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Rubix Industry Insights

RENEWABLE ENERGY

Renewable energy in India is witnessing remarkable growth with ambitious targets and substantial investments, aiming to achieve a significant share of non-fossil fuel-based energy by 2030. This expansion not only enhances energy security and reduces carbon emissions, but also generates economic opportunities through job creation and technological advancements in the renewable energy sector.

Snapshot

- The Indian Renewable Energy (RE) sector is undergoing a massive shift as the country transitions from pre-dominant fossil-fuel-based sources to non-fossil-fuel-based sources on the back of Government initiatives and rising consumer awareness.
- Renewable energy accounts for nearly 43.5% of the country's total installed power capacity and 20.9% of the country's total power generation[1].
- The cumulative installed capacity which stood at nearly 190 GW by the end of FY2024 has increased at 13% CAGR from FY2020 to FY2024. Solar energy accounts for the highest share of nearly 57%[2].
- India plans to have 485 GW of installed renewable energy out of a total installed capacity of 500 GW from non-fossil sources by 2030[3].
- Various Government initiatives, such as the PM Surya Ghar Muft Bijliee Yojana, Production Linked Incentive Scheme (PLI), solar parks, etc., are expected to drive the growth of the solar energy industry.
- Financial support such as the allocation of INR 191.1 billion (INR 19,110 crore) to the Ministry of New and Renewable Energy in the Union Budget 2024-25, against the revised estimates of INR 78.48 billion (INR 7,848 crores) in Budget 2023-24, is expected to support the growth of the sector[4].
- Credit offtake to the renewable energy sector has increased by 5 times since FY2019 indicating a rising interest from stakeholders[5].
- Challenges related to land availability, Chinese imports, and consistent supply have to be overcome for long-term sustainability.

CURRENT AND PROJECTED INSTALLED RENEWABLE ENERGY CAPACITY, INDIA, FY2024 AND FY2032

Installed Capacity	FY2024 (GW)	FY2032 (GW)
Solar	81.8	364.0
Wind	45.9	122.0
Large hydro	46.9	62.0
Small hydro	5.0	5.0
Bio Power	10.9	15.0

[1] *Central Electricity Authority*
[2] *Ministry of New and Renewable Energy*
[3] *Economic Times, January 2024, IBEF, Ministry of New and Renewable Energy*
[4] *Business Today, July 2024*
[5] *Reserve Bank of India*

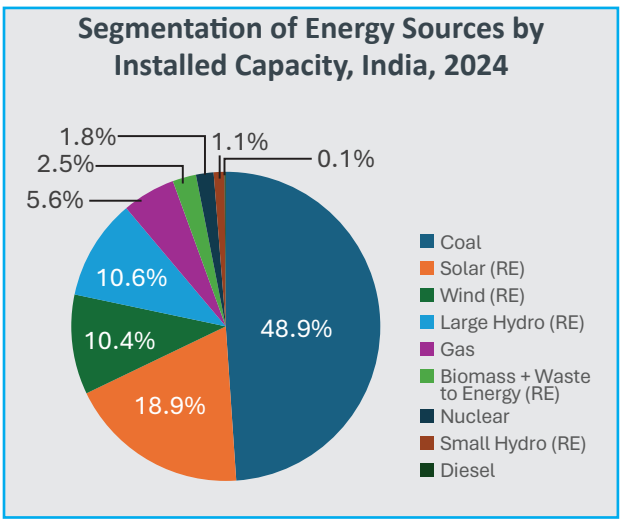
190 GW *Total Installed RE capacity, FY2024*

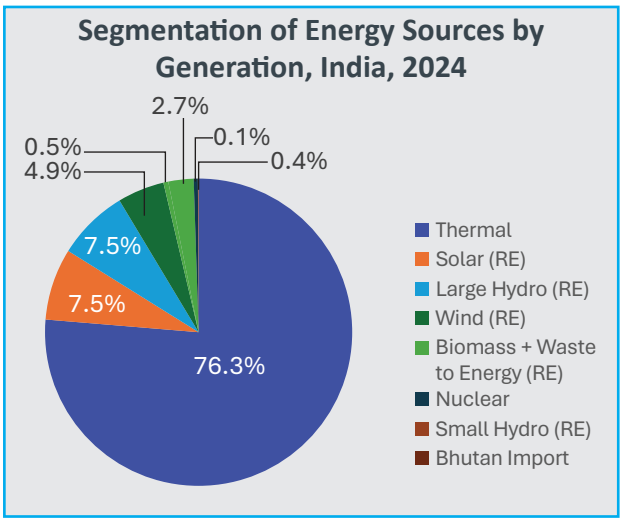
13% *CAGR FY2020–FY2024*

57% *Share of Solar Energy, FY2024*

Renewable Energy (RE) Industry Scenario

The Indian renewable sector is undergoing a massive shift as the country transitions from pre-dominant fossil-based sources to non-fossil-based sources on the back of Government initiatives and rising consumer interest.





Note: (RE) stands for Renewable Energy. Data as of 31st May 2024.

Source: Central Electricity Authority

INSTALLED RENEWABLE ENERGY CAPACITY (GW), FY2020–FY2024							
Segment	**FY2020**	**FY2021**	**FY2022**	**FY2023**	**FY2024**	**CAGR FY2022-FY2024**	**Share in FY204**
Solar Power	35.6	41.2	54	66.8	81.8	23%	43.0%
Wind Power	37.7	39.2	40.4	42.6	45.9	7%	24.1%
Small Hydro Power	4.7	4.8	4.8	4.9	5	2%	2.6%
Bio Power	10.2	10.5	10.7	10.8	10.9	1%	5.7%
Large Hydro Power	NA	NA	46.7	46.8	46.9	0.2%	24.6%
Total	**88.2**	**95.7**	**156.6**	**171.9**	**190.5**	**10%**	**100%**

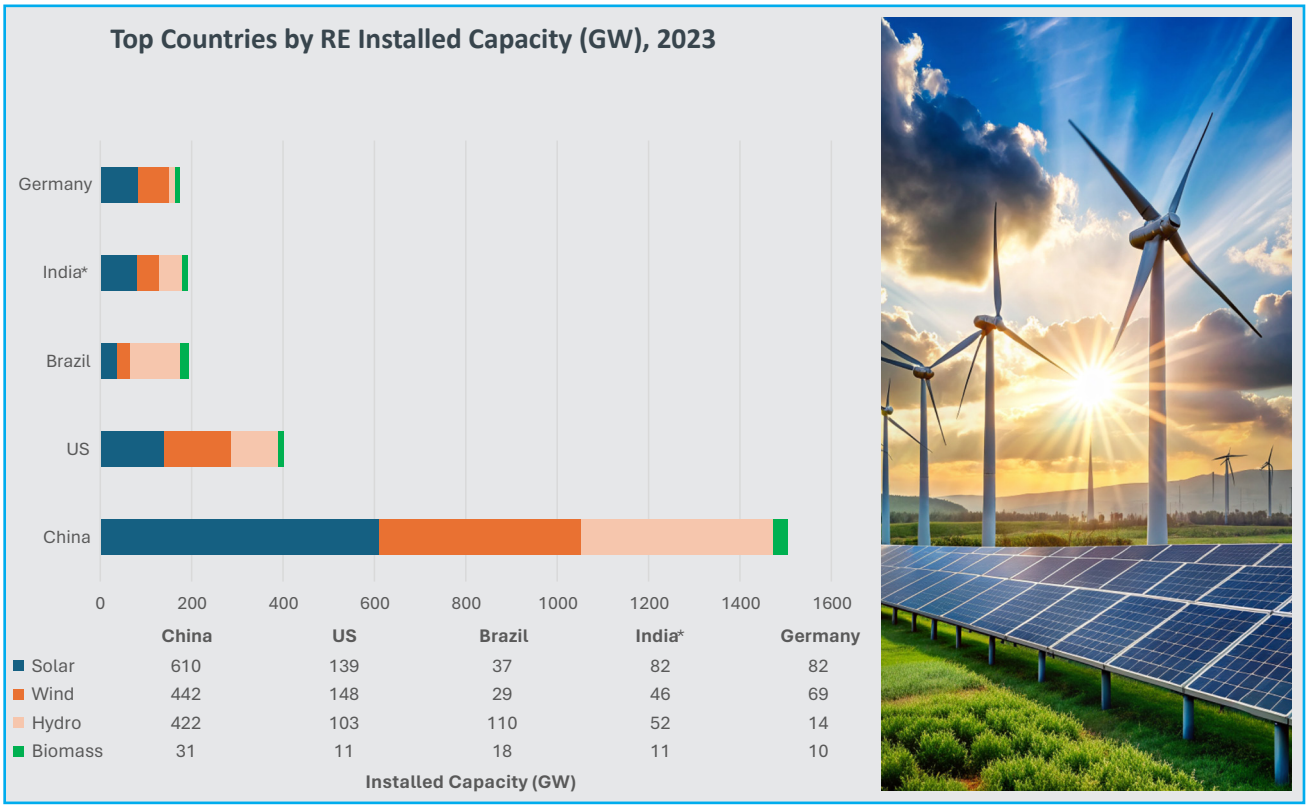
Note:
1. *Small hydropower projects are defined as facilities with generation capacities up to 25 MW and come under the ambit of the Ministry of New and Renewable Energy (MNRE); while large hydro, defined as above 25 MW, come under the ambit of the Ministry of Power.*
2. *In March 2019, large hydropower projects were declared as a renewable energy source (till then only hydropower projects less than 25 MW were considered as RE).*
3. *Due to the unavailability of data for large hydro power, for FY2020 and FY2021, CAGR has been calculated for the period FY2022–20224.*
4. *NA stands for Not Available.*
5. *Figures have been rounded off to the nearest decimal place.*
6. *Note: 1 GW (gigawatt) = 1,000 MW (1 megawatt).*

Source: Central Electricity Authority

Double Digit Growth in Installed Capacity: Installed renewable capacity has increased at a fast pace over the past few years, posting a CAGR of 13% between FY2020 and FY2024. The cumulative installed capacity stood at nearly 190 GW by the end of FY2024[6].

