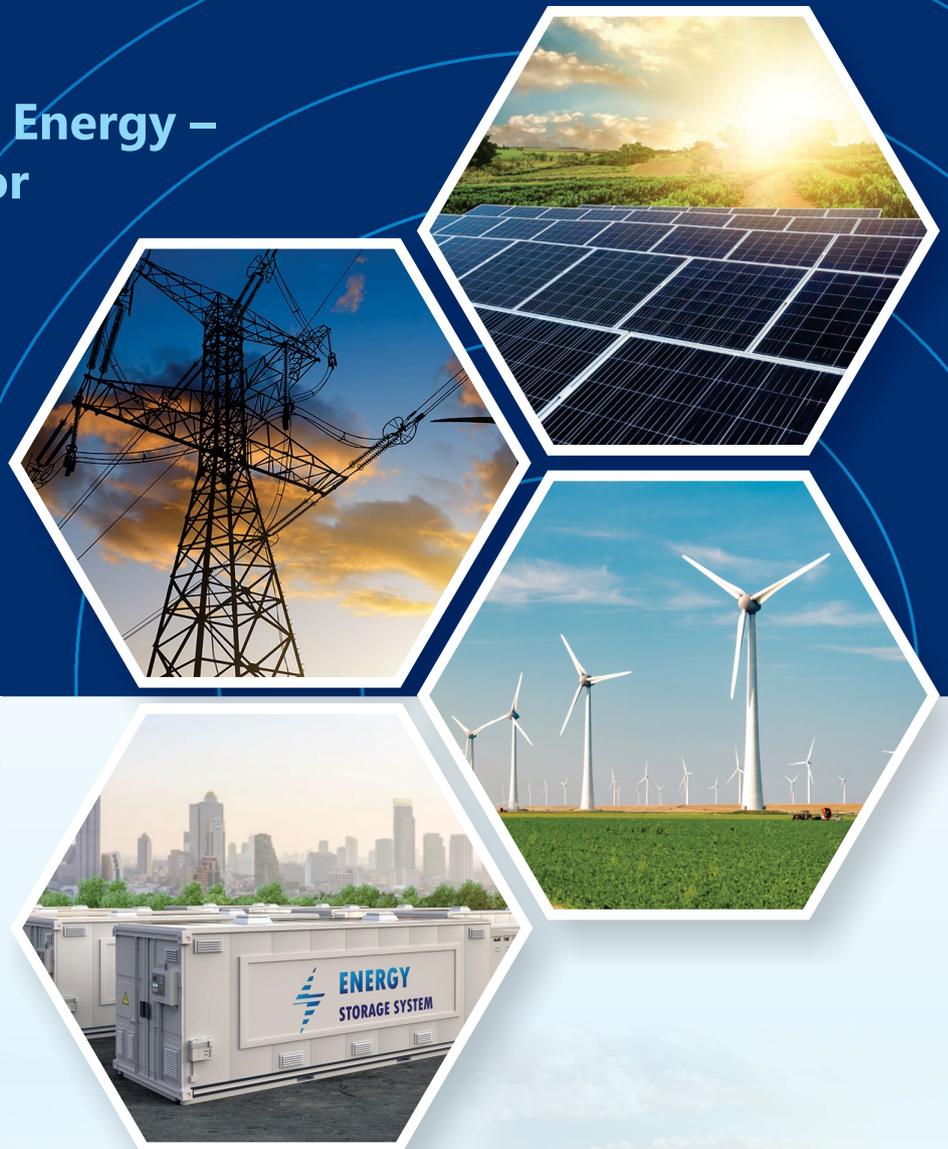


22nd RENEWABLE ENERGY SUMMIT

Theme: Renewable Energy –
Key to Power Sector
Decarbonisation

31th July 2025
Hotel Le Meridien
New Delhi



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31th July 2025, Hotel Le Meridien, New Delhi

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Key to Power Sector Decarbonisation**

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FOREWORD

Renewable energy is crucial for decarbonizing the power sector, offering a pathway to significantly reduce greenhouse gas emissions. By transitioning to solar, wind, hydro, and other renewable sources, the power sector can move away from fossil fuels and towards a cleaner, more sustainable energy system. This shift not only combats climate change but also offers numerous co-benefits like improved air quality, enhanced energy access, and economic opportunities.

India Energy Forum has been organizing national conferences to focus on challenges and opportunities in the development of clean and environment-friendly energies over the years. These conferences have created a niche position and are attended by energy professionals and policymakers from all over India.

This year, India Energy Forum is organizing **22nd National Annual Renewable Energy Conference on 31st July 2025** on the theme: **Renewable Energy – Key to Power Sector Decarbonisation**". The summit will deliberate on Accelerating RE Deployment – Challenges and Solutions; RE Integration Challenges – Planning and Storage Solutions; and DRE and Innovative RE Technologies – Clean Energy Alternatives.

The 22nd National Annual Renewable Energy Conference will bring together industry leaders, policymakers, and experts to discuss key solutions for accelerating renewable energy adoption while ensuring grid stability and affordability.

