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MAKE IN INDIA MITTELSTAND!

Powering Tomorrow:

Sector Overview and Opportunities in India's Renewable Energy Industry

MAKE IN INDIA

This report has been jointly written and published by Invest India and Rödl & Partner as part of the "Make in India Mittelstand!" Programme.

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Executive Summary

India has been one of the leading nations to determinedly transition towards clean energy. As the nation with fourth[1] largest installed renewable energy (RE) capacity, India has succeeded in doubling its installed RE capacity (including large hydro), from 80 GW in 2014 to 177.7 GW[2] in 2023. The Government of India's ambitious RE targets coupled with a robust and proactive policy and regulatory framework have been crucial in the development of sector. Gradual yet active substitution and phase-out of coal power since 2015 has acted as a positive tailwind for the RE sector and as an indicator to investors in the power sector. India's pre-construction coal power capacity decreased by nearly 88% from 2015 to 2022[3] while on the other hand, India's target of reaching 40% of the installed capacity from non-fossil energy sources by 2030 was achieved in November 2021.[4]

India has, by 2030, committed to reach 500 GW non-fossil energy capacity, shift 50% of energy requirements to renewable energy, lower overall anticipated carbon emissions by 1 billion tons, reduce carbon intensity of the economy by 45% over 2005 levels and finally achieve net zero emissions by 2070. The corporates, replicating the progressive outlook, have set ambitious RE targets for 2030, to name a few, 100 GW of capacity addition has been committed by Reliance Industries, 60 GW by NTPC Ltd., 25 GW each by ACME Solar, Tata Power, and Renew Power and 45 GW by Adani Green etc.

The robust policy and regulatory framework set into place since 2014 resulted in increasing investor confidence, reducing the costs and lowering risks. The global deflationary trend in renewable equipment prices (particularly solar PV modules) in the last decade coupled with strong industry outlook has resulted in non-fossil fuel sources capturing ~43% of total installed generation capacity in India. More than US$ 80 billion have been invested in the Indian renewable energy sector since 2014. India has, between April 2010 - March 2023[3] received ~US$ 13.3 billion FDI in the renewable energy sector. India ranked first in the power category among 107 emerging markets for investments as per BNEF's Climatescope survey 2021.[5]

Sectors such as solar energy have seen tremendous growth in the last decade compounding an annual growth rate of ~35%. Solar and wind energy together dominated 99% of overall capacity addition for the year 2022. India is also the most attractive market for solar investment and is actively diversifying its solar PV supply chain – the module production capacity is expected to reach a staggering 110 GW by 2026 while upstream manufacturing is likely to reach 38 GW for polysilicon and 56 GW for ingots/wafers (56GW).

India also launched the Green Hydrogen Mission with a target to achieve at least 5 MMT (million metric tonnes) of production capacity per annum, an electrolyser capacity of 60 GW[6] and an additional RE capacity of ~125 GW by 2030. To ensure grid stability and round the clock power there is a thrust towards energy storage solutions as well as wind-solar hybrid plants.

Several initiatives such as the PM KUSUM scheme and financial incentives for off grid solar, bioenergy and small hydro power have functioned as industry enablers – creating multiplier

[1] REN21 Renewables 2022 Global Status Report
[2] Installed Capacity Report – July 2023, Central Electricity Authority
[3] Global Energy Monitor's ninth annual survey of the coal plant pipeline
[4] PIB accessed on 19 June 2023
[5] Bloomberg NEF, Financing India's 2030 Renewables Ambition June 22, 2022
[6] Niti Aayog, 'Harnessing Green Hydrogen'

impact on the agriculture and transport sector, thereby playing a critical role in reducing GHG emissions. India is actively engaged in clean energy R&D initiatives and has undertaken significant efforts in the fields of Bio-Refineries, Sustainable Aviation Fuels, Materials Accelerated Platform, Building Energy Efficiency (Smart Grids), Carbon Capture, Hydrogen Valley Platforms among others.

The Indian government has enabled creation of a competitive RE market ecosystem based on the 'Aatma Nirbhar' philosophy - strong incentives for capacity addition and conducive policies for research led innovation. With India expected to grow more than 7% in the coming years, the booming economy, and rising energy demand pave the way for rapid scale up of renewable energy based on the clean energy transition targets.

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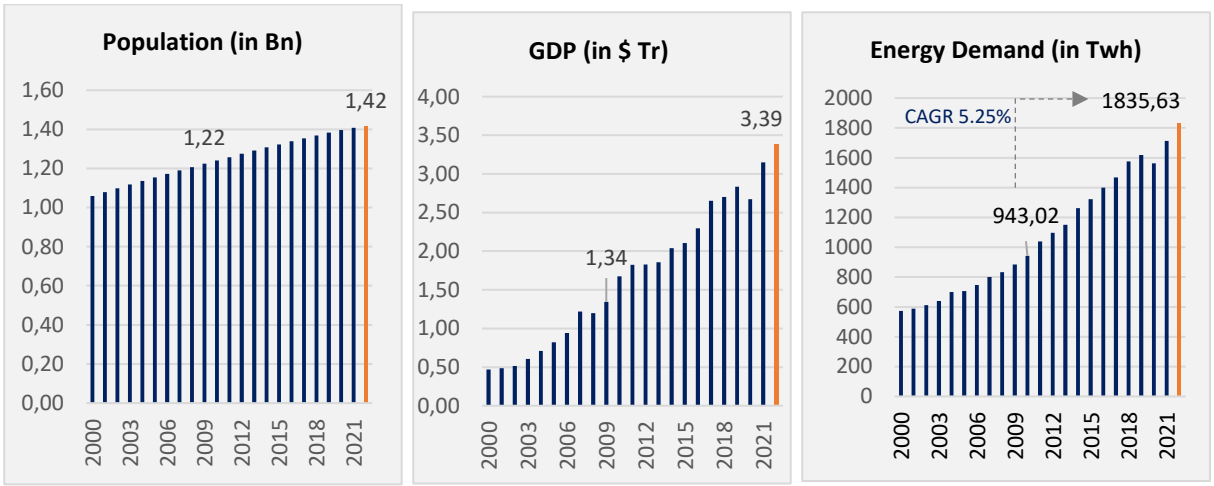
1. The India Advantage

India is one of the fastest growing economies in the world with an average annual growth rate of 6-7% since 2014. With over half of India's population under the age of 25[7], the economy is expected to grow rapidly. Growing standards of living, booming market, young and dynamic population along with strong macroeconomic forecasts make India an attractive market globally.

Energy has been crucial in India's growth trajectory so far, functioning both as a conduit for rapid development and as an outcome of the booming economy. India is following a two-pronged approach to ensure 'Energy security', wherein, on one hand, targeted reduction of crude oil and power equipment imports along with diversification of suppliers was undertaken, while on the other hand, diversification of energy sources, grid stability and improvement in energy efficiency has been focussed upon.



Sources: CEA, Ministry of Statistics and Programme Implementation, and World Bank data

The introduction of robust policies by Government of India for the solar and wind sectors in the late 2010s led to a dramatic reduction in the production cost and a substantial rise in the uptake of renewable energy across the spectrum.