India Ranks Among the Top Countries in RE: India has become a prominent global player in renewable energy adoption, driven by robust governmental backing, a burgeoning domestic market, and a skilled workforce. It stands 4th globally in overall renewable energy installed capacity, 4th in wind power capacity, and 5th in solar power capacity.

[6] *Ministry of New and Renewable Energy*



	China	US	Brazil	India*	Germany
Solar	610	139	37	82	82
Wind	442	148	29	46	69
Hydro	422	103	110	52	14
Biomass	31	11	18	11	10

Note:

1. *Renewable energy includes solar energy, wind, hydro power (including pumped storage) and bio power.*
2. **Data for India refers to FY24.*
3. *Although India was placed in the 5th position in solar energy rankings at the end of 2023 CY, in the above table it is in the 4th position, as we have provided India's updated values for FY24 instead of CY23 to keep it consistent with the values in the report.*

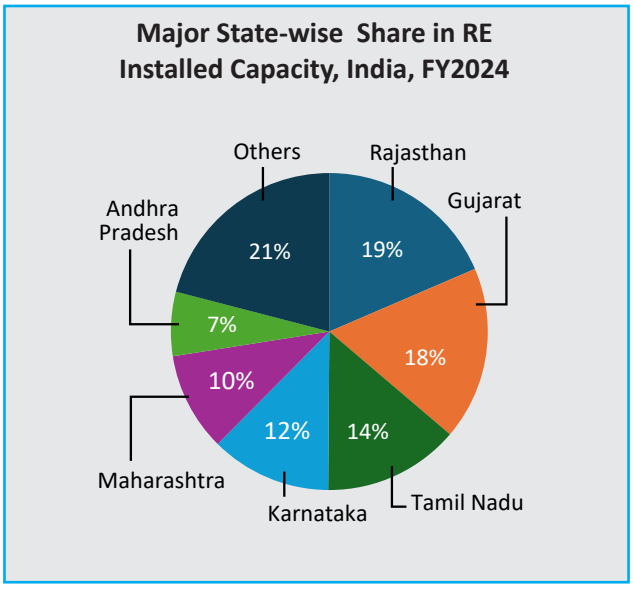
Source: International Renewable Energy Agency

Key Role of Government Initiatives in Laying a Strong Foundation: Key initiatives in the past such as the National Solar Mission, National Wind Energy Mission, and Integrated Energy Policy have established a solid policy framework for advancing renewable energy. As per present projections, India is expected to contribute to nearly half of the world's new renewable energy capacity by 2026[7].

On Track for Achieving the Target[8]

- India aims to achieve its target of 50% renewable energy capacity by 2030, ahead of schedule, as per Government sources. It also intends to achieve net zero carbon emissions by 2070.
- The country plans to have 485 GW of renewable energy out of a total capacity of 500 GW from non-fossil sources by 2030.
- The renewable energy capacity has increased from 76 GW in 2014 to 190 GW at present (as of the end of March 2024). Projects for another 175 GW of renewable energy capacity are underway[9].

High Concentration in Five States: Five states account for nearly 79% of the total RE installed capacity.



Source: Ministry of New and Renewable Energy, GoI

[7] *IBEF and International Energy Agency's 'Electricity 2024' Report*
[8] *The Economic Times, January 2024, IBEF, Ministry of New and Renewable Energy*
[9] *The Economic Times, January 2024*

Segment Scenario: Solar Power

INSTALLED SOLAR POWER CAPACITY (GW), INDIA, FY2020–FY2024							
Solar Segment Type	**FY2020**	**FY2021**	**FY2022**	**FY2023**	**FY2024**	**CAGR FY2020–FY2024**	**Share in FY2024**
Ground Mounted Solar	32.1	35.6	45.8	-	64.4	19%	78.6%
Rooftop Solar	2.5	4.4	6.6	-	11.9	47%	14.5%
Hybrid Solar Composite	-	-	-	-	2.6	-	3.2%
Off-grid Solar/ KUSUM	1.0	1.2	1.6	-	3.0	32%	3.7%
Total	**35.6**	**41.2**	**54.0**	**-**	**81.8**	**23%**	**100%**

Source: Ministry of New and Renewable Energy

Solar power installed capacity has increased nearly 2 times between FY2020 and FY2024.

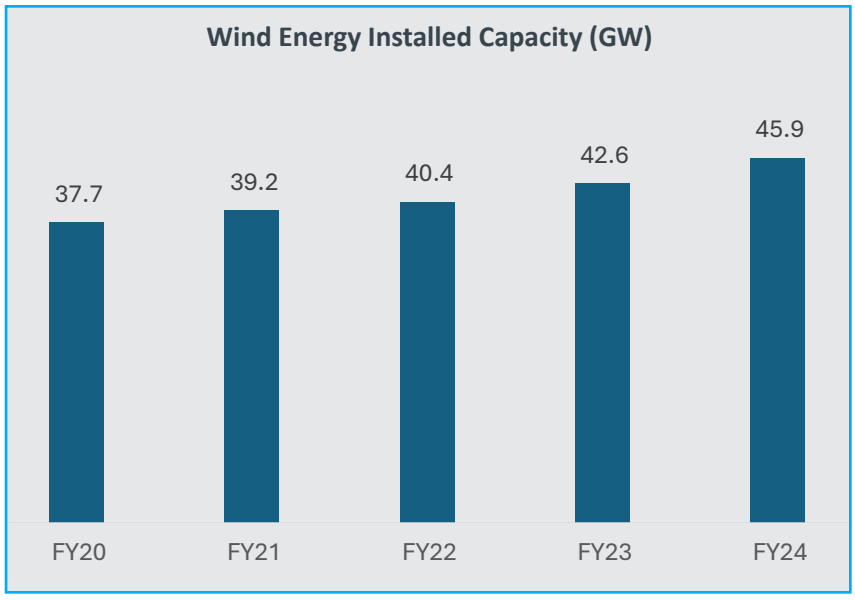
The rooftop solar segment, which has shown a robust 47% CAGR, is expected to continue its growth trajectory owing to recently launched Government initiatives such as PM Surya Ghar Muft Bijli Yojana.

Other initiatives such as the Grid-Connected Rooftop Solar Programme, Solar Cities Programme, etc., are also playing an important role in the implementation of solar rooftops.

Since December 2014, the Indian Government has sanctioned a total of 51 solar parks across 12 states with a total capacity of 38 GW, which has helped the overall solar segment grow at a CAGR of 23% since then[10].

The decline in the cost of solar modules is aiding in a sustained rise in solar capacity additions; the current solar tariff of INR 2.54/ unit is lower than that of new coal power plants (INR 5 to 6 per unit)[11].

Segment Scenario: Wind Power



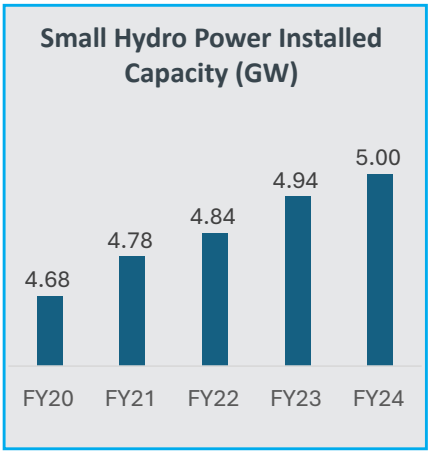
Wind power installed capacity has increased by 5% CAGR between FY2020 and FY2024.

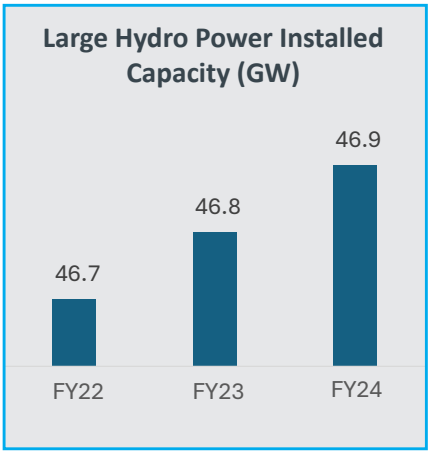
Cumulative capacity stood at 45.9 GW at the end of FY2024.

Average tariffs stabilised around INR 3.2 per unit in FY2023 and FY2024 and are expected to remain viable and profitable for developers despite the anticipated increase in project costs over the medium term.

[10] *Press Information Bureau of India, MNRE and ET Energy World*
[11] *RBI, State of the Economy, June 2024*

Segment Scenario: Small Hydro Power





Source: Ministry of New and Renewable Energy and Central Electricity Authority

Small hydro power installed capacity has increased by 2% CAGR between FY2019 and FY2024.

Cumulative small hydro power capacity stood at approximately 5 GW at the end of FY2024.

According to Central Electricity Authority (CEA) estimates, India has a massive hydroelectric potential of 145.32 GW, but only 29% has been harnessed so far primarily due to challenges in remote site locations and the associated costs of transmission infrastructure.

Segment Scenario: Bio Power

INSTALLED BIO POWER CAPACITY (GW)							
Bio Power Segment	**FY2020**	**FY2021**	**FY2022**	**FY2023**	**FY2024**	**CAGR FY2020–FY2024**	**Share in FY2024**
BM Power/Bagasse Cogeneration	9.2	9.4	9.4	9.4	9.4	1%	87%
BM Cogeneration (Non- Bagasse)	0.7	0.8	0.8	0.8	0.9	8%	8%
Waste to Energy	0.1	0.2	0.2	0.2	0.2	14%	2%
Waste to Energy (Off-grid)	0.2	0.2	0.3	0.3	0.3	14%	3%
Total	**10.2**	**10.5**	**10.7**	**10.8**	**10.9**	**2%**	**100%**

Source: Ministry of New and Renewable Energy

Biomass bagasse cogeneration accounted for 87% share of the total 10.9 GW installed capacity in FY2024.

Cumulative capacity stood at 10,941 MW at the end of March 2024.

India has 3,159 active waste dump sites, wherein about 75%–80% of the municipal waste gets collected. Out of this, only 22% to 28% is processed and treated, indicating the huge potential of this sector[12]. Efforts need to be taken for efficient usage of recycling, reducing, and reusing waste to improve the efficiency of waste to energy.