The contribution of our Knowledge Partner namely Idam Infrastructure and the Organising Committee Members under the chairmanship of Shri V S Verma, Former Member, CERC and CEA in finalizing the Theme Paper as well as other arrangements etc is highly appreciated.

I wish Conference a great success!

A handwritten signature in blue ink, appearing to read 'R V Shahi'.

R V Shahi

President, IEF and Former Secretary (Power)

adani

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We connect people, are friends with nature, and turn the wheels of the future. We love, we care, we respect. We give wings to every dream and light up a million smiles. We know it takes each one of us to build a nation, and anything can be achieved if we come together as one.





MESSAGE

The power sector is pivotal in the global effort to decarbonize, with renewable energy playing a central role in this transition. Renewable energy sources like solar, wind, and others offer sustainable alternatives to fossil fuels, enabling a significant reduction in greenhouse gas emissions. Achieving a decarbonized power sector requires not only expanding renewable energy capacity but also addressing challenges related to grid integration and energy storage.

India Energy Forum is organising its 22nd Renewable Energy Summit on 31st July 2025 on the theme “Renewable Energy – Key to Power Sector Decarbonisation”. The Conference will deliberate upon the key-issues like Make in India; Land Acquisition; Connectivity and Power Evacuation; Financing; Energy Storage and Hydrogen; Green Energy Corridor; Rooftop Solar; Virtual Net Metering; Peer to Peer Trading; Biogas; Floating Solar; Agri-voltaic and Power evacuation infrastructure etc. “Idam Infrastructure” is our Knowledge Partner in the Summit and in preparation of the Theme Paper. The Theme Paper has focused on the above various issues in good detail. The Conference is being attended by various industry groups and the top policy planners of the country namely, Secretary and Joint Secretary, Ministry of New and Renewable Energy, Chairperson, Central Electricity Authority, Chairman, NTPC, IREDA and others.

I am confident that the participants would be immensely benefited from the deliberations of the Summit. The conclusions of the Summit will also lead us the way forward to achieve the targets of Decarbonised Power Sector.

I wish the Summit a great Success!

V S Verma

Chairman, Renewable Group, IEF
Former Member, CEA and CERC



Preface

The 22nd Renewable Energy Summit, a flagship event of the India Energy Forum, is being organized on July 31, 2025. The theme is **“Renewable Energy – Key to Power Sector Decarbonisation”**. The Summit Knowledge partner is Idam Infrastructure Advisory.

Renewable energy is poised for a global takeoff. According to the International Renewable Energy Agency (IRENA), a marked rise in global renewable electricity capacity is seen, overtaking fossil fuel capacity. The global goal is to triple the utilization of renewable energy sources and achieve a total capacity of 11.2 terawatts by 2030. The annual addition of an average of 1,044 gigawatts of new renewable energy capacity is expected to help reach the goal, cutting carbon dioxide emissions by 43 percent by 2030 and 60 percent by 2035.

In India, the renewable energy sector is getting the highest momentum. India’s updated NDC target to reduce the emission intensity of its GDP by 45% and achieve 50% cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030 is set to make compliance for the negotiations to be held in COP-30 this year. In the current summit, the challenges in renewable energy capacity addition in terms of policy innovation, storage options, grid modernization, and development of the resilient infrastructure, etc, are deliberated in the **Inaugural Session**, and its three sessions, namely;

- **Panel Discussion on “Accelerating RE Deployment – Challenges and Solutions”**
- **Technical Session on “Renewable Energy (RE) Integration Challenges”**
- **Technical Session on “Distribution Renewable Energy (DRE) and Innovative RE Technologies”**

Our thanks are to Shri S. K. Sarangi, Secretary, MNRE, Shri R. V. Shahi President, India Energy Forum, distinguished guests, session chairmen, eminent speakers, and industry leaders. We would like to thank Mr. Balwant Joshi and his team for highlighting the issues and challenges associated with transitioning to RE in the theme paper and providing a forward-looking perspective for transforming the Indian power sector towards decarbonisation.

The theme paper and programme for the Summit are included here. Thank you for your contributions in making it a success.

Dr. (Mrs) Malti Goel

Honorary Convener, Renewable Energy Group, IEF
Former Adviser and Emeritus Scientist, Government of India

Programme

Registration and Networking Tea (9.30 a.m. – 10.00 a.m.)

Inaugural Session (10.10 a.m. – 11.00 a.m.)

- Welcome Address by **Shri V S Verma**, Chairman, Renewable Group, IEF and Former Member, CEA and CERC
- Special Address by **Shri Gurdeep Singh**, CMD, NTPC
- Presidential Address by **Shri R V Shahi**, President, IEF and Former Secretary (Power)
- Address by the Guest of Honour, **Shri Ghanshyam Prasad**, Chairperson, CEA
- Inaugural Address by the Chief Guest by **Shri Santosh Kumar Sarangi**, Secretary, MNRE
- Vote of Thanks by **Dr (Mrs) Malti Goel**, Convenor, Renewables Group, IEF

Tea Break (11.00 a.m. - 11.30 a.m.)

