix of renewable energy sources by biopower, which includes biomass and biogas energy. These bioenergy projects are essential for increasing the variety of renewable energy sources available in India by using organic materials and agricultural waste to produce electricity. While advancing the nation's transition to a more resilient and sustainable energy future, these renewable resources are working together to lessen reliance on conventional fossil fuels.

The International Renewable Energy Agency's (IRENA) 2024 Annual Review estimates that 1.02 million jobs were created in 2023, marking a major milestone for India's renewable energy sector. The number of people working in renewable energy increased from 13.7 million in 2022 to 16.2 million in 2023, with India being a major contributor to this increase. The report, which was produced in partnership with the International Labour Organization (ILO), highlights India's growing prominence in the clean energy sector and its dedication to creating green jobs that support economic expansion.

Total Generation and growth over the previous years in the country during 2009-10 to 2023-24		
Year	Total Generation Capacity (inc. RE Sources) (BU)	% of Growth
2009-10	808.498	7.56%
2010-11	850.387	5.59%
2011-12	928.113	9.14%
2012-13	969.506	4.46%
2013-14	1020.200	5.23%
2014-15	1110.392	8.84%
2015-16	1173.603	5.69%
2016-17	1241.689	5.80%
2017-18	1308.146	5.35%
2018-19	1376.095	5.19%
2019-20	1389.102	0.95%
2020-21	1381.855	-0.52%
2021-22	1491.859	7.96%
2022-23	1624.158	8.87%
2023-24	286.176	-0.72%
Up to May 2023 (Provisional)Source: CEA		



Around 453,000 jobs, or 20% of the total worldwide, were created by hydropower, making it the largest employer in the industry and second only to China. Following closely after, the solar photovoltaic (PV) industry employed over 318,600 individuals in combined off-grid and on-grid installations. With 9.7

GW of new installations and a cumulative capacity of 72.7 GW by the end of 2023, India ranked fifth in the world for solar PV capacity. About 80,000 people worked in the off-grid solar industry, while 238,000 jobs in grid-connected solar PV, an 18% growth from 2022, made up the whole solar workforce.

Of the approximately 52,200 workers in the wind industry, around 40% were employed in operations and maintenance, and 35% were involved in construction and installation. Additional jobs were created by other subsectors of renewable energy, including solid biomass (58,000 jobs), biogas (85,000 jobs), and liquid biofuels (35,000 jobs). A further indication of the varied and growing job prospects in India's renewable energy sector is the 17,000 jobs in the solar heating and cooling sector. India has demonstrated its commitment to combating climate change by implementing the five aspects discussed at COP26 in Glasgow into its upgraded Nationally Determined Contributions (NDCs) under the Paris Agreement.

Considering national conditions, these initiatives are in line with the Common but Differentiated Responsibilities and Respective Capabilities (CBDR-RC) and equality principles. The wind industry employed 52,200 people, of whom about 40% worked in operations and maintenance and 35% in installation and construction. Other subsectors of renewable energy also contributed to job creation, with liquid biofuels creating 35,000 jobs, solid biomass creating 58,000, and biogas producing 85,000. Additionally, 17,000 people were engaged in the solar heating and cooling sector, illustrating the variety of expanding employment opportunities in India's renewable energy sector.

India's enhanced Nationally Determined Contributions (NDCs) under the Paris Agreement show its commitment to addressing climate change by including the five elements outlined at COP26 in Glasgow. These programs align with the principles of equity and Common but Differentiated Responsibilities and Respective Capabilities (CBDR-RC), taking into consideration country conditions. India's enhanced NDCs under the Paris Agreement demonstrate its commitment to addressing climate change by incorporating the five elements outlined at COP26 in Glasgow. India has committed to reducing its emissions intensity by 45% by 2030 (compared to 2005 levels) as part of its updated NDC submitted to the UNFCCC (United Nations Framework Convention on Climate Change) in August 2022. It also aims to achieve 50% of cumulative electric power capacity from non-fossil fuel sources. Taking into account national circumstances, these initiatives are in line with the Common but Differentiated Responsibilities and Respective Capabilities (CBDR-RC) and equality principles. As part of the updated NDC submitted to the UNFCCC (United Nations Framework Convention on Climate Change) in August 2022, India committed to reducing its emissions intensity by 45% by 2030 (compared to 2005 levels), achieving 50% of its total electric power capacity from non-fossil fuel sources by 2030, and promoting a sustainable way of life through the 'LIFE' (Lifestyle for Environment) initiative.