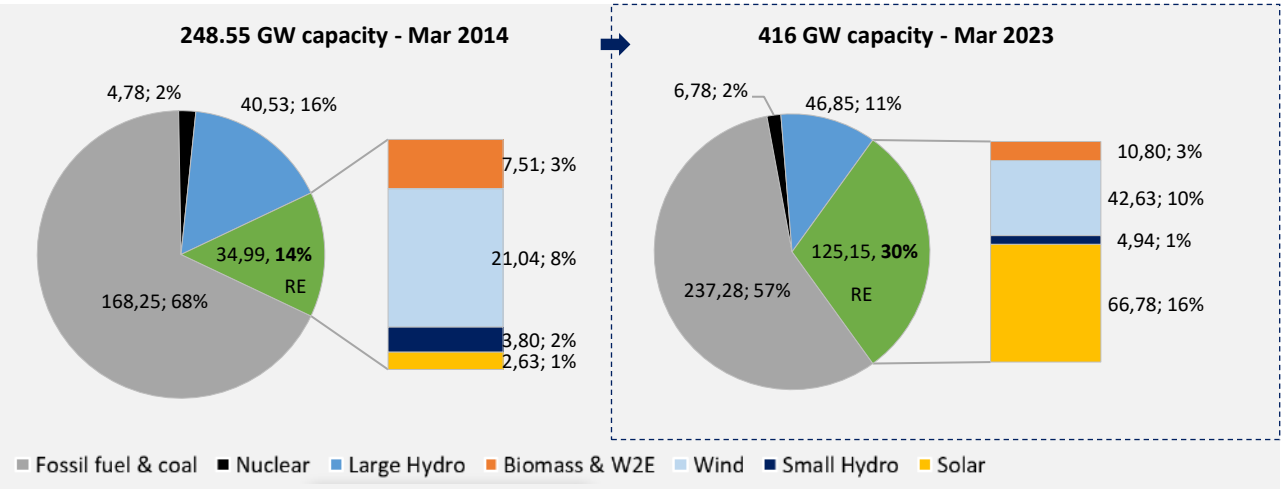
Rapid industrialization and a growing population doubled India's energy demand in the last two decades. As world's third-largest energy consumer, India's share in global primary energy consumption is projected to increase to ~9.8% by 2050 from the current 6.1%.[8] This significant rise in the energy demand will be met through a diversified energy ecosystem, with non-fossil energy meeting 50% of the energy demand by 2030.[9] It is critical to note that energy use per capita is less than half of the global average indicating differences in energy use and the importance of affordable and reliable source of energy for the Indian masses.[10]

This burgeoning energy demand will be met by factoring in critical macroeconomic and ecological priorities: (1) need for diversified, sustainable and affordable sources of energy, (2) need to gradually reduce energy imports, and improve balance of payments (3) need to meet the commitments as a part of Nationally Determined Contributions (NDC) under the Paris Agreement on Climate Change.

[7] State of World Population report 2023
[8] India Energy Outlook 2021, by International Energy Agency (IEA)
[9] As per Government of India's updated Nationally Determined Contributions (NDC) targets
[10] India Energy Outlook 2021

Installed RE capacity in GW - Over the years

The share of installed renewable energy (RE) capacity increased from 16% in the year 2014 to ~42% in the year 2023. The period highlights a dynamic shift in the RE sector from wind energy accounting for majority of the capacity additions in 2014 to a combination of solar and wind energy adding to capacity today.

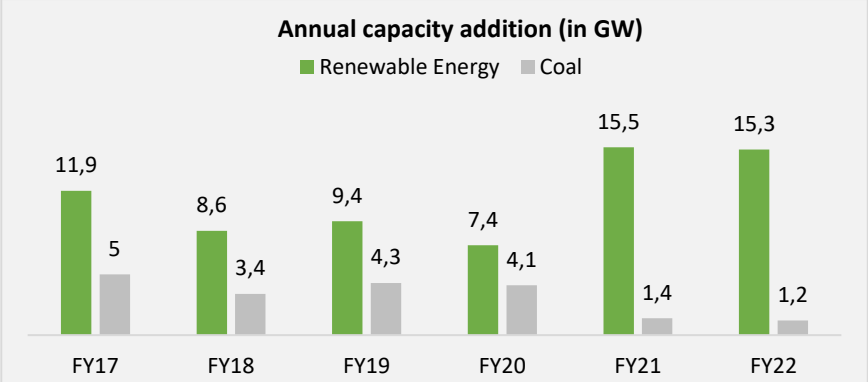


Source: CEA data

In India, four-fifths of energy needs are currently met by coal, oil and solid biomass. The share of coal as a part of the power generation mix, however, has been declining after it peaked in 2015 at 78%.[11] Share of coal (including lignite) based capacity in the total installed capacity of the country is likely to reduce to around 38.4% by March 2027 and to around 28.7% by March 2032. Share of coal-based generation is also likely to reduce to 58.9 % of the total generation mix by 2026-27 and to 49.9 % by 2031-32.[12]

This decline can be attributed to wide ranging factors such as increasing cost competitiveness and exponential growth of the solar and wind energy, pro-active measures[13] taken by the Government of India in the last decade, such as holding reverse auctions, creating solar parks and de-risking evacuation and offtake, technological innovation in battery storage systems and rise in use cases particularly in the agriculture and cold storage sector.

[11] IEA India Energy Outlook 2021
[12] PIB, accessed on 9 June 2023, https://pib.gov.in/PressReleseDetailm.aspx?PRID=1907720
[13] Ministry of Power and Ministry of New and Renewable Energy Annual Reports



*Source: CEA data (*Renewables excluding Large Hydro Power)*

The increase in uptake of renewable energy is likely to be supported by rising vehicle ownership and road transport use – evident with an increase in adoption of EV vehicles[14] in India and upsurge in investments in nascent sectors such as Green Hydrogen. Cost competitiveness of the renewable sources as well as rising use cases will further facilitate the diversion of fossil source-based demand to non-fossil sources.

India's commitment to a target of net zero emissions by 2070 as part of its updated NDCs[15] (5 targets given below) along with its 'Long-Term Low Carbon Development Strategy (LT-LEDS)' will further contribute to the shift towards green energy domination.

Commitments towards five nectar elements (Panchamrit) to deal with climate change.

By 2030, India aims to:

- Increase non-fossil energy capacity to 500 GW
- Meet 50% energy requirement from renewables
- Reduce carbon emissions by 1 Bn tons
- Reduce carbon intensity by 45%

By 2070, India aims to achieve the target of net zero emissions.

2. The consistent rise of RE

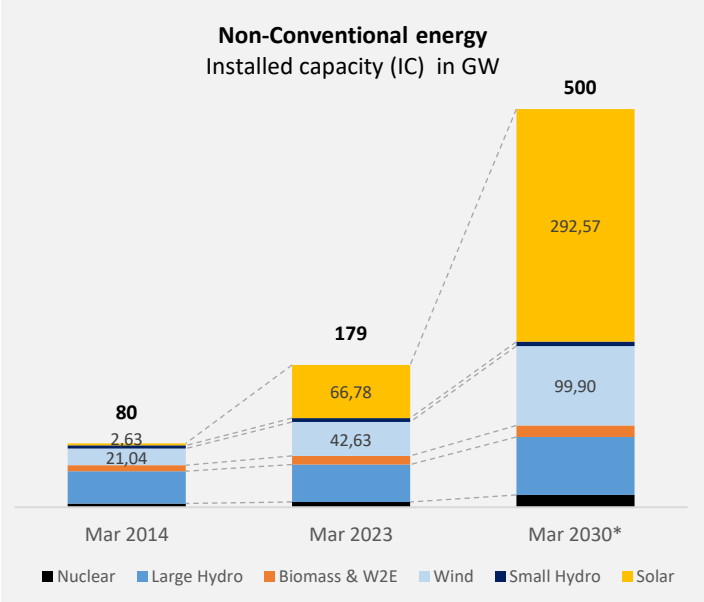
Today, India stands fourth in Renewable Energy Installed Capacity (including Large Hydro), Wind Power capacity and Solar Power capacity as per REN21 Renewables 2022 Global Status Report.

Renewables comprise nearly a third of India's total installed capacity – 185.21 GW in absolute terms, comprising 130.88 GW of Renewable energy, 46.85 GW of Large Hydro power and 7.48 GW of Nuclear power capacity.[16] India's renewable energy capacity has nearly doubled in the last five years.