SESSION I - 11:30 A.M. - 1.00 P.M.

Panel Discussion on “Accelerating RE Deployment – Challenges and Solutions”

- **Opening Remarks and Moderator: Shri Pradip K Das**, CMD, IREDA
- **Theme Presentation** by Knowledge Partner, Idam Infra - **Shri Balawant Joshi**, Managing Director, Idam Infra

Topics to be covered in the session:

- Make in India
- Land Acquisition
- Connectivity and Power Evacuation
- Financing

Distinguished Panelists:

- **Shri Sarit Maheshwari**, CEO - NTPC Renewable Energy Ltd
- **Shri Sivakumar V Vepakomma**, Director (Power System), SECI
- **Dr V K Garg**, Former CMD, PFC
- **Shri Vivek Srivastava**, CEO - Suzlon Energy
- **Shri Pawan Agrawal**, MD & CEO - Waaree Forever Energies
- **Shri Y K Sehgal**, ED, Greenko Energies

Question & Answer

Tea Break (1.00 p.m. - 2.00 p.m.)

SESSION II - 2.00 P.M. - 3.30 P.M.

Technical Session I: “RE Integration Challenges”

- **Opening Remarks and Moderator: Shri Samir Chandra Saxena**, CMD, Grid India

Topics to be covered in the session:

- Energy Storage
- Flexibility

- Planning Challenges
- State Issues
- Green Energy Corridor

Distinguished Panelists:

- **Dr S K Chatterjee**, Chief (Regulatory) – CERC
- **Shri Ashish Khanna**, CEO, Adani Green
- **Shri Alexander Hogeveen Rutter**, Manager Research & Diligence - Third Derivative
- **Shri Rahul Walawalkar**, President & MD, Customised Energy Solutions
- **Shri Ajit Pandit**, Founding Director & CEO – Idam Infra
- **Shri Sutripto De**, General Manager (NREB), BHEL

Question & Answer

TEA WILL BE SERVED ON THE TABLE

SESSION III - 3.30 P.M. - 5.00 P.M.

Technical Session II: “Distribution Renewable Energy (DRE) and Innovative RE Technologies”

- **Chairperson: Shri Hemant Jain**, Member (GO&D), CEA

Topics to be covered in the session:

- Rooftop Solar
- Virtual Net Metering
- Peer to Peer Trading
- Biogas
- Floating Solar
- Agrivoltaic
- Power evacuation infrastructure

Distinguished Panelists:

- **Shri Satyajit Ganguli**, Former MD, PXIL
- **Shri Mukesh Dadhich**, Head- Sustainability and Clean Technology, Business development and NTI, BSES Yamuna Power Limited
- **Dr Alok Mishra**, Director India Offers and Country Director Westinghouse India
- **Shri Amit Kumar Parihar**, Director, Shakti Foundation
- **Shri Sanjay Ganjoo**, Director General - Indian Federation of Green Energy on “Biogas”
- **Shri Pankaj Kumar**, Co-Founder & Director - Quant Solar
- **Shri Bhairaw Kumar**, Founder & CEO - Enerture Technologies Pvt Ltd

Question & Answer

Valedictory Session (5.00 p.m. - 5.30 p.m.)

Summing Up by **Shri R V Shahi**, President, IEF

Recommendations and Vote of Thanks by **Shri S M Mahajan**, SG, IEF

Theme
PAPER





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Executive **SUMMARY**



India’s power sector is undergoing a transformative shift, with renewable energy serving as the cornerstone for decarbonizing the nation’s energy landscape. As per the India’s Energy Landscape, PiB in June 2025, the non-fossil fuel sources, including solar, wind, hydro, nuclear, and biomass, contribute approximately 236 GW, representing nearly half of the total installed capacity of 476 GW. Despite coal’s dominance, contributing nearly 70% of electricity generation, India’s ambitious policies, technological innovations, and financial strategies are driving a rapid transition toward a sustainable energy future. This executive summary highlights the critical role of renewable energy in reducing carbon emissions, supported by robust data and strategic initiatives.

Progress in Renewable Energy Deployment

India has made remarkable strides in renewable energy deployment, ranking fourth globally in total renewable energy installations, third in solar, and fourth in wind power. Solar capacity has surged from nearly 2.8 GW in 2014 to over 110 GW in 2025, while wind energy has reached about 51.3 GW (refer **Figure 1**). These achievements are underpinned by strong policy frameworks, including the PM-KUSUM scheme, Production Linked Incentive (PLI) for solar and batteries, and the Surya Ghar Yojana. The Ministry of New and Renewable Energy (MNRE) has recently reported a total clean (non-fossil fuel) power capacity of approximately 243 GW as of July 2025 out of a total installed capacity of 485 GW, achieving the NDC (Nationally Determined Contribution) target five years ahead of the 2030 deadline.