According to the 'Long-term Low Carbon Development Strategy' that India presented to the UNFCCC in November 2022, these goals also help the country achieve its long-term objective of achieving net-zero emissions by 2070. In terms of renewable energy capability, a few of India's states have taken the lead, greatly advancing the country. With an astounding 29.98 GW of installed renewable energy capacity, Rajasthan tops the list. This is due to the state's large land area and plentiful sunshine. Gujarat, with its 29.52 GW capacity and a major emphasis on solar and wind energy projects, comes in second. Third place goes to Tamil Nadu, which uses its favorable wind patterns to produce a significant amount of energy (23.70 GW). With a 22.37 GW capacity, Karnataka completes the top four, aided by a combination of wind and solar projects.

India, home to about 1.4 billion people and one of the fastest-growing economies in the world, has recently strengthened its position as a leader in renewable energy. Endowed with significant renewable energy resources, India is rapidly transforming its energy landscape. As of 2023, India’s 176 gigawatts of installed renewable energy capacity makes it the fourth-leading nation in renewable power capacity worldwide. Moreover, the Asian country’s electricity production from renewable sources more than doubled between 2012 and 2023. Despite these developments, India’s overall energy mix was still dominated by thermal energy from coal and oil. However, the energy sector will see a shift towards renewables in the future.

Summary of India's Renewable Energy Capacity: New Milestone

India has achieved a significant milestone in its renewable energy journey, with the total renewable energy capacity surpassing 200 GW as of October 2024. This growth aligns with the country's target of reaching 500 GW from non-fossil sources by 2030. Renewable energy now constitutes more than 46.3% of India's total electricity generation capacity, at 452.69 GW. The renewable energy mix includes solar power (92.12 GW), wind power (47.72 GW), large hydro (46.93 GW), small hydro (5.07 GW), and biopower (11.32 GW). Including nuclear energy, the total non-fossil fuel capacity is 211.36 GW. The renewable energy sector

has also created significant employment opportunities, with an estimated 1.02 million jobs in 2023. Hydropower and solar PV are the largest employers within the industry. India's commitment to climate change is reflected in its enhanced Nationally Determined Contributions (NDCs) under the Paris Agreement, aiming to reduce emissions intensity by 45% by 2030 and achieve 50% of cumulative electric power capacity from non-fossil sources by 2030. Leading states in renewable energy capacity include Rajasthan, Gujarat, Tamil Nadu, and Karnataka.

As stated by the Prime Minister at COP26, the Ministry of New and Renewable Energy aims to generate 500 GW of electricity from non-fossil sources by 2030. It is anticipated that 13.5 GW of RE capacity will be installed in 2023, requiring an investment of roughly ₹74,000 crores. India stands 4th globally in Renewable Energy Installed Capacity, 4th in Wind Power capacity and 5th in Solar Power capacity (as per International Renewable Energy Agency - Renewable capacity statistics 2023). The 13th Assembly of the International Renewable Energy Agency (IRENA), the first global organization to concentrate solely on renewable energy, was held in Abu Dhabi from January 14–15, 2023, with India serving as its host nation.

Conclusion:

India's power and energy sector presents significant growth opportunities, driven by increasing demand, government initiatives, and a focus on renewable energy. The government's commitment to sustainable energy solutions and continuous investments in the sector contribute to its ongoing development and transformation. The lack of infrastructure and inadequate technology needed to implement renewable technologies should be addressed by research and development. The government ought to provide additional funding to encourage this industry's R&D and innovation efforts. The renewable energy market requires explicit policies and legal procedures to enhance the attention of investors. People's awareness of renewable energy should be promoted, and their sociocultural practices should be carefully considered. Governments ought to encourage investments in their expansion to expedite the commercialization of renewable energy technology. Every nation and individual should emulate the leading countries in renewable energy adoption. We must unite to address the crises that confront us all. Furthermore, even those nations at the forefront of this movement must accelerate their efforts to effectively tackle challenges and advance toward a sustainable future for everyone. These ongoing efforts reflect a holistic approach to building a greener economy, ensuring that India not only meets its energy needs but also addresses the pressing challenges of climate change and resource conservation.

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