[14] ~175% y-o-y growth from 4.5 lakh units in FY22 to 12.5 lakh units in FY23 as per Economic times

[15] Economic Survey of India 2022-23

[16] Installed Capacity Report – July 2023, Central Electricity Authority



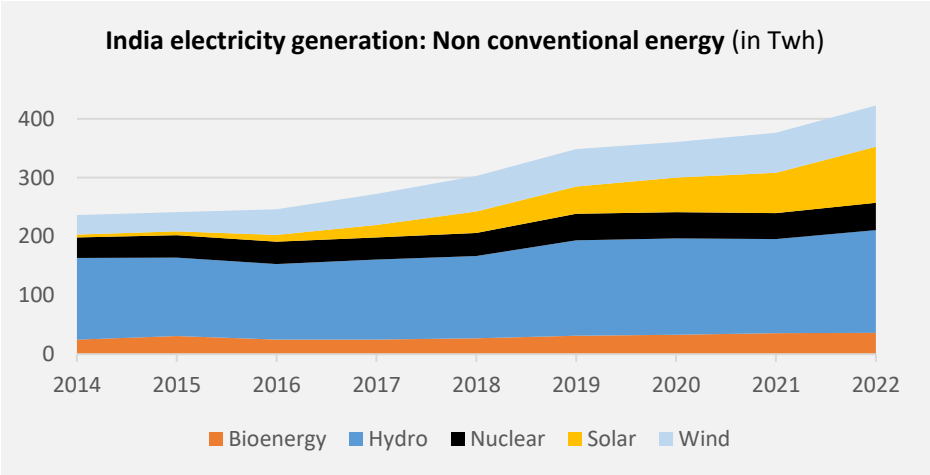
*2030: projected IC as per CEA

**Cumulative IC quantified (with Solar & Wind)

Source: CEA's annual capacity addition reports and CEA Optimal 2030 Mix 2.0, April 2023

With over a third of installed capacity, renewable energy commands 42.97% of total installed generation capacity in India. India's target of reaching 40% of the installed capacity from non-fossil energy sources by 2030 was achieved in November 2021 itself, well before its targeted timeline.[17]

The share of renewable energy in the overall electricity generation has risen in the last two decades and is attributable to sustainable rise in energy demand as well as lowering of the Levelized cost of electricity (LCOE) in India. Conducive policies and cost economies further created a positive ecosystem to make India one of the most attractive destinations for investments, thereby completing the virtuous cycle of growth in the renewable energy sector.

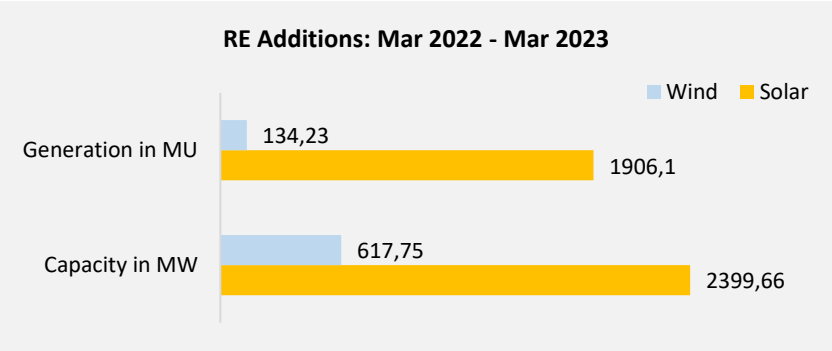


Source: CEA electricity generation data

[17] PIB accessed on 19 June 2023

Since 2014, electricity generation from renewable energy (excluding large hydro) has increased two-fold with CAGR of ~14%.

During the period March 2022-2023, renewable energy generation grew by ~10%.[18] Solar and wind energy dominated the annual capacity addition during the same period – contributing cumulatively to 99% of total capacity addition. [19]

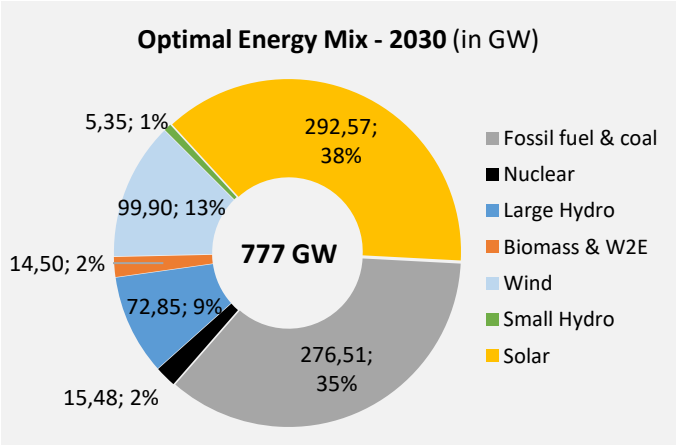


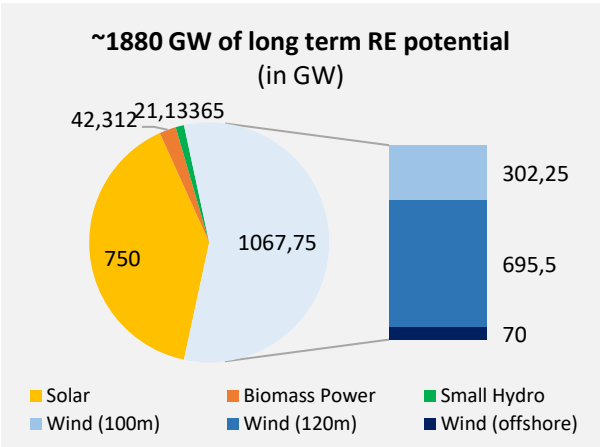
Source: CEA's Broad Overview of Monthly Renewable Energy Generation – March 2023

The New Paradigm: Renewable Energy Domination

India's renewable energy potential as envisioned by CEA comprises a 64% share of non-fossil fuel energy by installed capacity and ~45% of gross total electricity generation by 2029-30.[20] The 2030 mix is likely to ensure increase in solar capacity to 293 GW and wind capacity to 100 GW by 2030.

India's non-conventional capacity additions are projected to grow at ~40 GW year-over-year basis till 2030, reaching a cumulative 500 GW (including 15 GW of nuclear energy). Utility-scale projects will contribute a large majority of India's renewable energy capacity in the run-up to 2030.[21]





[18] CEA's Broad Overview of Monthly Renewable Energy Generation – April 2023
[19] CEA's Broad Overview of Monthly Renewable Energy Generation – March 2023
[20] CEA's Report on Optimal Generation Capacity Mix for 2029-30, Version 2.0, April 2023
[21] India's Renewable Energy Journey: Short-Term Hiccups but Long-Term Trajectory Intact, Institute of Energy Economics and Financial Analysis & Climate Energy Finance (CEF), October 2022

Source: CEA's optimal mix of installed energy capacity by 2029-30 and MNRE annual report

In the long term, Indian Energy security scenarios predict ~400 GW and ~500 GW of installed capacity in wind and Solar PV sector respectively, by 2047.

Strong tailwinds

In addition to projected potential, India has been frontrunning initiatives such as 'One Sun One World One Grid', 'World Solar Bank', 'Leadership Group for Industry Transition (LeadIT)' at the global scale, which will enable investments, and technology into the renewable energy sector.

Green Open Access Rules 2022 will further accelerate India's renewable energy programmes – democratizing access to energy for small consumers and ensuring quick turnaround period (<15 days) for grant of approvals. Banking of surplus green energy with the distribution licensee has been mandated under the new rules, thereby ushering in an era of RE hybrids, grid stability, and access to round-the-clock RE power.

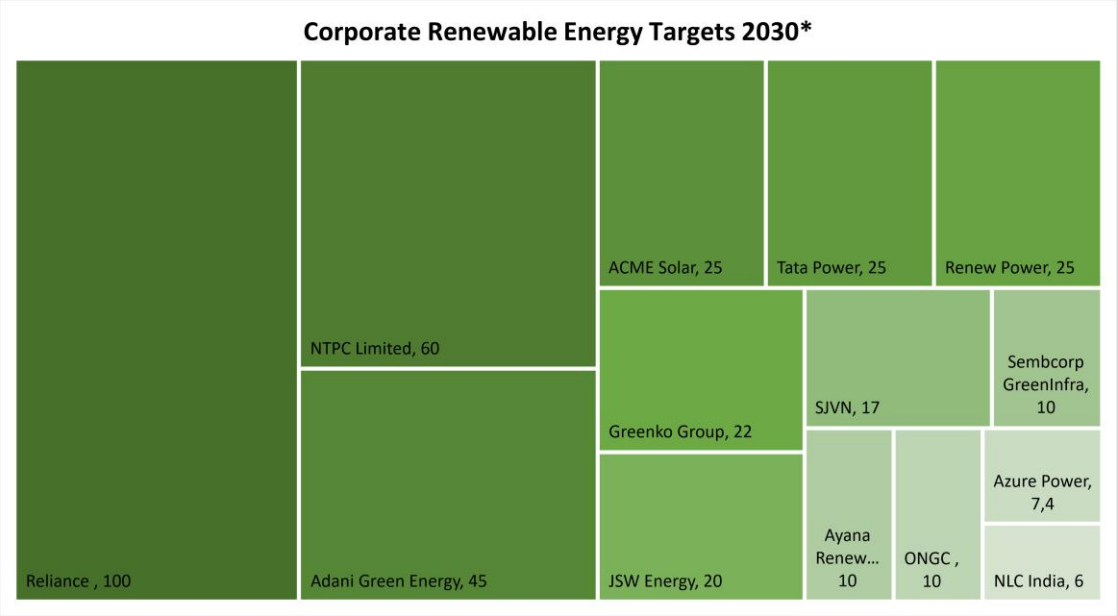
Strengthening of evacuation systems for large-scale renewable energy has been a key priority for the Indian government. The Green Energy Corridor project was introduced in 2015-16 with an aim of evacuating 20 GW of RE power – cumulatively worth US$ 5 Billion, the Intra State Transmission System (InSTS) aims at synchronizing electricity produced from RE sources, with conventional power stations in the grid. This policy coupled with the waiver of Inter State Transmission System charges, has led to a decline in RE generation costs.