[12] *Economic Times, August 2023*

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Segment Scenario: Green Hydrogen

National Green Hydrogen Mission[13]

In January 2023, the Government approved the National Green Hydrogen Mission with an initial outlay of INR 197.4 billion (INR 19,740 crore). This includes INR 174.9 billion (INR 17,490 crore) for the Strategic Interventions for Green Hydrogen Transition (SIGHT) program, INR 14.6 billion (INR 1,460 crore) for pilot projects, INR 4 billion (INR 400 crore) for research and development, and INR 3.8 billion (INR 380 crore) for other mission components. The mission aims to achieve several objectives: creating export opportunities for Green Hydrogen and its derivatives, decarbonising the industrial, mobility, and energy sectors, reducing dependence on imported fossil fuels, fostering indigenous manufacturing capabilities, generating employment, and advancing cutting-edge technologies. The expected outcomes of the Mission by 2030 are as follows:

- Development of green hydrogen production capacity of at least 5 Million Metric Tonnes (MMT) per annum with an associated renewable energy capacity addition of about 125 GW in the country
- Over INR 8 trillion (INR 8 lakh crore) in total investments
- Creation of more than 600,000 jobs
- A cumulative reduction in fossil fuel imports of over INR 1 trillion (INR 1 lakh crore)
- Aversion of nearly 50 MMT per annum of CO_2 emissions through the production and use of the targeted quantum of green hydrogen

Draft of Incentive Scheme for Electrolyzer Manufacturing and Green Hydrogen Production[14]

The draft of the incentive scheme for electrolyzer manufacturing and a portion of the incentive scheme for green hydrogen production has been completed and the scheme will be launched soon. The total incentives allocated under the Hydrogen Mission amount to over INR 170 billion until the year 2030. These incentives will be disbursed in phases, allowing the Government to gather insights from the initial phase and refine subsequent ones accordingly.

This phased approach is designed to optimise the effectiveness of the incentives and ensure they support the development and scaling of electrolyzer manufacturing and green hydrogen production in India. By learning from the implementation of the first phase, the Government aims to enhance the design and impact of future phases, fostering a competitive and sustainable hydrogen ecosystem that contributes significantly to India's energy transition goals.

[13] *Department for Promotion of Industry and Internal Trade, National Green Hydrogen Mission*
[14] *Economic Times, June 2024*

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INDUSTY DRIVERS			
DRIVER	IMPACT		
	1–2 years	3–5 years	6–10 years
OVERALL RENEWABLE ENERGY			
Budgetary support for the development of the RE sector	High	High	High
Robust growth in bank loans for the RE sector	High	High	Medium
New renewable energy consumption norms for Distribution Licensees (DISOCMS)	High	High	Medium
SOLAR ENERGY			
PM Surya Ghar Muft Bijliee Yojana: Boosting residential solar capacities	High	High	High
Production Linked Incentive Scheme (PLI) to boost domestic manufacturing	High	High	High
OSOWOG Initiative for creating a unified solar grid across the globe	High	High	High
Various Government initiatives for driving solar power growth	High	High	Medium
Solar power investment: Driving factor behind RE FDI	High	High	Medium
Higher tariffs by the US on Chinese solar imports: Larger window of opportunity for India	High	High	Medium
Building solar capacities (modules and cells) through domestic production and limiting Chinese imports	High	High	Medium
Expansion of Approved List of Models and Manufacturers (ALMM) to encourage domestic manufacturing	High	High	Medium
Unlocking the potential of floating solar power	High	High	Medium
Battery energy storage system: Integral element for achieving long-term renewable energy targets	High	High	Medium
WIND ENERGY			
Driving wind energy growth through auctions	High	High	High
Viability gap funding helping in capturing a higher share of APAC's offshore wind capacity	High	High	High
Offshore wind energy lease rules for enhancing wind energy capacities	High	High	High
HYDRO ENERGY			
Collaboration with Bhutan for renewable energy cooperation	High	High	Medium
Importing hydroelectricity from Nepal	High	High	Medium
BIO POWER			
Revised policy on biomass cofiring for coal-based thermal power plants	High	High	High
GREEN HYDROGEN			
State initiatives to promote green hydrogen	High	High	High
Hydrogen-powered train for eco-friendly transportation	High	Medium	Medium
World Bank support for developing green hydrogen[15]	High	Medium	Medium

[15] *Economic Times, June 2024*

"The Production Linked Incentive (PLI) schemes have incentivised the industries to invest in thorium, solar energy and green hydrogen sector. India has also joined hands with other countries to make progress in the renewable energy sector and in the coming future India will become a leader in the renewable energy sector."

Ms. Nirmala Sitharaman,
Hon'ble Finance Minister, Government of India

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Industry Drivers: Overall Renewable Energy

Budgetary Support for the Development of the RE Sector

The Union Budget 2024-25 has announced a slew of measures to support the renewable energy sector in multiple ways:

Higher actual allocation to MNRE compared to revised estimates	Allocation of INR 191.1 billion (INR 191,10 crore) to the Ministry of New and Renewable Energy against the revised estimates of INR 78.480 billion (INR 7,848 crore) in the Budget 2023-24. The largest share, nearly 86%, was allocated to the solar energy segment.
Impact (Positive)	This will help move towards achieving 500 GW for RE capacity by 2030.
BCD exemption on certain capital goods	Specified machinery and equipment (certain capital goods) used in the manufacture of solar cells and modules are now exempt from Basic Customs Duty (BCD). Previously, these machines were subject to a 7.5% customs duty.
Impact (Positive)	It will lower the costs for solar cell and module manufacturers.
BCD exemption on certain input materials	Import duty (BCD) exemption has been extended for specified goods used in the manufacture of silicon wafers, specified material for the manufacture of Ethylene Vinyl Acetate (EVA) sheets, and flat copper wire used to manufacture the photovoltaic ribbon. These are now exempted from BCD up to March 31, 2026. Further, the scope of materials which can be imported is being expanded.
Impact (Neutral)	This will lower the costs for solar cell and module manufacturers, but local manufacturing can be adversely impacted if imports go up substantially.
BCD exemption on AECs	Customs duty exemption on active energy controller (AEC) for use in the manufacture of renewable power system inverters will also lapse from September 30, 2024
Impact (Neutral)	The resumption of customs duty could make products costlier and encourage local manufacturing.
Allocation for Suryaghar Muft Bijli Yojana	INR 62.5 billion (INR 625 crores) has been allocated to the PM Suryaghar Muft Bijli Yojana residential rooftop solar scheme for FY2024-25. Till July 2024, the scheme had garnered over 12.8 million registrations and 0.14 million applications.
Impact (Positive)	It is expected to lead to an increase in residential rooftop solar installations.
Policy for PSPs	A policy to promote Pumped Storage Projects (PSPs) for electricity storage will be introduced.
Impact (Positive)	It will facilitate a smooth integration of the growing contribution of renewable energy in the overall energy mix.
Roadmap for the carbon market	A roadmap for moving the 'hard to abate' industries from 'energy efficiency' targets to 'emission targets' will be formulated. Appropriate regulations for the transition of these industries from the current 'perform, achieve and trade' mode to the 'Indian carbon market' mode will be put in place.
Impact (Positive)	This will drive investment in sustainable technologies and lay the framework for developing the carbon market. In short, it will be a step towards de-carbonisation.
Levy on customs duty on solar glass and copper interconnect	Customs duties of 10% and 5% have been imposed on solar glass and tinned copper interconnect, respectively, used in the manufacture of solar cells or modules. These duties will take effect from October 2024.
Impact (Neutral)	It will result in higher input costs for domestic producers but in the long term, it will strengthen the domestic supply chain.
Exemption of BCDs on 25 critical minerals	Customs duties on 25 critical minerals, including lithium, copper, cobalt, and rare earth elements, essential for sectors like nuclear and renewable energy, will be exempted. Additionally, basic customs duty on two of these minerals will be reduced.
Impact (Positive)	This will encourage manufacturing in emerging segments like battery storage.
Taxonomy for climate finance	The Government will soon come out with a taxonomy for climate finance, which will make it easier for companies to raise capital at preferential rates for funding green projects.
Impact (Positive)	It will facilitate the development of the market for green bonds and fund sectors such as renewable energy.
*Phased introduction of CBG	This initiative aims to establish 750 Compressed Bio-Gas (CBG) projects by 2028-29, with a potential investment of INR 375 billion (INR 37,500 crore) to promote widespread adoption of CBG in vehicles for pollution reduction and clean cooking in households.
Impact (Positive)	It will help in achieving 20% ethanol blending with petrol by 2025 and establish 5,000 CBG projects across the country in the next few years.

**Refers to announcement in the Interim Budget of 2024-25*

Robust Growth in Bank Loans for the Renewable Energy Sector

Bank loans extended to India's renewable energy sector have shown remarkable growth, increasing by 3.5 times from INR 16.9 billion (INR 1690 crores) in FY2019 to INR 59.9 billion (INR 5990 crores) in FY2024[16]. This surge in renewable energy financing reflects the nation's growing climate consciousness. With excess capacity in traditional power sectors and challenges faced by state distribution companies, there's a notable shift towards renewables. Power producers are increasingly embracing renewable energy, aligning with future sectoral goals.