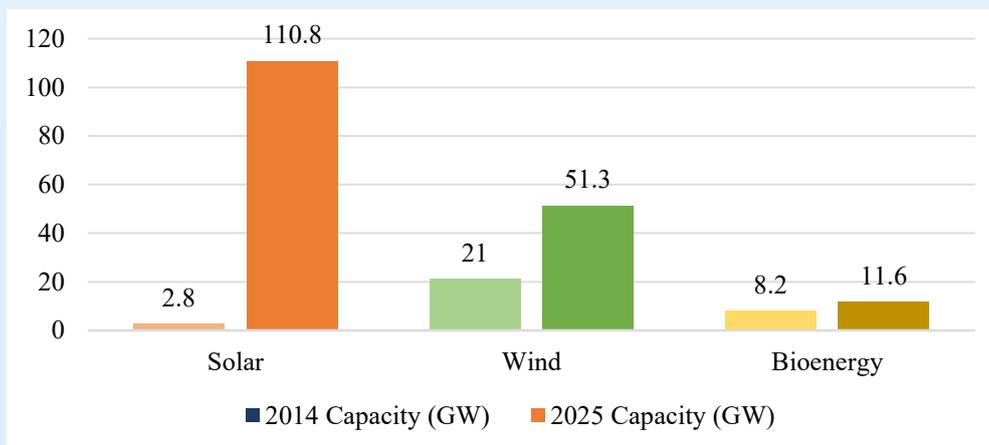


Figure 1 India’s Renewable Capacity Growth (2014 to 2025)

Future Targets & Policy Framework

The National Electricity Plan (NEP) 2023¹ outlines an ambitious target of 874 GW installed capacity by 2031-32, with 68% (approximately 596 GW) from non-fossil sources, including 179 GW from solar and 49 GW from wind (refer **Figure 2**). This transition is expected to reduce the grid’s carbon intensity from 0.548 kg CO₂/kWh in 2026-27 to 0.430 kg CO₂/kWh by 2031-32, significantly advancing India’s decarbonization goals. The India Energy Stack (IES)², launched by the Ministry of Power on July 1, 2025, is a pivotal initiative aimed at digitizing the energy value chain. By enhancing data transparency, consumer choice, and integration of distributed renewable sources like rooftop solar and electric vehicles, the Integrated Energy Storage (IES) is being piloted in Gujarat, Delhi, and Mumbai, setting the stage for a more efficient and sustainable power sector.

Meeting Growing Energy Demands

India’s electricity demand is projected to increase from approximately 250 GW in 2025 to 366 GW by 2032, with an energy requirement of 2,474 billion units (BU). To meet this demand sustainably, the Central Electricity Authority (CEA) emphasizes the need for rapid expansion of non-fossil fuel capacity. The NEP 2023 projects that by 2032, over 68% of the installed capacity will come from non-fossil sources, necessitating significant investments in grid infrastructure, energy storage, and flexible generation systems to ensure reliability and stability.

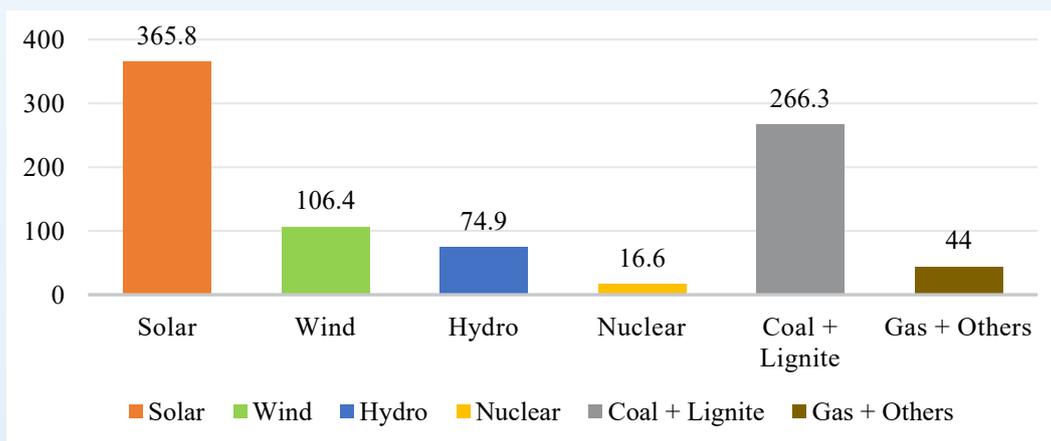


Figure 2 Installed Capacity Targets for 2032 (in GW), NEP 2023

Emerging Technologies & Sectoral Innovations

Emerging technologies are vital to sustaining India’s renewable energy growth. High-efficiency solar cells (>20%) and higher-rated modules (>700 Wp) are enhancing land-use efficiency by requiring less area (<2.5 m² per module). The deployment of these advanced modules is expected to fundamentally boost solar energy’s share in India’s energy mix by delivering more power per unit of land. Energy storage is also a key alternative, with plans to add 38.6 GW/201.5 GWh of battery storage and 19.2 GW of pumped hydro by 2032, which are further supported by Viability Gap Funding (VGF) schemes and regulations mandating energy storage obligations (ESO). Additionally, the National Green Hydrogen Mission targets 5 million metric tons per year by 2030, positioning India to become a global leader in green hydrogen production. Innovations in floating solar, offshore wind, and state-level renewable energy integration are also gaining traction, for instance, a ₹.7,453 crore VGF scheme was approved for the first 1 GW of offshore wind capacity off Gujarat and Tamil Nadu. Such technologies are deemed essential for addressing grid complexity and ensuring a stable power supply as renewable energy penetration increase.