The power booster: Industry thrust

The entry of independent power producers (IPPs), such as ReNew, Greenko, and Azure Power etc. has expanded the booming RE market over the last decade. The clarity in policy, government-backed 25-year PPAs by the Solar Energy Corporation of India (SECI), transmission charge waivers, decline in tariffs etc. led to a massive growth in the solar and wind sector.

Ambitious plans by industry players in the renewables spaces in the recent years provide the growth thrust needed to further improve efficiencies. Thermal power giants such as NTPC, Tata Power and JSW Energy have pivoted towards green energy with ambitious capacity addition commitments.[22]

[22] India's Renewable Energy Journey: Short-Term Hiccups but Long-Term Trajectory Intact, Institute of Energy Economics and Financial Analysis & Climate Energy Finance (CEF), October 2022



Source: Industry analysis

*Some companies have intermediate targets/ targets stretching till 2032

**Companies with targets <= 5 GW are not included in the representation above

The corporate capacity stands at ~56 GW[23] and the capacity addition projected basis the 2030 targets is cumulatively more than 380 GW – translating into seven-fold jump from the current capacity and ~75% of the country's 2030 target.[24]

Case study: How policies introduced in the last decade ushered in a new era of Renewable energy dominance[25]

In early to late 2000s, the renewable energy sector was driven by Feed-in-Tariff regime, under which wind energy dominated the sector with more than 70% of the market share. During this period various financial and tax incentives such as accelerated depreciation, and generation-based incentives were introduced. De-licensing of generation under the Electricity Act 2003 was a major steppingstone, thus allowing private sector investments in the renewables space.

With the introduction of National Solar Mission (NSM) in 2010, the spotlight shifted to utility scale solar projects. The NSM lowered offtake and payment risks[26], with creditworthy intermediaries signing long-term power purchase agreements (PPAs) with project proponents. The NSM by introducing competitive bidding in the solar power sector – inspired the pace of solar capacity deployment in India leading to 68 GW in 2023 from just 2 GW in

[23] India's Renewable Energy Journey: Short-Term Hiccups but Long-Term Trajectory Intact, Institute of Energy Economics and Financial Analysis & Climate Energy Finance (CEF), October 2022

[24] India's Renewable Energy Journey: Short-Term Hiccups but Long-Term Trajectory Intact, Institute of Energy Economics and Financial Analysis & Climate Energy Finance (CEF), October 2022

[25] "How India's Solar and Wind Policies Enabled its Energy Transition", Council on Energy, Environment and Water (CEEW), April 2021

[26] High relative cost of solar power, and poor financial health of Discoms/distribution company posed serious offtake challenges and huge payment risks.

2008. The incorporation of Solar Energy Corporation of India Limited (SECI) and introduction of NSM Bundling scheme Phase II in 2011 was welcomed by investors.

The policies introduced in the period between 2014-2017 offered a major thrust to RE based private sector investments while sharpening the capacity deployment graph for wind and solar sector as we observe today. The introduction of Solar Parks and Ultra Mega Parks scheme in 2014, India's signing of Paris Climate deal in 2015, launch of Green energy Corridor for evacuation of RE power and introduction of National Tariff Policy in 2016, SECI's role as an intermediary with effect from 2017 and mandatory competitive bidding for the wind sector from 2017 onwards – all led to improved investor risk perception and reduction in financing costs. This is evident from improved credit ratings of these projects to A and above for almost 50% of solar projects and above BBB for all considered wind projects in 2020.[27] Strong policy stance coupled with a decline in global technology costs led to approximately an eighty percent decline in solar tariffs since 2014.

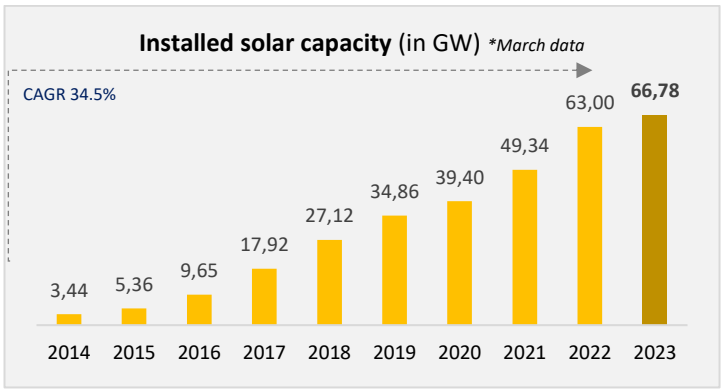
The waiver of inter-state transmission charges, grant of 'Must run statuses to solar and wind projects, bundling of RE power, provision of Viability Gap Funding and capital subsidy[28] for select projects in the past five years have played a major role in reducing solar tariffs to a record low of US$ 0.024/ kWh (INR 2/kWh) by December 2020.

3. Sector focus: Solar Energy

Solar energy has played a major role in India's transition to renewable energy. The initiatives in the last decade by the Government of India has helped achieve cost efficiencies, increase investments in the sector while pushing for aggressive technological improvements.

Today, India is one of the largest markets for solar PV capacity with huge geographic advantage - over 300+ sunny days and 4-7kWh/me/day radiation.

Presently, India's installed solar capacity stands at 71.15 GW[29] with a CAGR of ~35%. It accounts for 15% of total installed capacity and ~38% of total installed renewable capacity. The solar capacity increased by ~200% in the last 5 years.[30]



The capacity increased remarkably by 13 GW in 2022 alone – with a 27% year-over-year growth and accounting for ~80% of the additional capacity installed[31] in the year while the

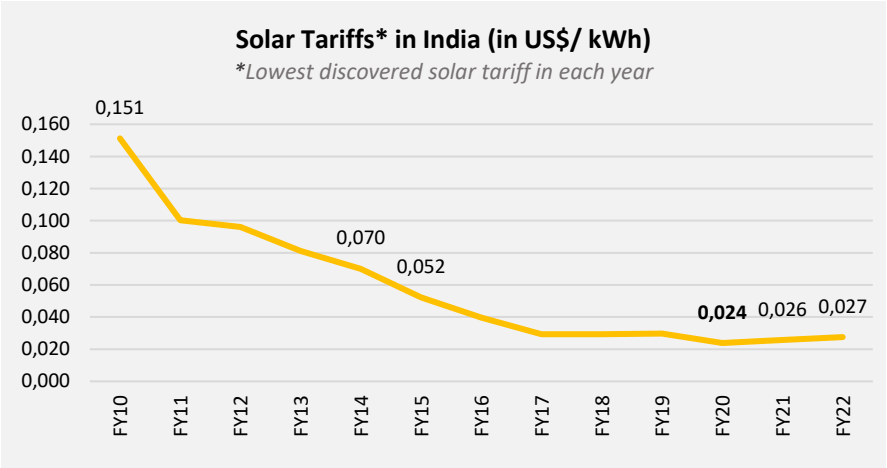
[27] CEEW, How have India's RE Policies Impacted its Wind and Solar Projects?
[28] Capital subsidy of ~30% - 70% on benchmark cost for rooftop solar projects under PM KUSUM
[29] Installed Capacity Report – July 2023, Central Electricity Authority
[30] PIB report accessed 20 June 2023
[31] Coal accounted for less than 5% of new installed capacity in 2022

quantum of solar capacity tendered increased by ~23%.[32] Rajasthan, Karnataka, and Gujarat were the top three states for cumulative large-scale solar capacity accounting for 54% of installations in the country as of December 2022.