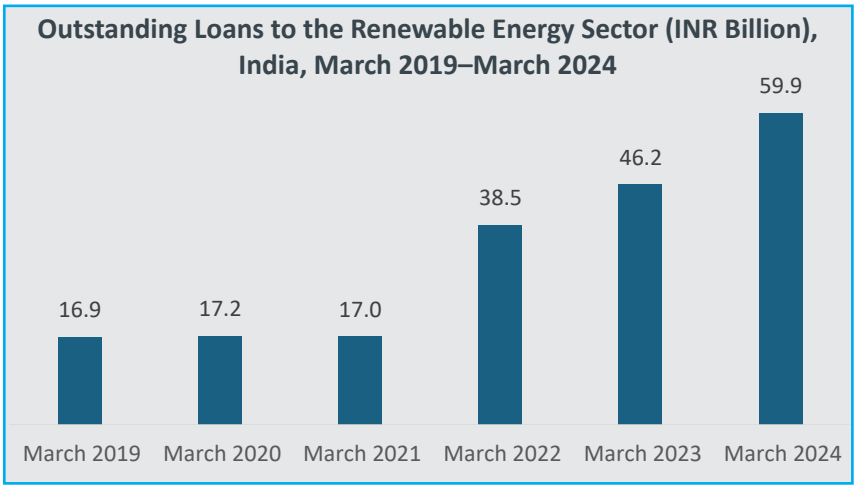
Banks are also adopting proactive strategies. Canara Bank, for instance, has positioned itself as a key player in sustainable finance, offering a variety of products tailored to renewable energy initiatives. These include financing options for renewable projects, compressed biogas, and solar pump schemes under PM-KUSUM. Bank of Maharashtra has partnered with the Indian Renewable Energy Development Agency to strengthen lending in this sector.

Additionally, the Reserve Bank of India has included the small renewable sector in the Priority Lending Scheme (PLS), allowing eligible firms to access loans up to INR 300 million (INR 30 crore) and households up to INR 1 million (INR 10 lakh) specifically for investing in renewable energy.

New Renewable Energy Consumption Norms for Distribution Licensees (DISOCMS)[17]

The Government has initiated the implementation of new regulations for distribution licensees regarding the consumption of renewable energy starting from April 1, 2024. These regulations mandate that a certain percentage of electricity consumption by distribution licensees must originate from renewable energy sources. As per the latest data, India's installed renewable energy capacity exceeds 180 GW.

According to the ministry's notification dated October 20, 2023, these regulations specify the minimum proportion of renewable energy consumption as a percentage of total



Source: Reserve Bank of India, As reported on last Friday of the respective financial year

Some examples of nationalised banks' products for solar energy include –

BANK	SCHEME	BRIEF DETAILS
State Bank of India	SBI Surya Ghar – Loan for Solar Roof Top	Installation of Roof Top Solar (RTS) up to 3 kW and installation of solar roof top of more than 3 kW and up to 10 kW
	Surya Shakti – Solar Finance	For the installation of RTS or ground-mounted grid-connected systems for captive use
Bank of Baroda	PM-Surya Ghar Yojana-Composite	Grid-connected RTS systems for individuals
Canara Bank	Canara Rooftop Solar CRTS PMSGY (up to 3 kW)	Installation of RTS on-grid PV system (residential) up to 3 kW, which includes the cost and installation of grid-interactive rooftop solar PV equipment
Bank of Maharashtra	Mahabank Rooftop Solar Panel Loan scheme (PM Suryaghar: Muft Bijli Yojna)	For installation of grid-connected RTS up to 3 kW for residential purposes only; as well as for installation of grid-connected RTS (3 kW to 10 kW) for residential purposes only
Union Bank of India	Union Roof Top Solar Scheme (URTS)	Setting up of grid-connected RTS system up to 25 kW plant to an individual having an existing independent house

Note:
1. Data is as of 20th August 2024.
2. The above list of banks and schemes should in no way be considered an exhaustive list but rather a representative sample of the respective banks' products and services for the renewable energy sector.
Source: Respective Bank Websites

[16] *Reserve Bank of India*
[17] *ET Energy World, February 2024*

energy consumption, with specific targets outlined for various types of renewable energy sources. State Electricity Regulatory Commissions (SERCs) have also defined Renewable Purchase Obligations (RPOs) for electricity distribution utilities (DISCOMs), with periodic guidelines issued by the Ministry of Power on RPO trajectories.

To encourage the establishment of renewable energy plants, several provisions have been instituted, including permitting 100% Foreign Direct Investment (FDI) under the automatic route and exempting Inter State Transmission System (ISTS) charges for the interstate sale of solar and wind power until June 30, 2025. Additionally, incentives such as accelerated depreciation and exemptions from Environment Impact Assessment (EIA) for solar and wind power projects aim to stimulate investments in renewable energy infrastructure.

SOLAR ENERGY

PM Surya Ghar Muft Bijliee Yojana: Boosting Residential Solar Capacities[18]

In February 2024, the Government launched the 'PM Surya Ghar Muft Bijliee Yojana' to accelerate rooftop solar installations, aligning with its ambitious goal of achieving 500 GW of renewable energy capacity by 2030. Previous efforts aimed at reaching a 40 GW rooftop solar capacity target by 2022 fell short, with only 10 GW installed by 2023, including merely 3 GW in residential sectors.

The new initiative aims to make rooftop solar systems more accessible by providing financial support. With a massive investment of over INR 750 billion (INR 75,000 crores), the Government will offer a subsidy of 60% for 2 kW systems and 40% for systems between 2 kW and 3 kW. The maximum system size eligible for this subsidy is 3 kW. Besides, loans will be available at a competitive interest rate of 7% to further reduce upfront costs. Additionally, around 10 million households are set to receive 300 units of free electricity per month under this initiative. Muft Bijli Yojana is projected to add 30 GW of solar capacity through rooftop solar in the residential sector, generating 1,000 Billion Units (BUs) of electricity.

Industry experts now highlight that the primary remaining challenges include raising consumer awareness, ensuring the availability of reputable vendors, and effective implementation at the state level.

Production Linked Incentive Scheme (PLI) to Boost Domestic Manufacturing[19]

The Ministry of New and Renewable Energy launched the Production Linked Incentive (PLI) Scheme under the National Programme on High Efficiency Solar PV Modules in 2021. This initiative aimed to achieve gigawatt-scale manufacturing capacity for high-efficiency solar PV modules, with an initial allocation of INR 45 billion (INR 4,500 crore) in tranche I. Subsequently, in September 2022, the Government issued guidelines for implementing tranche-II of the PLI Scheme, allocating INR 195 billion (INR 19,500 crores). The objectives of the scheme include expanding manufacturing capacities for high-efficiency solar PV modules, introducing advanced technology to India, encouraging integrated plant setups for enhanced quality control and competitiveness, and fostering a local material ecosystem for solar manufacturing, among other goals.

OSOWOG Initiative for Creating a Unified Solar Grid Across the Globe

One World, One Sun, One Grid (OSOWOG) is a collaborative initiative spearheaded by India and the UK aimed at linking solar energy systems on a vast scale. The concept behind OSOWOG revolves around the idea that 'the sun never sets', envisioning the utilisation of solar and other renewable energy sources from various global regions where sunlight is abundant at any given time. This energy would then be efficiently transmitted to regions requiring power. OSOWOG is structured into three phases: the first phase involves integrating the Indian grid with those of the Middle East, South Asia, and Southeast Asia to establish a unified grid. The second phase extends this network to incorporate Africa's renewable energy resources. Ultimately, the third phase aims for comprehensive global interconnection, targeting a capacity of 2,600 GW by 2050.

OSOWOG presents a golden opportunity for India to harness its solar potential, become a global energy powerhouse, and contribute significantly to a sustainable future.

[18] *Financial Express, March 2024, Press Information Bureau of India, February 2024*
[19] *Ministry of New and Renewable Energy*

VARIOUS GOVERNMENT INITIATIVES FOR DRIVING SOLAR POWER GROWTH

Government of India's Initiatives to Encourage Solar Power

1. Waiver of Inter State Transmission System (ISTS) charges for interstate sale of solar and wind power for projects scheduled for commissioning by June 30, 2025
2. Declaration of trajectory for Renewable Purchase Obligation (RPO) trajectory till 2030
3. Establishment of Ultra Mega Renewable Energy Parks offering land and transmission infrastructure to renewable energy (RE) developers on a plug-and-play basis
4. Initiatives such as Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) Scheme, Solar Rooftop Phase II, 12000 MW CPSU Scheme Phase II, and Production Linked Incentive (PLI) Scheme for High Efficiency Solar PV Modules
5. Expansion of transmission infrastructure and substation capacity under the Green Energy Corridor Scheme for efficient solar power evacuation
6. Issuance of standards for deployment of solar photovoltaic systems/devices
7. Establishment of a Project Development Cell to attract and facilitate investments
8. Implementation of Standard Bidding Guidelines for competitive tariff-based procurement of power from Grid Connected Solar PV Projects
9. Enforcement of Government orders ensuring power dispatch against Letter of Credit (LC) or advance payment to ensure timely payments to RE generators by distribution licensees
10. Conducting skill development programs to train skilled manpower for the setup, operation, and maintenance of solar energy projects

Solar Power Investment: Driving Factor Behind RE FDI[20]

Under the current FDI policy, renewable energy sector investments are permitted up to 100% FDI through the automatic route. India's renewable energy sector has attracted FDI to the tune of nearly USD 6.137 billion from April 2020 to September 2023. Solar energy was a major recipient of FDI during this period, accounting for nearly 63% share with USD 3.86 billion. In terms of origin of the FDI, 4 countries accounted for nearly 71% share of solar power FDI, namely Singapore (20%), the UK (20%), Mauritius (16%), and the UAE (14%).

Higher Tariffs by the US on Chinese Solar Imports: Larger Window of Opportunity for India[21]

India's solar energy landscape has undergone a significant transformation. In FY2023, China supplied an overwhelming 94% of India's total solar PV cell imports and 93% of module imports. However, in FY2024, China's share of solar PV cell and module imports fell to 56% and 66%, respectively. For April-May of FY2025, China's share was 68% for cells and 59% for modules[22].

Clearly, India, once heavily reliant on imports from China and Southeast, has rapidly expanded its domestic manufacturing capabilities. This shift has been fuelled partially by increased Government support and a growing emphasis on energy independence.

During the calendar year 2023, India added 20.8 GW capacity of solar modules and 3.2 GW capacity of solar cells, taking the cumulative solar module manufacturing capacity to 64.5 GW and solar cell manufacturing capacity to 5.8 GW in December 2023[23]. Module manufacturing capacity is expected to surpass 150 GW and cell capacity is expected to cross 75 GW by 2026[24]. In February 2024, R K Singh, Union Minister for New and Renewable Energy and Power said India has achieved self-sufficiency in the production of solar modules/panels but is yet to achieve substantial capacity in solar cell production.