Distributed and Inclusive Energy Transition

Decentralized renewable energy solutions, such as rooftop solar, agrivoltaics, and floating photovoltaic systems, are central to India’s inclusive energy transition. Programs like PM Surya Ghar and PM JANMAN are connecting urban and tribal households to clean energy, fostering equitable access. Innovations in peer-to-peer (P2P) trading, energy-as-a-service (EaaS) models, and community participation are empowering prosumers and driving grassroots adoption. Additionally, the renewable energy sector is boosting job creation, rural livelihoods, and manufacturing competitiveness, with domestic solar module manufacturing exceeding 50 GW (refer **Table 1**) and wind component production scaling up in states like Tamil Nadu, Gujarat, and Maharashtra.

Financing and Risk Mitigation

Achieving the 500 GW non-fossil fuel capacity target by 2030 requires an estimated ₹. 30 lakh crores (USD 360 billion) in investments (**Figure 3** illustrates the estimated investments to achieve 500 GW RE target by 2030). Challenges such as DISCOM payment delays, hedging risks, and lengthy project gestation periods persist, but India is addressing these through financial innovations. The government is expanding credit enhancement tools, pooled procurement structures, and payment security mechanisms to reduce project risks. The development of carbon markets, electricity derivatives, and green trading platforms, such as the Indian Energy Exchange’s Green Term Ahead Markets (GTAM) and Green Day Ahead Markets (GDAM), is enhancing the financial viability of renewable energy projects. Total renewable energy investments are projected to exceed USD 360 billion by 2030, supported by foreign direct investment, green bonds, and domestic institutions like IREDA and PFC.

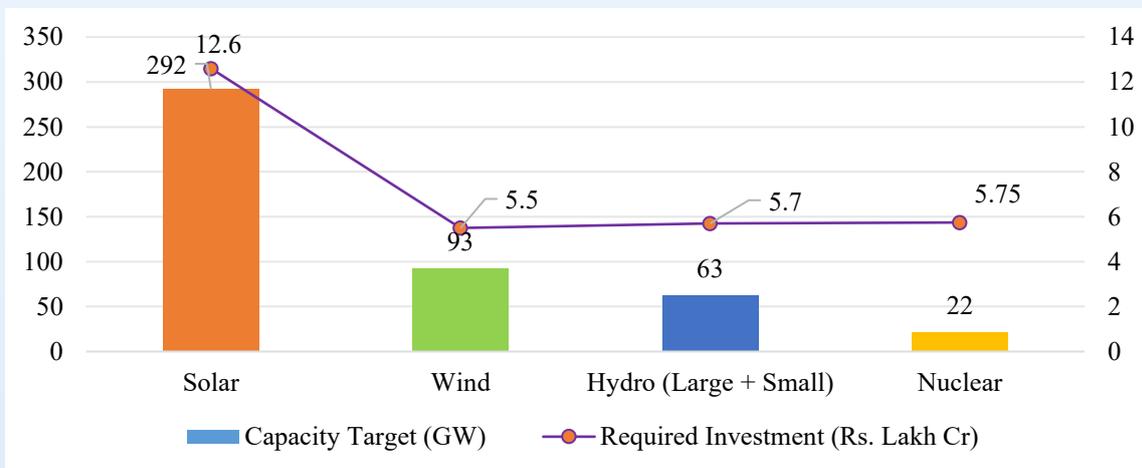


Figure 3 Capacity Targets and Estimated Investments for Achieving 500 GW Non-fossil Energy by 2030.

To bolster its rapidly evolving energy sector, India is launching two landmark reforms: market coupling³ and electricity derivatives⁴. The move toward market coupling will integrate the nation's power exchanges to establish a single, uniform price for electricity, a foundational step to enhance market efficiency and optimize resource allocation. Complementing this, newly introduced SEBI-regulated derivatives provide a vital financial tool for generators and consumers to hedge against price volatility. Together, these initiatives are designed to de-risk investments, enhance financial stability, and mark a critical step towards creating a more mature and resilient national power market.

As India accelerates its energy transition, managing financial risk is paramount to attracting the necessary investment in renewable power. A key mechanism to achieve this is the Contract for Difference (CfD), a sophisticated risk management tool that provides revenue certainty for generators. By guaranteeing a stable price for clean energy projects (which is based on the difference between the market price and an agreed “strike price”), CfDs de-risk investments, enhance investor confidence, and can play a pivotal role in ensuring the stable, long-term growth of India's renewable capacity.