To reach a target of 270 GW[33] of solar PV capacity in India, ~30 GW of solar capacity addition is required annually – offering huge investment potential especially since India has one of the lowest capex/MW globally for installed solar power plants.

Growth in adoption of solar PVs can be attributed to several factors such as:

1. Steep decline in solar tariffs: The deflationary nature of solar tariffs over the last decade and a half has been a key driver in development of the sector. The drop in tariffs has been a function of decline in the cost of two key input variables, i.e., financing costs and cost of solar equipment (specifically module prices). The Indian government's policies in the last decade have also played a critical role in facilitating investor confidence – resultantly, the solar tariffs in India hit an all-time low of US$ 0.024/ kWh (INR 1.99/kWh) in 2020.

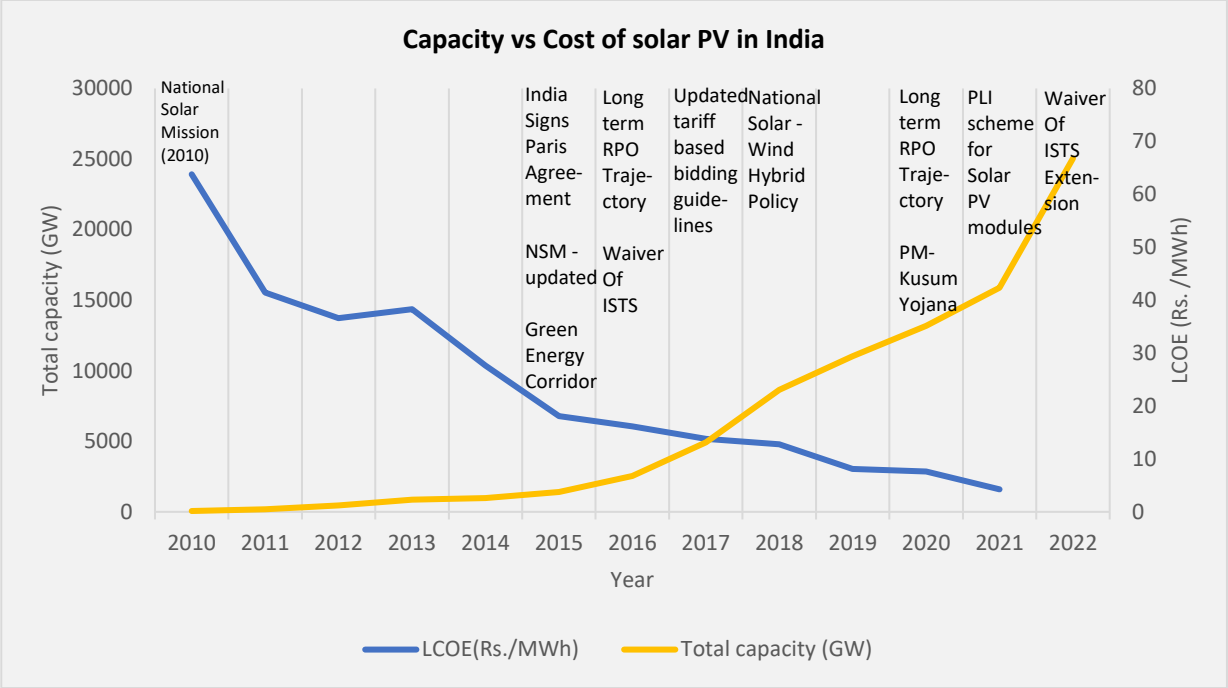


Source: Mercom Solar Industry Research[34]

2. The price of solar modules and battery packs globally have plunged by approximately 90% since 2010 while onshore wind turbine prices have halved during the last decade. Consequently, the levelized cost of electricity (LCOE) for solar PVs in India saw a sharp decline by approximately 15 times since 2010.
   Although the prices show an upward trend since 2020 owing to commodity price hikes (especially polysilicon and glass), demand-supply mismatch, and geo-political risks, the long-term price of solar PV is expected to reach US$ 0.012/ kWh (INR 1/kWh) by 2030.[35]

[32] Mercom India, 'India-installs-record-13-gw-solar-in-2022' dated 22 February 2023
[33] PIB report accessed 20 June 2023
[34] Mercom Exclusive: Solar Tariffs in India Have Fallen by 73 Percent Since 2010 (mercomindia.com), Mercom Lowest Solar Tariffs for the year 2018 - 2022
[35] India's Renewable Energy Journey: Short-Term Hiccups but Long-Term Trajectory Intact, Institute of Energy Economics and Financial Analysis & Climate Energy Finance (CEF), October 2022

Rapidly expanding global solar PV supply chain (especially module manufacturing[36]) and zero marginal cost of generation render a competitive advantage to the solar industry and is likely to improve cost economies of the solar PV modules in the medium to long future.



3. Decline in solar financing costs: Given the capital-intensive nature of most RE generation technologies, the weighted average cost of capital (WACC) has a critical impact on the levelised cost of electricity (LCOE).
   Financing costs account for the largest chunk of the overall LCOE for solar and wind-based generation.[37] The base rate and the risk premium on borrowings are expected to decline as the sectors mature in line with the projections.[38] While favourable policies lowered the business risk, strong fiscal and monetary measures lowered benchmark rates and improved sovereign credit rating. Increasing familiarity of the technologies and maturing markets have lowered risk perceptions among financiers in India leading to a decline in the risk premium.[39]
   On the equity side, the sector has seen increasing interest from mature long-term passive investors such as sovereign wealth funds (Abu Dhabi Investment Authority and Singapore's GIC) and pension funds (Canada Pension Plan Investment Board and Caisse de dépôt et placement du Québec (CDPQ)). The typical equity returns for wind

[36] Global solar module manufacturing capacity is set to treble in the next decade to 900 GW+ annually as per Bloomberg's 'The Supply Chain to Beat Climate Change Is Already Being Built' report
[37] Financing costs accounted for 62% and 53% of the LCOE for the respective wind and solar tariffs of February and May 2017
[38] Analysing the Falling Solar and Wind Tariffs: Evidence from India', Kanika Chawla, Manu Aggarwal, and Arjun Dutt, February 2020
[39] 'Analysing the Falling Solar and Wind Tariffs: Evidence from India', Kanika Chawla, Manu Aggarwal, and Arjun Dutt, February 2020

and solar have been averaging around 13% and 12%[40] respectively for the Indian market.

Key policy measures which have facilitated the growth of the solar energy sector are listed below:

- Ministry of Power revised the Tariff Policy 2016 and listed renewable purchase obligation (RPO)[41] targets till 2030, with a target of 27.08% for 2023-23.
- Tariff bundling[42] via the Generation Flexibility Program of the Ministry of Power[43] for competitive procurement of renewable power by thermal and hydropower station. Tariff bundling will enhance the bankability of projects and encourage investments.
- Waiver of Inter-state Transmission charges on transmission of electricity generated from solar and wind power sources of energy has been extended for projects commissioned by June 30, 2025.[44]
- Encouraging solar–wind hybrid parks to improve utilisation factors;
- Creating payment security mechanisms to address counterparty risks;
- Grid integration cost optimization via testing and introduction of protocols and mechanisms such as security constrained economic dispatch (SCED), a real-time market (RTM), market based economic dispatch (MBED), and a green term-ahead market (GTAM) etc.

India brought in a slew of measures to ramp up the supply of solar power, namely:

- Grid connected solar roof-top program: a portal for simplifying adoption of rooftop solar has been introduced – subsidies offered have been standardized and residential consumers no longer have to wait for Discoms to finalise tender and empanel vendors. Since its launch in July 2022, total number of applications received on the national portal is for 117 MW solar capacity and the feasibility of more than 18 MW projects is granted.
- PM KUSUM: Feeder level solarization has been introduced under Component-C of the Scheme. As of March 2023, 89.45 MW of the grid-connected solar power plants have been installed and 2.09 lakh agriculture pumps have been solarized.
- Other various schemes such as Off-grid Decentralized and Solar PV Applications Programme for Solar Street Lights, Study Lamps and Power Packs, and Atal Jyoti Yojana (AJAY), policy for Promotion of DRE (Decentralized Renewable Energy) Livelihood Applications have been introduced.