In contrast, supply from the four Southeast Asian countries—Cambodia, Malaysia, Thailand, and Vietnam—constituted 87.5% of PV imports into the US in the first quarter of 2024[25].

This is because, in June 2022, after Chinese and Taiwanese imports were restricted with anti-dumping duties and anti-circumvention duties, the US Department of Commerce allowed 24 months of duty-free access to solar cells and modules from Cambodia, Malaysia, Thailand, and Vietnam to ensure that supplies and projects were not affected. That two-year window ended in June 2024.

Besides, in May 2024, the US implemented stricter tariffs on Chinese solar equipment, increasing the tariff rate on solar cells (whether assembled into modules or not) from 25% to 50% in 2024. This has spurred the growth of India's solar equipment industry, which is viewing this as a 'Make In India' opportunity

[20] *Economic Times, Energy World, December 2023 and Saur Energy, February 2024*
[21] *Fortune India, April 2024*
[22] *Chemical Industry Digest, August 2024*
[23] *Mercom India*
[24] *The Hindu Business Line, March 2024*
[25] *S&P Global Market Intelligence*

with potential for exports. In fact, in 2023, Indian solar exports surged by 227%, reaching USD 1.8 billion from USD 561 million in 2022. This number is expected to be even higher in 2024.

Building Solar Capacities (Modules and Cells) Through Domestic Production and Limiting Chinese Imports

India anticipates a substantial increase in its domestic production capacity for solar modules and cells in the coming months. The aim is to reduce the reliance on imported materials from China for manufacturing solar panels. India's cumulative solar module manufacturing capacity has grown to 64.5 GW and is projected to exceed 150 GW by 2026. Similarly, solar cell manufacturing capacity, currently at 5.8 GW, is anticipated to reach 75 GW by 2026, indicating significant progress in domestic production capabilities[26].

In 2021, the Indian Government mandated solar project developers to procure modules from an Approved List of Models and Manufacturers (ALMM) to promote domestic manufacturing. However, due to insufficient domestic capacity, the rules were temporarily relaxed leading to increased imports from China and Vietnam. From April 2024, India has reinstated limits on imported solar modules to bolster domestic manufacturing, supported by initiatives like the PLI scheme.

The next phase will focus on restricting solar cell imports, with the Government planning a cautious approach, allowing the industry around two years to prepare and ensure sufficient domestic capacity. These measures follow past challenges when import restrictions on modules were briefly withdrawn last year due to concerns from the local industry about disruptions to ongoing projects. The nation's solar cell capacity is expected to grow five-fold to approximately 30 GW per year by March 2025[27]. This expansion will enable the Government to increase import restrictions to promote local adoption of solar power technology and achieve greater self-sufficiency in the sector.

Expansion of Approved List of Models and Manufacturers (ALMM) to Encourage Domestic Manufacturing[28]

The Ministry of New and Renewable Energy has recently expanded the Approved List of Models and Manufacturers (ALMM) List-I by granting provisional enlistment to numerous new solar PV module models from different companies. The total number of companies in this list is now 93. This move marks a substantial advancement in India's renewable energy sector, aimed at increasing the accessibility of certified solar modules for a wide range of projects.

Provisional enlistment means that these newly added solar PV module models have met the MNRE's stringent criteria for quality and performance standards. By expanding the ALMM List-I, the MNRE aims to bolster confidence among developers, investors, and stakeholders in the reliability and efficiency of solar PV modules available in the Indian market.

This development is crucial as India strives to ramp up its renewable energy capacity and achieve its ambitious targets. It not only supports the growth of the domestic solar industry but also aligns with the Government's broader objectives of promoting sustainable and clean energy solutions nationwide.

Unlocking the Potential of Floating Solar Power

Floating solar involves placing solar panels on floating platforms on water bodies such as lakes and reservoirs. This method utilises unused water surfaces, enhances solar panel efficiency by utilising water cooling, and reduces water evaporation losses, thereby conserving resources. India has the potential capacity to generate 280–300 GW through floating solar power, yet current installations are limited, primarily in states like Madhya Pradesh, West Bengal, Andhra Pradesh, Kerala, Telangana, Bihar, and Rajasthan[29]. One of India's largest floating solar power projects of 100 MW was commissioned in July 2022 by NTPC at Ramagundam with advanced technology and environment-friendly features[30]. The Tata Power Solar Systems Ltd's floating solar power project, with a capacity of 101.6 MW, operating in Kayamkulam, Kerala on a 350-acre water body[31] is another example of large floating solar power.

As costs decrease and technology improves efficiency, a significant increase in floating solar projects is expected across India, as major players are actively participating in this segment. For example, in March 2024, the Solar Energy Corporation of India (SECI) awarded Larsen & Toubro (L&T) with a five-year Engineering Procurement and Construction (EPC) contract for a 100 MW floating solar project to be built at Getalsud Dam in Ranchi, Jharkhand[32].

Battery Energy Storage System: Integral Element for Achieving Long-term Renewable Energy Targets

India has set ambitious targets to achieve 50% of its cumulative installed capacity from non-fossil fuel-based energy sources by 2030

[26] *Times of India, April 2024*
[27] *ET Energy World, June 204*
[28] *Solar Quarter, July 2024*
[29] *World Bank, March 2024*
[30] *Ministry of Power, Press Information Bureau of India, July 2022*
[31] *Tata Power Solar Systems Ltd*
[32] *Mercom India, March 2024*

and aims to reduce the emission intensity of its GDP by 45% from 2005 levels by the same year[33]. Integrating a significant amount of variable and intermittent renewable energy into the energy mix poses challenges in maintaining grid stability and ensuring uninterrupted power supply. Energy Storage Systems (ESS) play a crucial role in storing available energy from renewable sources, which can then be utilised during peak demand hours. India needs the most advanced battery storage ecosystem with over 238 GWh of capacity to support its 500 GW non-fossil fuel energy target by 2032[34].

In February 2024, the Solar Energy Corporation of India Limited (SECI), operating under the Ministry of New and Renewable Energy, commissioned India's largest Battery Energy Storage System (BESS) in Rajnandgaon, Chhattisgarh. This system, which utilises solar energy for storage, has a capacity of 40 MW/120 MWh and is seamlessly integrated with a 152.325 MW solar PV plant. The project, supported by funding from the World Bank and Clean Technology Fund through the Innovation in Solar Power & Hybrid Technologies Project, also secured financing from domestic agencies[35].

Similarly, Reliance Industries Limited initiated pilot projects in July 2024 for solar and battery storage in Jamnagar, paving the way for its 9.6 GW solar module production. The company is investing over USD 10 billion in this green energy initiative[36].

WIND ENERGY

Driving Wind Energy Growth Through Auctions[37]

India's focus on wind energy had slackened, as annual capacity additions had slowed down considerably from 2018 to 2023 due to challenges such as limited suitable sites with high wind potential and reduced profitability for developers. In response, the Government has implemented several policies to rejuvenate the sector, including setting targets to auction 50 GW of renewable projects annually, with a specific focus on 10 GW for standalone wind projects. Since FY2023, around 5 GW of standalone wind projects have been auctioned, compared to approximately 3 GW in FY2021 and FY2022[38]. Additionally, auctions for hybrid and storage-linked projects have increased significantly, from 4 GW in fiscal years 2021 and 2022 to nearly 18 GW in fiscal years 2023 and 2024.

Average tariffs have stabilised at around INR 3.2 per unit in fiscal years 2023 and 2024 and are expected to remain viable and attractive to developers, given the estimated project costs in the medium term, compared to INR 2.8 per unit during fiscal years 2020, 2021 and 2022.

Viability Gap Funding Helping Capture Higher Share in APAC's Offshore Wind Capacity[39]

India's offshore wind energy sector is poised for significant growth, driven in part by Government support. A key driver is the introduction of the Viability Gap Funding (VGF) scheme. This financial incentive aims to bridge the gap between the project's total cost and expected returns, making offshore wind projects more commercially attractive. By allocating INR 74.53 billion for the development of 1 GW of offshore wind capacity in Gujarat and Tamil Nadu, the Indian Government has signalled its commitment to becoming a major player in the Asia-Pacific's offshore wind market.

Essentially, the VGF scheme is a catalyst that can accelerate the development of India's offshore wind industry and help the country achieve its ambitious target of securing 3% of the region's offshore wind capacity within the next decade.

Offshore Wind Energy Lease Rules for Enhancing Wind Energy Capacities[40]

Currently, India's wind energy generation is primarily reliant on onshore wind farms, which collectively have a capacity of 44 GW. However, the new rules pave the way for the development of offshore wind projects by defining lease areas, ranging from 25 to 500 square km, based on the scale of the project, and establishing a regulatory framework. To ensure the security and viability of these projects, the Government has imposed stringent clearance requirements from various ministries such as the Ministry of Defence, Ministry of Home Affairs, and Ministry of Environment, Forest and Climate Change.

By tapping into offshore wind resources, India can significantly expand its renewable energy capacity, reduce dependence on fossil fuels, and contribute to its broader climate goals. The Offshore Wind Energy Lease Rules are a crucial step towards achieving these objectives and establishing India as a global leader in clean energy.

In June 2024, the Government approved the development of the country's first 1 GW offshore wind energy projects located in Tamil Nadu and Gujarat. These projects, with a total estimated cost of INR 74,530 million, represent a significant step towards India's renewable energy goals.

Once operational, these offshore wind projects are projected to

[33] *Ministry of New and Renewable Energy*
[34] *India Energy Storage Alliance, Stationary Energy Storage India (SESI)*
[35] *Ministry of New and Renewable Energy, Press Information Bureau of India, February 2024*
[36] *Hindu Business Line, July 2024*
[37] *ET Energy World, May 2024*
[38] *India Business & Trade, June 2024*
[39] *ET Energy World, July 2024 and Global Wind Energy Council's 'Global Offshore Wind Report 2024'*
[40] *Moneycontrol, December 2023*

generate approximately 3.72 billion units of renewable electricity annually. In a span of 25 years, they are expected to contribute to an annual reduction of 2.98 million tonnes of CO_2 emissions.