Recommendations

Renewable energy is critical to decarbonizing India’s power sector and achieving its Net Zero target by 2070. With targeted policy interventions, rapid technological advancements, and strong financing mechanisms, India is well-positioned to meet its ambitious energy transition goals. The sharp increase in solar and wind capacity,

along with emerging innovations such as the IES system and green hydrogen, reflects India's strong commitment to a sustainable energy future. By enabling an inclusive transition and tackling financial and infrastructure challenges, India is charting a path toward a cleaner, more resilient power system that supports both national economic growth and global climate goals.

To provide deeper insight into the opportunities and challenges in this transition, this theme paper is structured across the following chapters:

- **Chapter 1** provides an overview of India's energy landscape, progress in the energy transition, key drivers of renewable growth, regulatory enablers, and the role of innovation and inclusivity, while outlining the purpose and structure of the theme paper.
- **Chapter 2** explores the key challenges and enabling measures for accelerating renewable energy deployment. It focuses on domestic manufacturing, grid connectivity, land acquisition, and financing mechanisms. This chapter aims to highlight how policy and investment can align to scale RE capacity efficiently and equitably.
- **Chapter 3** focuses on how renewable energy is being integrated into India's power system. It explains the importance of energy storage, green hydrogen, grid flexibility, and long-term system planning in managing variable generation. It also reviews the Green Energy Corridor initiative and examines integration challenges at the state level. Together, these insights frame the technical and operational shifts needed to support a high-renewable energy future.
- **Chapter 4** focuses on decentralized renewable energy and emerging technologies such as rooftop solar, floating solar, peer-to-peer energy trading, virtual net metering, biogas, and agrivoltaics. This chapter underscores the importance of innovation and community-based solutions in achieving energy access, sustainability, and localized benefits.
- **Chapter 5** presents overarching insights, outlines actionable recommendations for stakeholders, and suggests a clear policy and implementation roadmap to support India's renewable energy transition.

Together, the chapters offer key insights to guide policy, foster innovation, and shape strategic planning for a low-carbon energy future. As India advances its energy transition, the focus must shift to:

- **Investment readiness** by streamlining clearances, strengthening contracts, and ensuring bankable power offtake.
- **Grid integration** through flexible assets, Battery Energy Storage Systems (BESS), pumped storage (PSP), and smart control systems.
- **De-risking** by extending VGF, PLI, and guarantees emerging technologies like green hydrogen and offshore wind
- **Promoting** inclusive access by enhancing support for C&I rooftop solar, community-based renewable projects, and electrification in tribal regions.
- **Regulatory certainty** via ISTS waivers, standardized PPAs, and robust ancillary service markets to boost investor confidence.

INTRODUCTION



The power sector plays a pivotal role in determining the pace and scale of emissions reduction in India. Decarbonizing this sector is crucial, as electricity is expected to become the dominant source of energy for meeting future demand across various sectors.

1.1 India’s Current Energy Landscape

At the 26th UN Climate Change Conference (COP26) in Glasgow, India updated its Nationally Determined Contributions (NDCs), committing to reduce the emissions intensity of its GDP by 45% from 2005 levels by 2030 and to achieve around 50% of its cumulative installed electric power capacity from non-fossil fuel sources by the same year.

In line with the above targets set, as of June 2025⁵, the total installed capacity from non-fossil fuel sources - comprising solar, wind, large hydro, nuclear, biomass, and waste-to-energy - has reached around 236 GW, making up nearly 50% of India’s total installed power capacity of 476 GW. The rapid growth in solar energy, which crossed 110 GW, illustrates India’s strategic emphasis on scalable and cost-effective decarbonization technologies. **Figure 4** and **Figure 5** illustrate the total installed power capacity and non-fossil fuel installed capacity.

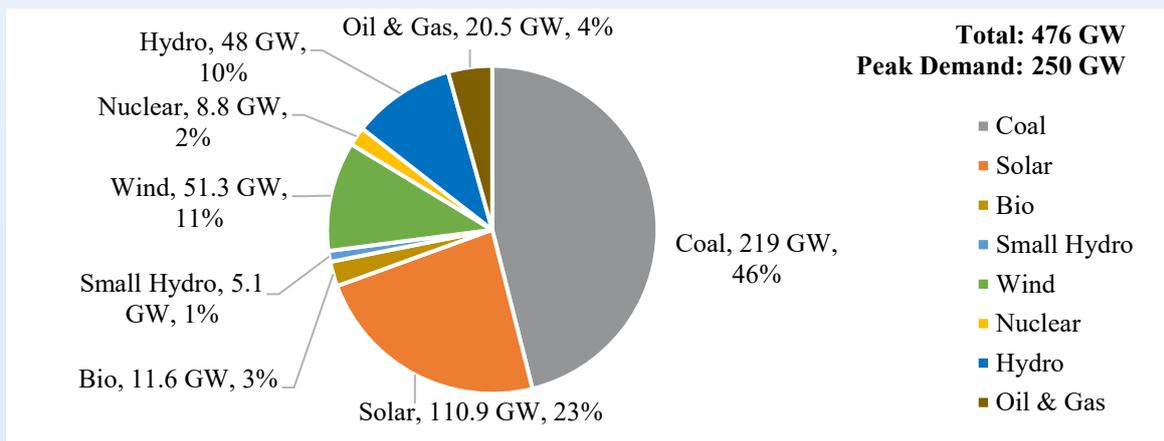


Figure 4 Installed Power Capacity Mix (GW) as of June 2025.