Roof-top solar

The Government of India has a target of 40 GW of installed rooftop solar capacity under the Rooftop solar program II, out of which ~ 3377 MW capacity has been allocated to various state implementing agencies based on the demand received.

The current rooftop installed capacity stands at 8.03 GW and the commercial and industrial (C&I) customers currently contribute ~70-80% to the total installed capacity. The rate of adoption is likely to increase on two accounts, (1) extension of the Rooftop Solar Programme

[40] 'Energy Transition and Clean Energy Investment in India', Avendus, March 2023
[41] Renewable Purchase Obligation (RPO) and Energy Purchase Obligation Trajectory till 2029-30
[42] https://indianexpress.com/article/explained/solar-tariffs-pooling-renewable-energy-thermal-power-bundling-7761845/
[43] read://https_www.mercomindia.com/?url=https%3A%2F%2Fwww.mercomindia.com%2Frules-issued-bundling-renewables-thermal-hydro
[44] Waiver of Inter State Transmission Charges on transmission of the electricity generated from solar and Orders

Ph-II till 2026, and (2) rise of corporate decarbonisation and net zero pledges under the Science-Based Targets Initiative (SBTi)—a global alliance enabling businesses to establish their own climate pledges.[45]

Solar Pumps and the PM KUSUM scheme

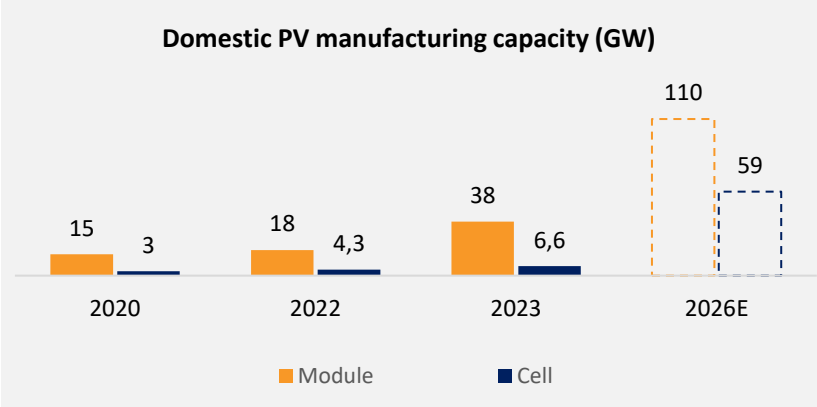
India has been promoting adoption of stand- alone and grid-connected solar pumps in the agricultural sector. India, through introduction of the KUSUM scheme, has set a target to achieve 30.8 GW of solar capacity expansion through installation of grid-connected solar power plants and solarisation of 35 lakh agriculture pumps with up to 60% subsidy on the capital cost.

A total of 89.45 MW capacity has been installed under grid-connected solar component and ~2.09 lakh agricultural pumps have been solarized, till date, cumulatively amounting to 1,140 MW of installed solar capacity. Companies such as Tata Power and Shakti Pumps, two of the biggest solar pump players, have seen installed capacity volumes increase substantially over the last couple of years, indicating a positive scenario.[46]

As the third-largest regional market for water pumps, India's KUSUM scheme is likely to transform the energy consumption patterns in the agriculture sector.

3(a). Solar Manufacturing

India currently has one of the largest solar module manufacturing capacities outside China. The nameplate PV manufacturing capacity in India for solar PV modules stands at 38 GW and that of solar PV cells stands at 6.6 GW with a cumulative operational capacity at ~24GW.[47] During the period, March 2022-23, the downstream component manufacturing (cells and modules) of the PV value chain grew significantly - by more than 100% for modules and 50% for cells.



Source: JMK Research, 'India's Photovoltaic manufacturing capacity set to surge', April 2023

The Indian government's Production Linked Incentive (PLI) Scheme worth US$ 3.2 billion and tariff (Basic customs duty (BCD)) and non-tariff ((Approved List of Models and Manufacturers (ALMM)) based import barriers have played a critical role in this exponential

[45] India's Renewable Energy Journey: Short-Term Hiccups but Long-Term Trajectory Intact, Institute of Energy Economics and Financial Analysis & Climate Energy Finance (CEF), October 2022
[46] India's Renewable Energy Journey: Short-Term Hiccups but Long-Term Trajectory Intact, Institute of Energy Economics and Financial Analysis & Climate Energy Finance (CEF), October 2022
[47] As of March 2023 as per JMK Research

rise in the production capacity. The Tranche II of the PLI scheme is expected to result in setting up of ~65 GW of fully / partially integrated solar PV manufacturing while the imposition of BCD[48] (introduced in 2022) and introduction of ALMM led to a decrease in imports by ~25% year-over-year (YoY) to US$ 3.5 Billion in 2022[49].

The Indian PV exports (cells and modules), on the other hand, saw a ~320% rise in exports – from US$ 134 million in 2022 to US$ 561 million in 2021 with USA accounting for more than 99% of overall exports.[50]

The module production capacity in India is expected to reach a staggering 110 GW by 2026. Other schemes such as domestic content requirement (DCR) aid through the mandatory sourcing of domestically manufactured modules[51] and an overarching "China+1" policy is expected to bolster the domestic solar PV manufacturing capabilities in the next five years.

4. Sector focus: Wind

Wind and solar energy are complementary. Wind energy, just like the solar sector, saw tremendous growth in the last decade owing the government led thrust and increasing cost economies.

Onshore wind turbine prices have halved in the last decade leading to a lower LCOE for wind energy. The introduction of competitive bidding in 2017 saw wind energy tariffs reducing to US$ 0.030/ kWh (INR 2.43/kWh) from more than US$ 0.055/kWh (INR 4.50/kWh) tariffs in most Indian states.

Today, India has the fourth largest installed capacity in wind power standing at 43.9 GW[52] with a CAGR of ~8%.[53] 3.5 GW of capacity was added during the period from April 2022-July 2023.

The near-term wind potential is estimated to be more than 300 GW at a hub height of 100 metre and more than 690 GW at 120 metre hub height. Almost 95% of the wind energy is exploitable in seven states[54]. Ministry of New and Renewable Energy is now targeting to bid out 50 GW of Renewable energy capacity per annum between 2024-2028 including 10+ GW per annum of wind energy capacity.[55]

Policy support to the sector:

- Guidelines[56] for Tariff Based Competitive Bidding Process for Procurement Power from Grid Connected Wind Power Projects have been introduced on 26th July 2023
- Declaration of trajectory for Wind Renewable Purchase Obligation (Wind RPO) up to the year 2030.[57]
- Technical support including wind resource assessment and identification of potential sites through the National Institute of Wind Energy, Chennai

[48] BCD imposed on Solar Cells: 25% and BCD imposed on Solar Modules: 40%
[49] As per Department of Commerce data; https://www.mercomindia.com/indias-solar-exports-surge-imports-drop-25
[50] https://www.mercomindia.com/indias-solar-exports-surge-imports-drop-25
[51] Applicable for PM-KUSUM, 12000 MW - Government Producers Scheme (CPSU Scheme) and the New Roof-top Scheme
[52] Installed Capacity Report – July 2023, Central Electricity Authority
[53] Mordor Intelligence Industry Report
[54] Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan and Tamil Nadu.
[55] https://mnre.gov.in/img/documents/uploads/file_f-1680367776122.pdf
[56] Guidelines for Tariff Based Competitive Bidding Process for Procurement Power from Grid Connected Wind Power Projects
[57] Renewable Purchase Obligation (RPO) and Energy Purchase Obligation Trajectory till 2029-30

Offshore Wind: the emerging sector with huge potential

India has been bestowed with a coastline of about 7,600 km, which offers the potential to install ~195 GW of offshore wind capacity with utilisation factors of more than 50-55%.

The Indian government came out with National Offshore Wind Energy policy in 2015 to boost cost competitiveness in the sector. To achieve a target of achieving 30 GW of offshore wind energy by 2030, Ministry of New and Renewable Energy (MNRE) brought out the revised strategy[58] for establishment of offshore wind energy projects.

The Ministry plans to bid out projects worth 4 GW of capacity by December 2023 and has brought out a trajectory to bid out offshore wind energy blocks worth 37 GW capacity till FY 2029-30 projecting strong policy support. The recent amendment to Green Energy Open Access Rules 2023[59] extended the benefits of surcharge exemption under open access for offshore wind projects commissioned on or before December 31, 2032.