The approval marks a milestone in India's renewable energy sector, showcasing the Government's commitment to diversifying its energy mix and enhancing sustainable development. These offshore wind projects not only harness the country's coastal resources but also pave the way for future expansions in offshore wind energy capacity, aiming to achieve India's ambitious target of installing 140 GW of renewable energy capacity by 2030.

HYDRO POWER

Collaboration with Bhutan for Renewable Energy Cooperation[41]

In March 2024, India and Bhutan unveiled a Joint Vision Document aimed at fostering cooperation in new energy initiatives, encompassing hydropower, solar energy, and green hydrogen projects. Under this agreement, Indian entities will play pivotal roles as strategic partners in the development of these projects. Both nations will collaborate closely to finalise the implementation specifics for various ventures, including reservoir hydro projects.

India will support these efforts by facilitating access to financing through Indian financial institutions and creating a market for the sale of electricity generated by Bhutan's new and forthcoming hydropower projects, as detailed in the joint vision document.

In essence, the India-Bhutan partnership is propelling the hydropower sector forward by creating new opportunities for investment, development, and

energy trade.

Importing Hydroelectricity from Nepal[42]

The Government of Nepal has made it a priority to advance its hydropower sector and intends to partner with the private sector to export 10,000 MW of hydroelectricity to India over the next ten years. Currently generating approximately 3,300 MW of electricity, Nepal plans to utilise the surplus energy generated during the monsoon season for export purposes. In 2023, Nepal earned nearly INR 15 billion (INR 1,500 crore) from hydroelectricity exports to India, underscoring its strategic emphasis on improving energy infrastructure and fostering economic cooperation within the region.

BIO POWER

Revised Policy on Biomass Cofiring for Coal-based Thermal Power Plants

In May 2024, the Ministry of Power issued a revised policy on biomass cofiring, which includes the following:

- All coal-based thermal power plants owned by utilities having bowl mills will be required to use a 5% blend of biomass pellets made primarily of agri-residues, starting from May 2025. The obligation will increase to 7% two years later.
- Similarly, coal-based thermal power plants owned by utilities that have ball and race mills will be required to use a 5% blend of torrefied biomass pellets by May 2025, which will increase to 7% two years later.
- Coal-based thermal power plants owned by utilities having ball and tube mills will be required to use a 5% blend of torrefied pellets with a volatile content below 22% by May 2025.

These changes will have the following positive impacts:

- The demand for biomass pellets made from agricultural residues and torrefied biomass pellets will increase, opening up new market opportunities for producers of these pellets and encouraging investment and development in the biomass supply chain.
- It can lead to lower carbon emissions and a smaller carbon footprint for thermal power plants.
- The policy also supports the diversification of energy sources by incorporating renewable biomass into the energy mix.

[41] *Economic Times, March 2024*
[42] *Business Standard, April 2024*

GREEN HYDROGEN

State Initiatives to Promote Green Hydrogen

A few states in India have declared their Green Hydrogen policy.

STATEWISE GREEN HYDROGEN POLICY IN INDIA	
STATE	**TARGET**
Maharashtra Harit Hydrogen Policy	To achieve 500 Kilotonnes Per Annum (KTPA) of green hydrogen production capacity by 2030
Andhra Pradesh Green Hydrogen and Green Ammonia Policy	To achieve green hydrogen production up to the capacity of 0.5 Million Metric Tonnes Per Annum (MMTPA)
Uttar Pradesh Green Hydrogen Policy	To achieve 1 MMTPA production of green hydrogen by 2028
Rajasthan Green Hydrogen Policy	To achieve 2,000 KTPA of green hydrogen production capacity by 2030

Source: India's Green Hydrogen Revolution, May 2024, EY and Ministry of New and Renewable Energy

These policies will incentivise the development of dedicated renewable energy projects,such as solar and wind farms, to produce green hydrogen, thus lowering the cost of production. Additionally, these policies will attract investments in electrolysis technology and create a robust supply chain, enabling industries like steel, ammonia, and refineries to transition to cleaner energy sources and meet decarbonisation targets.

Hydrogen-powered Train for Eco-friendly Transportation

The Indian Railways is set to introduce its first hydrogen-powered train by the end of 2024, marking a significant step towards greener transportation. The prototype will run on the Jind-Sonipat route and is a part of the "Hydrogen for Heritage" program, which aims to deploy 35 hydrogen trains on heritage and hill routes across India. It is part of a pilot project to retrofit existing Diesel Electric Multiple Unit (DEMU) trains with hydrogen fuel cells. The project will cost INR 800 million (INR 80 crores) per train, with an additional INR 700 million (INR 70 crores) per route for infrastructure. The Indian Railways has allocated INR 1,118 million for this initiative, which is a part of its broader strategy to cut carbon emissions and promote sustainable energy. The goal is to operate 50 hydrogen trains by 2047, advancing the modernisation of India's railway infrastructure with eco-friendly technology[43].

World Bank Support for Developing Green Hydrogen[44]

The World Bank has granted India a USD 1.5 billion loan to expedite the development of low-carbon energy solutions. This initiative focuses on fostering a robust market for green hydrogen and electrolyzers and enhancing renewable energy penetration across the country. The loan is expected to support India's efforts in scaling up renewable energy infrastructure, reducing the dependence on fossil fuels and advancing towards sustainability goals. By encouraging finance for low-carbon energy projects, the World Bank aims to facilitate the transition to cleaner energy sources and contribute to global efforts in combating climate change. Such a collaborative funding approach will help India achieve a greener and more resilient energy landscape faster.

[43] *ET Energy World, July 2024*
[44] *Economic Times, June 2024*

INDUSTRY CHALLENGES			
CHALLENGE	IMPACT		
	1–2 years	3–5 years	6–10 years
OVERALL RENEWABLE ENERGY INDUSTRY			
Need to overcome issues related to inconsistent supply	High	High	High
Skewed critical mineral availability poses procurement imbalance	High	High	High
Land availability poses a major challenge	High	High	High
SOLAR ENERGY			
Chinese imports still pose a threat to the Indian solar industry	High	High	High
Environmental impact of solar PV waste	High	High	High
Natural calamity hazards for floating solar power	High	High	High
HYDRO ENERGY			
Site locations, high cost of construction and high tariffs as key challenges	High	High	Medium
BIO POWER			
Need to increase the level of waste processing	High	High	Medium
GREEN HYDROGEN			
Challenges in achieving the green hydrogen target	High	Medium	Medium

OVERALL RENEWABLE ENERGY

Need to Overcome Issues Related to Inconsistent Supply

Renewable energy sources encounter challenges related to their intermittent and unpredictable supply patterns, which can destabilise the grid without adequate battery storage infrastructure. As India progresses towards its goal of 'Viksit Bharat' (Developed India), energy demand is anticipated to surge. To meet this demand sustainably, there will be a significant increase in renewable energy capacity. However, integrating large amounts of renewables into the grid can reduce the efficiency of baseload power generation, as the energy mix becomes more diverse.

The widespread adoption of renewables at scale introduces several risks associated with their intermittency and variability in power delivery. This variability makes it challenging to predict and manage energy supply, affecting grid stability and reliability. Addressing these challenges is crucial to facilitate the broader deployment of renewable energy in India's energy mix. Solutions must focus on ensuring a reliable and resilient energy transition by enhancing grid flexibility, developing robust storage systems, and implementing advanced grid management technologies.

Skewed Critical Mineral Availability Poses Procurement Imbalance

Critical minerals are essential for advancing renewable energy and battery storage technologies. However, their sources are highly concentrated geographically. For instance, China supplies 79% of the world's graphite, the Democratic Republic of Congo produces 70% of cobalt, China dominates 60% of rare earth production, and Australia accounts for 55% of lithium production[45]. China is also dominant in mineral processing across these categories. India's recent efforts to enhance the domestic production capacity of rare earth minerals reflect concerns over the skewed supply chain for these minerals in renewable energy. India's participation in the Mineral Security Partnership (MSP), which includes 14 countries (with India being the sole developing nation), aims to ensure reliable access to critical minerals essential for facilitating a smoother transition to green technologies. The Indian Government has also identified and released a list of 30 critical minerals, underscoring a heightened focus on domestic exploration to bolster national mineral security. Further, to give a fillip to the processing and refining of critical minerals, the 2024-25 Union Budget has fully exempted customs duties on 25 rare earth minerals like lithium and reduced the basic customs duty on two of them.

Land Availability Poses a Major Challenge for Renewable Energy

Most renewable energy sources are land-intensive and require the highest land use requirements among the different energy sources. Scaling up these technologies presents significant challenges, primarily due to their substantial land demands. For instance, studies indicate that approximately 1 MW of solar PV installations could necessitate between 1 to 1.5 hectares (ha) of land. Therefore, achieving a goal of 60 GW of solar power across India would require approximately 600 to 900 square km of land area[46].

[45] *Economic Survey 2023-24*
[46] *Economic Survey, 2023-24*

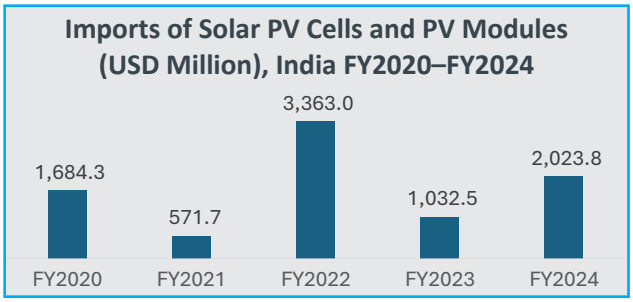
India faces a critical hurdle in this regard, as it possesses the lowest per capita land availability among the G20 nations[47]. This scarcity of available land poses a significant barrier to expanding renewable energy infrastructure across the country and necessitates careful planning and innovative solutions to optimise land use efficiently.

SOLAR ENERGY

Chinese Imports Still Pose a Threat to the Indian Solar Industry

Despite achieving sufficient domestic capacity to meet its solar module manufacturing needs, India continues to import a substantial quantity of solar modules and panels, as Chinese suppliers remain dominant due to competitive pricing.