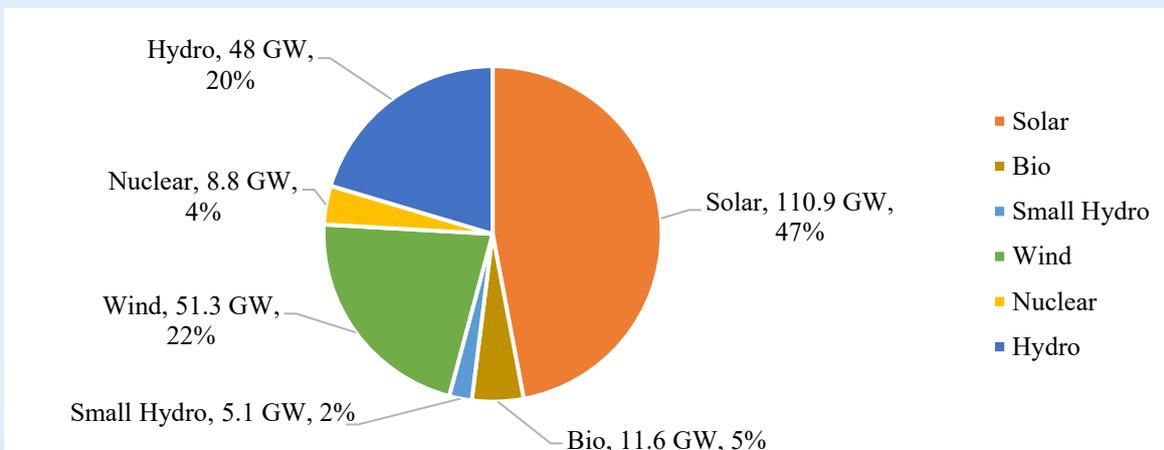


Figure 5 Non-Fossil Fuel Installed Capacity India (GW) as of June 2025.

India's power sector marked a major milestone by meeting a record peak power demand of 250 GW on May 30, 2024. Additionally, the country recorded its highest-ever non-solar demand met at 234.3 GW on May 29,

2024⁶. These figures highlight the combined effects of increased weather-driven loads and rising industrial and residential electricity consumption.

India's peak electricity demand is expected to reach 366 GW, with an annual energy requirement of 2,474 BU by 2031–32. To ensure the power system can meet this growing demand reliably, the CEA has undertaken generation expansion planning and formally notified the NEP, Volume I: Generation in May 2023⁷.

India's power sector is undergoing a major transformation as it accelerates the shift toward cleaner energy sources. As per the NEP 2023, peak electricity demand and total energy requirement are projected to reach 366 GW and 2,474 BU, respectively, by 2031-32. To meet this rising demand reliably, the CEA has undertaken generation expansion planning and estimates the installed generation capacity will rise to approximately 874 GW by 2031-32. The source-wise capacity breakup as per the Plan is provided below **Figure 6**.

As this energy transition advances, the share of non-fossil fuel-based capacity is expected to grow from around 40% in March 2022 to 57.4% by 2026-27, and further to 68.4% by 2031-32. To achieve this, the required capacity addition during 2027-32 is projected at 291.8 GW, which includes 32.1 GW of conventional capacity - comprising 25.5 GW of coal and 6.6 GW of nuclear - and 259.7 GW of renewable-based capacity, including 179 GW of solar, 49 GW of wind, 9.7 GW of large hydro, 2.5 GW of biomass, 250 MW of small hydro, and 19.2 GW of PSP. In addition, BESS of around 38.6 GW/201.5 GWh are expected to be deployed to enhance system flexibility and support VRE integration. According to the reassessment study conducted by the CEA between 2017-2023⁸, the country's exploitable large hydro potential stands at 133 GW, while the identified PSP potential amounts to 176 GW.