5. Solar-Wind Hybrids and Energy Storage Systems

Greater share of renewables in the overall energy mix necessitates the need for reliable Round the Clock (RTC) energy supply – offered by Solar-wind Hybrid projects.

The Ministry of New and Renewable Energy has rolled out several RTC and Hybrid tenders under the National Wind-Solar Hybrid Policy 2018. More than 15 GW of hybrid and RTC capacity has been tendered so far, of which ~12.5 GW has been allocated, and 7.5 GW is expected to come up by December 2023. In 2022 alone, a total of 4 GW of solar-wind hybrids were floated, out of which 2.2 GW were auctioned. Tata Power, AMP Energy, NTPC and SJVN emerged as winners in SECI's 1.2 GW Wind-Solar Hybrid Auction in May 2022, where the discovered price was US$ 0.031/ kWh (INR 2.53/kWh).

The Solar-Wind hybrids coupled with battery storage systems complement the intermittency of renewable energy sources and are crucial to India's energy ecosystem. The overall energy storage capacity in India stands at 4.75 GW from Hydro Pumped Storage Projects (PSPs) and 39.12 MWh from Battery Energy Storage System (BESS).

Battery Energy Storage System (BESS) market in India will witness a steep upward trajectory owing to strong policy support and deflationary trend in the global lithium-ion battery prices, which have fallen from US$ 1,220/kWh in 2010 to US$ 132/kWh in 2021. The prices are expected to decline to US$ 59/kWh by 2030 which will further boost the market growth.[60]

The Indian government brought out several initiatives since 2022 to support the industry:

1. RE Bundling Scheme for Scheduling of Thermal/ Hydro Power Stations through bundling with Renewable Energy and Hydro Power
2. Energy Storage Obligations (4% by 2029-30) have been notified
3. Legal Status for Energy Storage Systems (ESS)
4. Waiver of ISTS Charges on Hydro PSP, BESS Projects commissioned up to 30.06.2025 – applicable for 25 years for Hydro PSP or for a period of 12 years for BESS
5. Viability Gap Funding support for 4,000 MWh BESS was announced in the Union Budget 2023-24

[58] Strategy for Establishment of Offshore Wind Energy Projects
[59] Electricity (Promoting Renewable Energy Through Green Energy Open Access) (Second Amendment) Rules, 2023
[60] India's Renewable Energy Journey: Short-Term Hiccups but Long-Term Trajectory Intact, Institute of Energy Economics and Financial Analysis & Climate Energy Finance (CEF), October 2022

6. Guidelines[61] to promote development of Pumped Storage Projects (PSP) were introduced in April 2023

6. Sector focus: Green Hydrogen

India has recently introduced the "Green Hydrogen Mission"[62] worth US$ 2.38 billion with a target of achieving at least 5 MMT (million metric tonnes) of production capacity per annum, an electrolyser capacity of 60 GW[63] and an additional RE capacity of ~125 GW by 2030. The policy is expected to bring in investments and boost technology adoption across sectors.

The sub-scheme wise project outlay is given below:

1. Strategic Interventions for Green Hydrogen Transition (SIGHT) programme (incentives for manufacturing of electrolysers etc.): US$ 2.13 billion
2. Pilot projects (for steel, mobility, shipping etc): US$ 17 million
3. Research and Development: US$ 48.74 million
4. Other components (listed below): US$ 47.28 million
    - Development of Green Hydrogen Hubs
    - Benefit of Renewable Purchase Obligation (RPO)
    - Subsidized and priority land allotment.
    - Priority grid connectivity and Connectivity at the generation end and Green Hydrogen /Ammonia manufacturing end, to the RE ISTS
    - Manufacturers allowed to set up storage bunkers near Ports for exports

Green hydrogen (GH2) market is critically dependent on the renewable energy (~60-65% of production cost) and sourcing of electrolysers, both of which are conducive for production in the Indian market. As the fourth largest renewable energy producer and rapid ramp up of capacity, India will be an attractive GH2 market by 2030 with projected market value of US$ 8 billion by 2030. On the other hand, the electrolyser market is expected to reach a capacity of 20 MW by 2030 in India[64] and will be affiliated by rapid decline in electrolyser cost globally (more than 50% decline in the last 8 years).

More than four fifth of India's hydrogen is projected to be 'green' by 2050 with an estimated market value of US$ 340 billion. The demand is likely to be driven majorly by Refinery and Fertilizer sector, followed by Cement, Iron and Steel, and chemicals sector. To promote and facilitate production in the sector, the Ministry of New and Renewable Energy came out with standards[65] for Green Hydrogen

In the long term, growth in the sector is estimated to be driven by large use cases in the Indian market, and increasingly flexibility of adoption and production. The industry has supported the green hydrogen policy wholeheartedly with several significant commitments to invest in this nascent technology.[66]

[61] Guidelines for Pumped Storage Projects (PSP)
[62] National Green Hydrogen Mission
[63] Niti Aayog, 'Harnessing Green Hydrogen' report
[64] Niti Aayog, 'Harnessing Green Hydrogen' report
[65] Green Hydrogen Standard, India
[66] India's Renewable Energy Journey: Short-Term Hiccups but Long-Term Trajectory Intact, Institute of Energy Economics and Financial Analysis & Climate Energy Finance (CEF), October 2022

7. Sector focus: Biomass Power and Waste to Energy

The potential for power generation from agricultural residue is estimated at ~29 GW and that from bagasse cogeneration is estimated at ~14 GW, cumulatively totalling to power generation potential of ~42 GW.

Currently, the installed capacity of biomass power and cogeneration projects stands at ~ 10.81 GW[67] and that of waste to energy stands at 522.42 MW eq. 800+ Biomass IPP and Bagasse/non bagasse cogeneration-based power plants with an aggregate capacity of ~10 GW have been installed – inclusive of ~7.5 GW from Bagasse Cogeneration Sectors. [68]

The Government of India mandated all thermal power plants to use 5-10% of biomass for power generation through co-firing (SAMARTH Mission - National Mission on Use of Biomass in Thermal Power Plants) in October 2021. To realize full potential of the sector, India also rolled out the National Bioenergy Programme, in November 2022 for the period, 2022-2026. Central Financial Assistance (CFA) will be provided for setting up Bio Gasifiers, Biogas based power generation plants, BioGas and BioCNG plants.

Key components of National Bioenergy Programme:

(i) Waste to Energy Programme (Programme on Energy from Urban, Industrial and Agricultural Wastes/ Residues)
(ii) Biomass Programme (Scheme to support Manufacturing of Briquettes & Pellets and Promotion of Biomass (non-bagasse) based cogeneration in Industries.
(iii) Biogas Programme: for promotion of family type Biogas plants.
(iv) Equity infusion of ~US$ 182.87 Mn (INR 1500 crore) in IREDA & US$ 122 Mn (INR 1000 crore) in SECI.

As noted, special emphasis has been placed on 'Waste to Energy (W2E) Programme' owing to huge surplus of urban, industrial and agricultural bio-waste generation.

The current capacity stands at 248 MWeq for grid connect W2E projects, and 274 MWeq for off-grid W2E projects with 90+ W2E projects under various stages of implementation: [69]

- 7 Biogas Generation plants - cumulative production capacity of ~ 83400 m3/day
- 34 BioCNG Generation plants - cumulative production capacity of ~ 248000 kgs/day
- 49 Power generation plants - cumulative production capacity of ~330 MW

India's Galvanizing Organic Bio-Agro Resources scheme (GOBAR-DHAN) introduced in 2018 under the Swatch Bharat Mission (Clean India Mission) has been driving growth in the sector – 500 new W2E plants have been planned as a part of Union budget 2023-24. Enhanced production and availability of CBG has also been seen an alternative and affordable clean fuel for cooking and transportation alike, which may drive up the sector's growth trajectory in the medium term.

Various other initiatives such as Sustainable Alternative Towards Affordable Transportation (SATAT) initiative of Ministry of Petroleum and Natural Gas (MoPNG) - envisage setting up of 5000 BioCNG plants with production target of 15 MMT of BioCNG by 2023-24.