To encourage domestic manufacturing and discourage Chinese imports, India started levying a customs duty of 40% on solar modules and 25% on solar cells from April 2022 onwards, which significantly brought down the imports in FY2023[48]. However, it seems that Chinese manufacturers are circumventing these duties by routing their products through Southeast Asian countries like Cambodia, Malaysia, Thailand, and Vietnam for minimal processing, as reported by the US Department of Commerce, which seems to have resulted in imports rising again.



Note: Till FY 2020-21, Solar Cells, whether or not assembled in modules were classified under HS Code 85414011.
In FY 2021-22, the HS Code 85414011 was retained for Solar PV Cells and a new HS Code 85414012 was brought in for Solar PV Modules. Subsequently, from FY 2022-23, the Solar PV Cells and Solar PV Modules (other than those exclusively used with ITA-1 items) are put under HS Codes 85414200 and 85414300 respectively.

Source: Ministry of New and Renewable Energy / Press Information Bureau of India), December 2023 and Directorate General of Foreign Trade (DGFT)

Environmental Impact of Solar PV Waste

Recycling renewable waste presents a significant challenge. Globally, the volume of solar PV waste is projected to reach up to 78 million tonnes by 2050[49]. Solar PV panels typically have a lifespan of 25–30 years, after which they are either sent to landfills or recycled. Landfill disposal is often cheaper than recycling but can result in harmful chemicals and heavy metals leaching into the soil. Recycling PV waste as scrap carries environmental and human health risks due to toxic metals, necessitating a robust policy framework for managing PV waste. India's revised E-Waste (Management) Rules of 2022 aim to address concerns about disposal practices, but the sheer scale of PV waste remains a daunting challenge that cannot be overlooked.

Natural Calamity Hazards for Floating Solar Power

India is exploring the potential of floating solar power. However, some challenges associated with it include higher costs compared to ground-mounted solar due to unclear site eligibility criteria and limited manufacturing capacity for floating solar equipment. Besides, challenges from natural calamities pose grave dangers. For example, in February 2024, a floating solar plant built on the backwaters of Omkareshwar Dam as a JV between the National Hydroelectric Power Corporation and the Government of Madhya Pradesh was damaged after being slammed around by 50kmph winds in a summer storm[50].

HYDRO ENERGY

Site Locations, High Cost of Construction, and High Tariffs as Key Challenges

India has a considerable Small-Hydro Power (SHP) potential of approximately 19.7 GW but utilisation remains below 20% due to the challenges associated with remote site locations and high costs of transmission infrastructure. Despite their shorter construction periods, small-hydro projects frequently exceed initial capital cost estimates.

[47] *Economic Survey 2023-24*
[48] *The Indian Express, September 2023*
[49] *Economic Survey, 2023-24*
[50] *Times of India, April 2024*

"The rising penetration of renewables in the energy mix also necessitates increasing energy storage capacity to address system integration challenges arising from the variable nature of renewable energy and supply-demand mismatch."

Debi Prasad Dash,
Executive Director, India Energy Storage Alliance (IESA) and Secretary,
US-India Energy Storage Taskforce (ESTF) Secretariat

BIO POWER

Challenges in Waste to Energy Processing

While waste-to-energy plants have achieved relative success in the European Union, environmentalists and scientists caution that this approach may not be suitable for addressing India's waste management challenges. The effectiveness of a waste-to-energy facility in meeting its energy production targets largely depends on the quality of its waste feedstock, which is influenced by three main factors: composition (biodegradable versus non-biodegradable), calorific value (energy content), and moisture content (water content in the waste).

In countries like Sweden, Norway, Germany, and the United States, waste typically has a high calorific value, ranging from 1,900 kcal/kg to 3,800 kcal/kg, making incineration an efficient method for waste disposal[51]. However, in India, the situation is different. Studies reveal that domestic waste in India generally has high moisture content and low calorific value, making it less suitable for efficient combustion in waste-to-energy plants. The calorific value of Indian waste varies by city but averages between 1,411 kcal/kg and 2,150 kcal/kg, with a significant moisture content[52]. Additionally, waste-to-energy plants in India often process mixed waste, which includes organic and recyclable materials. This mixed waste, with its high moisture content, requires additional energy to burn effectively, thereby reducing the efficiency of waste-to-energy generation.

GREEN HYDROGEN

Challenges in Achieving the Green Hydrogen Target

India faces several challenges in achieving its ambitious green hydrogen production targets of 5 MMT per annum, stemming from both supply and demand constraints.

- On the supply side, the costs associated with production and delivery are critical factors, heavily influenced by the expense of electrolysers and renewable energy inputs.
- Additionally, the overall cost of green hydrogen includes considerations such as capital expenses, water availability and treatment, storage and distribution logistics, conversion processes to derivative forms, and the necessary infrastructure.
- Moreover, since green hydrogen relies on renewable energy sources, it inherits the limitations of the renewable sector, such as intermittency and the substantial land requirements for solar and wind energy generation.
- The electrolyzer technology is still under development, and the efficiency and cost of electrolyzers need to improve for green hydrogen to become commercially viable.

Collectively, these factors make green hydrogen production expensive compared to grey hydrogen produced from fossil fuels, thus impacting the feasibility and cost-effectiveness of deploying green hydrogen across various industrial applications in India.

[51] *India Development Review (IDR), March 2024*
[52] *India Development Review (IDR), March 2024*

RUBIX

Key Initiatives by Major Players

COMPANY AND INITIATIVE	BRIEF DESCRIPTION
Hygenco Green Energies: MoU with Mitsubishi Power	In August 2024, Hygenco Green Energies entered into an MoU with Mitsubishi Power to explore the development of green hydrogen and ammonia-fired Gas Turbine Combined Cycle (GTCC) power plants. This agreement is focused on delivering these integrated solutions both within India and on an international scale.
Tata Power: Hydropower Project in Bhutan	In August 2024, Tata Power and Bhutan-based Druk Green Power Corporation Ltd (DGPC) entered into a partnership for the Khorlochhu Hydropower Project in Bhutan, with an investment of INR 69 billion (INR 6,900 crores). Tata Power will contribute a 40% equity investment, and the project is projected to be completed within 5 years.
ENGIE Group: Develop and operate a 400-megawatt solar photovoltaic power plant	In July 2024, the Asian Development Bank (ADB) and the ENGIE Group entered into a long-term local currency loan agreement to develop and operate a 400-megawatt solar PV power plant in Surendranagar District, Gujarat. This marks ADB's second financing venture for the ENGIE Group in India.
Tata Power Renewable Energy: MoU with NHPC	In July 2024, Tata Power Renewable Energy and NHPC signed an MoU to implement rooftop solar projects across Government buildings under the PM Surya Ghar Yojana.
AM Green: MoU with SJVN	In July 2024, AM Green entered into an MoU with SJVN Green Energy Limited (SGEL) for a long-term collaboration focused on supplying and sourcing renewable energy under which SGEL will deliver 4.5 GW of carbon-free energy to AM Green's upcoming green ammonia facilities in India. This capacity will be generated from solar and wind power. AM Green will integrate it with pumped hydro storage to ensure a steady supply of green energy to its operations.
Apple: JV with Clean Max Enviro Energy Solutions (CleanMax)	In April 2024, tech giant Apple entered into a JV with Mumbai-based renewable energy firm CleanMax to supply its operations in India with renewable energy for which CleanMax has set up 14.4 MW of rooftop solar power across 6 industrial sites in India.
Envision Energy: MoU with Hero Future Energies	In May 2024, Envision Energy and Hero Future Energies signed a framework agreement to advance renewable energy projects. This partnership will include the supply of Wind Turbine Generators (WTGs), Battery Energy Storage Systems (BESS), and green hydrogen technologies. Envision Energy will deliver 588 MW of 3.3 MW WTGs to Hero Future Energies over the next 1.5 years.
Adani Green Energy Ltd: Building the world's largest renewable energy park	Adani Green Energy Ltd is constructing the world's largest renewable energy park in Khavda, Gujarat, with plans to achieve an immense electricity generation capacity of 45 GW, primarily from solar energy. Covering an expansive area of 538 square km, the park's 30 GW capacity in Khavda alone exceeds the size of Paris by more than five times, making it a monumental global initiative in renewable energy.
Inox Wind Ltd: Manufacturing 4.X MW series of WTGs	In February 2024, Inox Wind Ltd entered into a partnership with W2E Wind to Energy GmbH, a Germany-based company, to collaborate on the development of 4.X MW series Wind Turbine Generators (WTGs). Under this agreement, W2E will provide its technology and design expertise tailored for low wind regimes in India. Currently, Inox Wind Ltd manufactures 2 MW and 3 MW turbines under existing licenses with American Superconductor (AMSC).
NTPC Green Energy Limited (NGEL) and Mahatma Phule Renewable Energy and Infrastructure Technology Limited (MAHAPREIT): MoU to develop RE in Maharashtra	In May 2024, NGEL and MAHAPREIT signed an MoU to develop renewable energy projects up to 10 GW in Maharashtra. The MoU envisages the joint development of grid-connected renewable energy parks and projects, including solar, wind, hybrid, etc.
Mahindra Susten: Investment of INR 12,000 million in RE	In April 2024, the Mahindra Group announced its plan to build a 150 MW hybrid RE (solar + wind) project at a total project cost of about INR 12 billion (INR 1,200 crores) through its subsidiary Mahindra Susten. The project includes the installation of 101 MW wind and 52 MW solar capacity. The facility is expected to generate 460 million kWh of clean energy, offsetting 420,000 tonnes of CO_2 emissions.

COMPANY AND INITIATIVE	BRIEF DESCRIPTION
Juniper Green Energy Pvt Ltd: PPA with SJVN	In May 2024, Juniper Green Energy Pvt Ltd signed a Power Purchase Agreement (PPA) with state-run SJVN Ltd to supply 320 MW of Firm and Dispatchable Renewable Energy (FDRE) for 25 years. The agreement sets the stage for the development of around 1 GW capacity across Gujarat and Rajasthan. Juniper Green Energy Pvt Ltd will supply SJVN renewable energy at a tariff of INR 4.38 per unit.
REC Power Development and Consultancy Limited (RECPDCL) and Bharat Heavy Electricals Ltd (BHEL): Collaboration for utility-scale RE projects	In March 2024, RECPDCL, a wholly owned subsidiary of REC Ltd and BHEL collaborated to form a Special Purpose Vehicle (SPV) for utility-scale renewable energy projects (projects of 10 MW or more), targeting the commercial and industrial sector with a capacity of 1 GW.
US-based First Solar: Investing in India for solar plant	In January 2024, US-based First Solar invested USD 700 million in setting up India's first integrated solar manufacturing plant in Tamil Nadu with an annual capacity of 3.3 GW to produce the 'company's series 7' PV solar modules for the Indian market.
Tata Power Company Ltd: Developing Pumped Hydro Storage (PHS)	In February 2024, Tata Power Company Ltd announced its intention to develop pumped hydro storage facilities with a total capacity of 2,800 MW at an estimated investment of INR 150 billion (INR 15,000 crores) by FY2028–2029. The project will be executed in collaboration with its subsidiary, Tata Power Renewable Energy (TPREL) which aims to integrate these pumped hydro storage projects with other energy sources to ensure a reliable power supply for utilities, commercial sectors, and industries.
Tata Power Company Ltd.: Investment in Tamil Nadu	In January 2024, Tata Power Company Ltd. announced an investment of INR 700 billion (INR 70,000 crores) to develop 10 GW of solar and wind power capacity in Tamil Nadu over the next 5–7 years.
Oil and Natural Gas Corporation (ONGC) Ltd: Incorporation of a subsidiary for RE	In February 2024, ONGC announced that it had incorporated a wholly owned subsidiary, ONGC Green, to engage in the business of energy value chains, namely that of renewable energy (solar, wind, hybrid, hydel, tidal, geothermal, etc.), bio-fuels/bio-gas, green hydrogen and its derivatives like green ammonia, green methanol, storage, carbon capture utilisation and storage, and Liquefied Natural Gas (LNG).
Torrent Power Limited: Investment in Gujarat	In January 2024, Torrent Power Limited signed four initial pacts with the Gujarat Government to invest INR 473.5 billion (INR 47,350 crores) in renewable energy, green hydrogen, and electricity distribution.

Note: Selected initiatives available in the public domain have been considered for selected major players. Initiatives are arranged in chronological order, with the most recent appearing first.
Source: Company press releases, news sources

Key Mergers/Acquisitions/JVs

COMPANY AND INITIATIVE	BRIEF DESCRIPTION
Brookfield: Majority stake in Leap Green	In July 2024, Canadian asset management firm Brookfield announced that it would acquire a majority controlling stake in Leap Green Energy, a Tamil Nadu-based provider of renewable energy solutions for Commercial and Industrial (C&I) customers. Brookfield will make an initial equity investment exceeding USD 200 million in Leap Green, through both the subscription of new shares and the purchase of existing shares from current shareholders. Additionally, Brookfield has the option to invest up to USD 350 million more in incremental equity to support Leap Green's future growth.
GE Power India Ltd: Sale of hydro and gas power business	In July 2024, GE Power India Ltd announced the sale and transfer of its hydro and gas power business undertakings as a going concern through a slump sale. This will see the hydro business encompassing the development, design, engineering, marketing, manufacturing, selling, supplying, transporting, assembling, installing, and servicing of hydro turbines, generators, and associated systems for hydroelectric power stations to be sold to GE Power Electronics (India) Private Limited.

COMPANY AND INITIATIVE	BRIEF DESCRIPTION
Aerem Solutions: Acquisition of Spinkraft Ventures	In May 2024, Aerem Solutions, a solar fintech company in India, entered into a definitive agreement to acquire Spinkraft Ventures, a solar equipment distributor.
Siemens Energy AG: Sale of Indian wind turbines business	In May 2024, Siemens Energy AG announced that it had initiated the sale of its Indian wind turbine business, a subsidiary of Siemens Gamesa Renewable Energy, as part of a strategic move to address losses and aim for profitability. The decision is in line with Siemens Gamesa's strategy to concentrate on its core markets in Europe and the US.
BluPine Energy: Acquisition of solar power assets from the Acme Group	In March 2024, BluPine Energy, a renewable energy services company established in India by UK investor Actis, announced the acquisition of 369 MW of solar power assets from the Acme Group spread across 14 special-purpose vehicles in the states of Uttarakhand, Punjab, and Karnataka.
Greenko Group: Acquisition of hydroelectric project from GI Hydro	In March 2024, the Greenko Group which has a notable presence in the hydro projects segment, with an operating capacity of 1,789 MW across 25 projects, completed the acquisition of the 110 MW Chuzachen hydro-electric project in East Sikkim from GI Hydro at an enterprise value of INR 10 billion (INR 1000 crores).
IndiGrid: Share Purchase Agreement to acquire ReNew Solar Urja Pvt Ltd	In January 2024, IndiGrid executed the share purchase agreement to acquire ReNew Solar Urja Pvt Ltd from ReNew Solar Power, which operates a 300 MW (AC) solar project in Rajasthan. The total enterprise value of the acquisition is USD 199 million (INR 1,650 crore) including net working capital and cash.

Note: Selected deals available in the public domain have been considered for selected major players. Deals are arranged in chronological order, with the most recent appearing first.
Source: Company press releases, news sources

Key Government Initiatives

Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM)	This scheme seeks to boost solar power installation in rural areas by installing solar power plants on barren or unused land, promoting solar pumps, etc.
Production Linked Incentive (PLI) Scheme for National Programme on High Efficiency Solar Photovoltaic (PV) Modules	The goal of this initiative is to attain a gigawatt-level manufacturing capacity in high-efficiency solar PV modules through an investment of INR 240 billion (INR 24,000 crores). As of 31 March 2024, four manufacturers had started manufacturing solar PV modules.
Solar Parks Scheme	This scheme has a sanctioned capacity of 39.7 GW for the development of 56 Solar Parks in 13 states, of which 51 solar parks have already been commissioned.
PM - Surya Ghar: Muft Bijli Yojana	This initiative aims to install rooftop solar plants in 10 million households and has a total financial outlay of INR 750 billion (INR 75,000 crores) to be implemented until FY27. This is expected to enable an installation of around 30 GW of residential rooftop solar capacity and 40–45 GW of overall rooftop solar capacity addition by FY27.
CPSU Scheme Phase-II (Government Producer Scheme)	The objective of this scheme is to help PSUs and Government organisations set up grid-connected solar PV power projects using domestically manufactured solar PV cells and modules, with VGF support for self-use or use by the Government or Government entities. Out of the 8.2 GW capacity of solar PV power plants, about 1.66 GW capacity has been commissioned and the rest is under implementation as of 31 March 2024.
New Solar Power Scheme (for Particularly Vulnerable Tribal Groups [PVTG] Habitations/ Villages)	It was launched on 4 January 2024 under the Pradhan Mantri Janjati Adivasi Nyaya Maha Abhiyan for electrification of 1 lakh un-electrified PVTG households in 18 states and 1 Union Territory. It aims to provide off-grid solar systems where electricity supply through the grid is not techno-economically feasible.

Green Energy Corridor (GEC) projects	This scheme was Initiated to facilitate renewable power evacuation and reshaping of the grid for future requirements. GEC-I is under implementation in 8 states with a cumulative achievement of 9,111 circuit kilometre (ckm) transmission lines and 21,303 MVA substations. GEC-II is under implementation in 7 states.
National Bio Energy Programme	The National Bioenergy Programme was notified in November 2022 and is to be implemented from 1 April 2022 to 31 March 2026 in two phases. Under the Biogas Programme, about 51.04 lakhs of small biogas plants and 349 medium-sized biogas plants have been installed.
National Green Hydrogen Mission	This programme was approved in January 2023 with an outlay of INR 197.4 billion, this mission targets to achieve about 5 MMT of annual green hydrogen production capacity.

Note: Selected key initiatives available in the public domain have been considered.
Source: Economic Survey 2023-24 and Ministry of New and Renewable Energy

Outlook

India is projected to maintain its status as the world's fastest-growing major economy, driven by increasing domestic demand and robust growth in manufacturing and services sectors. This underscores the growing importance of renewable energy, as India aims to achieve 50% of its total installed capacity from non-fossil fuel sources by 2030.

According to the National Electricity Plan by the Central Electricity Authority, non-fossil fuel capacity, including renewable energy, nuclear, and large hydro, is set to increase significantly. It stood at approximately 203.4 GW (46% of total capacity) in 2023-24 and is projected to reach 500.6 GW (64.4%) by 2029-30[53]. This growth trajectory is expected to attract investments totalling around INR 30.5 trillion from 2024 to 2030, creating substantial economic opportunities across various sectors[54].

As per the Central Electricity Authority, National Electricity Plan 2022-32, the projected installed capacities for various segments would be – solar (364 GW), wind (122 GW), large hydro (62 GW), small hydro (5 GW) and bio power (15 GW).

India's renewable energy sector is poised for further growth, supported by favourable policy reforms, such as the Electricity Amendment Rules 2023, waivers on Inter State Transmission System (ISTS) charges for solar and wind power projects, revised renewable generation obligations, structured annual auctions for 50 GW of renewables capacity, and the introduction of Offshore Wind Energy Lease Rules 2023.

Private sector investments in large-scale renewable projects are expected to drive manufacturing and innovation in critical renewable energy technologies, equipment, and raw materials supply chains. Wind and solar energy remain attractive due to significantly reduced costs—wind power costs have dropped by 49% and solar costs by 84% since 2010, making them compelling options for new investments and market entrants[55].

Energy storage solutions will play a crucial role in supporting the expansion of renewable energy capacity, necessitating innovative technologies and business models to efficiently harness low-cost intermittent renewable energy sources. Hybrid projects are also gaining traction within India's renewable energy landscape.

With these positive developments, India is well-positioned to make substantial advancements in its renewable energy sector in the years ahead.

[53] *Economic Survey 2023-24*
[54] *Economic Survey 2023-24*
[55] *Economic Times, Energy World, March 2024*

""Overall, India appears well-prepared to achieve its renewable energy target of 500 GW installed capacity and reach 50 per cent cumulative electric power installed capacity from clean energy sources by 2030."

A Nithyanand, MD & CEO,
Renewables Business, Sembcorp India

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