[67] Installed Capacity Report – July 2023, Central Electricity Authority
[68] Ministry of New and Renewable Energy, Annual Report 2022-23
[69] Ministry of New and Renewable Energy, Annual Report 2022-23

8. Sector focus: Small Hydro Power projects

The large hydro power (above 25 MW) capacity stands at 46.85 GW[70] and the long-term projected potential is ~ 145 GW.[71] Couple of initiatives by the Government of India have facilitated the growth of the sector such as provision of Hydro Purchase Obligation (HPO) as a separate entity, notification of tariff rationalization measures to bring down hydro power tariffs, Notification of a 'Dispute Avoidance Mechanism' and mechanism to bring down time and cost overruns.

Government of India is also looking to leverage small hydro power through incentivisation and active promotion of small hydel and run of the river projects. The estimated potential of small hydro power projects[72] (<25 MW capacity) is 21.2 GW from more than 7000 sites in India. Presently, the installed capacity stands at ~5 GW[73] from ~1150+ projects with an 0.5 GW additional capacity under various stages of development. The Small hydro capacity account cumulatively accounts for ~ 7% of the total RE capacity.

The Himalayas/ hilly regions cumulatively hold 50% of the total development potential – especially Ladakh and Kargil, Himachal Pradesh, Uttarakhand, and the Northeast Region. The Northeast region has a potential for development of ~3.3 GW of small hydro power with the state of Arunachal Pradesh alone accounting for approximately two thirds of the total potential. [74]

For strong and speedy development of the sector, an exclusive policy for the Small Hydro power sector is underway at Ministry of New and Renewable Energy – it is likely to offer benefits such as setting separate hydro purchase obligation, interest rate subventions and ease in regulatory processes.

9. Innovation

Innovation is critical to development and increasing process efficiencies in the RE sector. Ministry of New and Renewable Energy, Government of India rolled out the **'Renewable Energy Research and Technology Development Programme'** for promotion of indigenous technology development for widespread deployment of new and renewable energy, including ocean energy, in an efficient and cost-effective manner across India.

To accelerate Clean Energy revolution, India supported the launch of the '**Mission Innovation (MI)**'[75] at COP21 in 2015. In its first phase (2015-2020), India funded Innovation Challenges, such as Smart Grids, Off Grid Access to Electricity and Sustainable Biofuels while supporting R&D via technical and financial support. The ongoing second phase (2020-2030), MI2.0, is focussed on rapid scaling-up and deployment of innovative clean energy technology by driving public-private action. India on its part launched the 'Mission Innovation CleanTech Exchange' in June 2021 - a global initiative to create a network of incubators across member countries to accelerate clean energy innovation. India remains as one of the key members with active participation in MI initiatives such as Integrated Biorefineries

[70] Installed Capacity Report – July 2023, Central Electricity Authority
[71] PIB report dated 21 March 2023
[72] Small Hydro Power includes the following three categories: Micro Hydel ≤ 0.1 MW, Mini Hydel > 0.10 MW to ≤ 2.00 MW, and Small Hydel > 2.00 MW to ≤ 25.00 MW
[73] Installed Capacity Report – July 2023, Central Electricity Authority
[74] Ministry of New and Renewable Energy, Annual Report 2022-23
[75] The term 'Mission Innovation' was coined by the Prime Minister Shri Narendra Modi. Mission Innovation (MI) is a global initiative of 23 Countries and the European Commission (on behalf of the European Union) to catalyse a decade of action and investment in research, development and demonstration to make clean energy affordable, attractive and accessible for all. India is one of the founding members of Mission Innovation.

Mission, Clean Hydrogen Mission, Green Powered Future Mission (GPFM), and Carbon Dioxide Removal Mission etc.

The '**Mission on Advanced and High-Impact Research (MAHIR)**' was recently[76] launched by Ministry of Power and the Ministry of New and Renewable Energy to leverage Emerging Technologies in Power Sector with an aim to promote indigenous research, development, demonstration, and at-scale deployment of the latest and emerging technologies in the power sector. MAHIR has been planned for an initial period of five years from 2023-24 to 2027-28, with the technology life cycle approach of Idea to Product.

Areas identified for research under MAHIR[77]:

- Alternatives to Lithium-Ion storage batteries
- Geo-thermal energy
- Green hydrogen for mobility (High Efficiency Fuel Cell)
- Indigenous CRGO technology
- Carbon capture
- Nano technology for EV battery
- Modifying electric cookers / pans to suit Indian cooking methods.
- Solid state refrigeration

India's efforts towards groundbreaking innovation in the clean energy sector has been focussed on creation of an innovation ecosystem based on **Industry-Academia - Government** collaboration. Several industry players have tied up with key academic and research institutes to accelerate deployment of transformational technologies at commercial scale where these institutes also provide incubation centre for earlystage start-ups. Recently, Denmark based Danfoss collaborated with IIT Madras to promote cooperation in engineering education and scientific research in the realm of water. On similar lines, IIT Delhi is running several sponsored projects from Fortune 500 companies on Sustainable Energy, Environment and Climate Change and providing innovation ecosystem to startups[78].

Invest India has also facilitated collaborations among major research institutions/academia and key disruptive technology players in the renewable energy space to improve use efficiencies and optimize costs.

10. Legislative Framework for Renewable Energy in India

The Indian Constitution is the supreme law of the land and establishes a framework for political, economic, and social democracy in the country. The Indian Constitution specifies the distribution of executive and legislative powers between the Union and States. 'Electricity' is listed in the concurrent list under the Constitution of India and the Central/Union Parliament and state legislatures have concurrent powers to enact laws on this subject.

The Electricity Act 2003 enacted by the Union Parliament is the principal legislation that governs the electricity sector in India. It provides the framework for generation, transmission, distribution, trading and use of electricity in India – for both conventional and non-conventional sources of power. The act, among other things, provides for the establishment

[76] PIB report dated 7 June 2023
[77] PIB report dated 7 June 2023
[78] https://www.indiatimes.com/news/india/iit-delhi-ready-to-showcase-its-research-and-innovation-during-industry-day-2022-587060.html

of regulatory commissions at the central level and state level (CERC and SERCs) to administer generation, distribution and transmission of electricity. The commissions enjoy legislative and judicial powers, issue regulations and subordinate legislation, and have judicial powers to preside over disputes between generators and distribution licensees, or distributions licensees and consumers. Central or state commission orders can be appealed before the Appellate Tribunal for Electricity (APTEL), a specialised body to review disputes pertaining to electricity. The decisions of the APTEL may be challenged before the Supreme Court of India.

'Renewable energy' has been defined as grid quality electricity generated from renewable energy sources under Central Electricity Regulatory Commission (CERC Terms and Conditions for Tariff Determination from Renewable Energy Sources) Regulations 2017.

'Renewable energy sources' have been further defined to include small hydro, wind, solar including its integration with combined cycle, biomass, biofuel cogeneration, urban or municipal waste and other such sources as may be approved by the Ministry of New and Renewable Energy (MNRE) – the nodal agency of the Government of India for promotion of renewable energy, both grid-connected and off-grid.

The Electricity Act, the National Electricity Policy 2005 and the Tariff Policy 2016 (Tariff Policy) encourage private sector participation in renewable energy through measures such as fixing renewable purchase obligations (RPOs) for certain entities which are mandated to comply with RPOs.

11. Invest India Initiatives

The Energy vertical at Invest India has closely worked with the government and Industry alike to drive green investments in the sector, identify sectoral gaps, and de-bottleneck policy and regulatory challenges faced in the sector.

The team engages with all concerned line ministries of the Union government, all state governments and their respective departments, Indian missions abroad and foreign missions in India. Strategic and facilitation support is also provided to concerned state governments to promote cohesion and collaboration in the Energy space. The team handholds the investors by assisting them in identifying investible opportunities in line with the investment strategy, offering pro-bono end-to-end facilitation, and facilitating any regulatory issues.

The investors are supported end-to-end in their investment journey, via a three pronged approach: (1) the Pre-Investment stage wherein market research and consumer analysis, information on commercial aspects, tax and FDI regulations is provided, (2) the Investment stage: wherein location assessment, compliance regulations, grounding of projects, policy and issue resolution support is during project implementation, and (3) After-service: wherein Investor/Industry - government interaction is facilitated to de-bottleneck executional/operational hurdles. The team also assists the investors/industry with their ongoing/future expansion project.

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