- ❖ *As of 2024, Coal supplies ~75% of India's electricity*
- ❖ *Renewables contribute over 20%, mainly solar and wind*
- ❖ *Nuclear and gas have minor roles in the mix*
- ❖ *Power sector still heavily dependent on coal*
- ❖ *RE share has doubled in a decade, but grid flexibility and storage are key for deeper decarbonization*

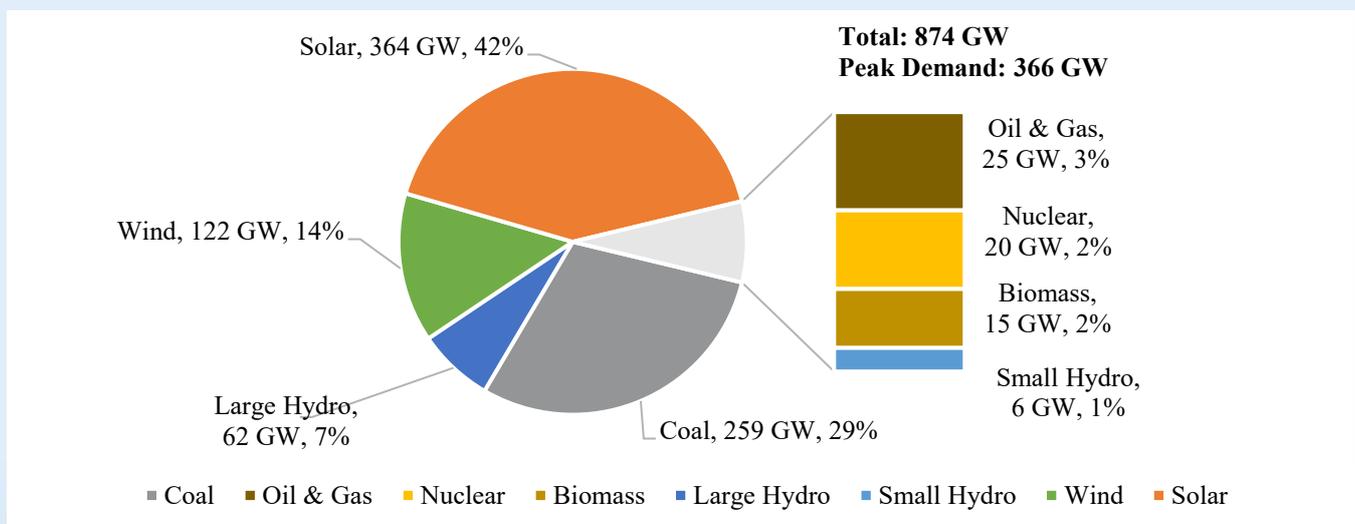


Figure 6 Installed Capacity in 2032 (GW), NEP 2023.

The details of source wise likely generation for the year 2032, as projected in NEP 2023, are tabulated below **Figure 7**.

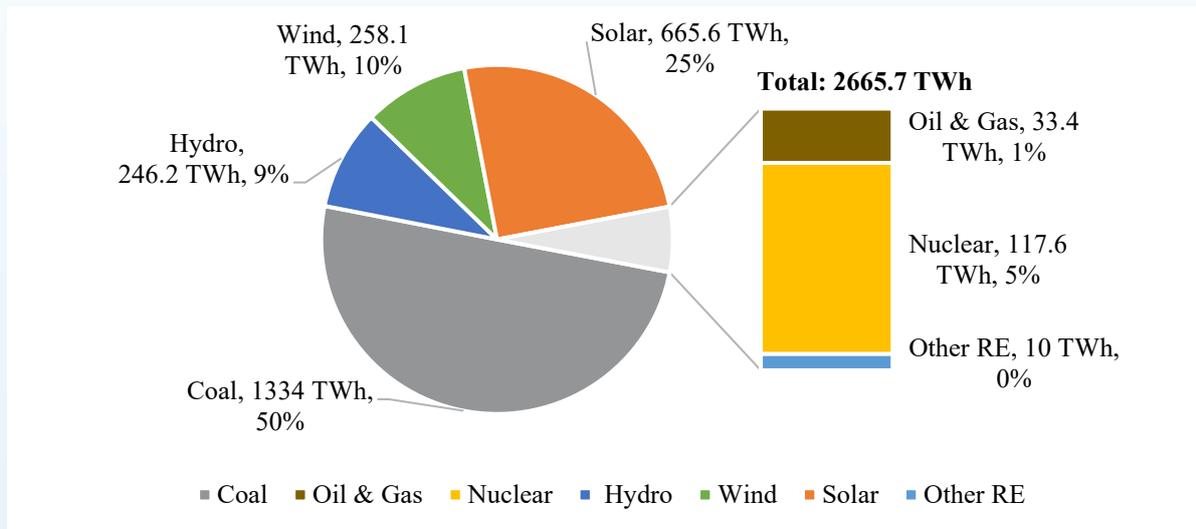


Figure 7 Gross Generation in 2032 (TWh), NEP 2023.

India's journey from Independence in 1947 to the centenary year of 2047 has been the most significant, which **Figure 8** below depicts, highlighting the historical and projected growth in installed power capacity, electricity generation, and per capita energy consumption over these 100 years.

Source: CEA (Growth of Electricity Sector in India from 1947-2022⁹), NEP 2023, TERI¹⁰, IESS 2047 Version 3.0¹¹

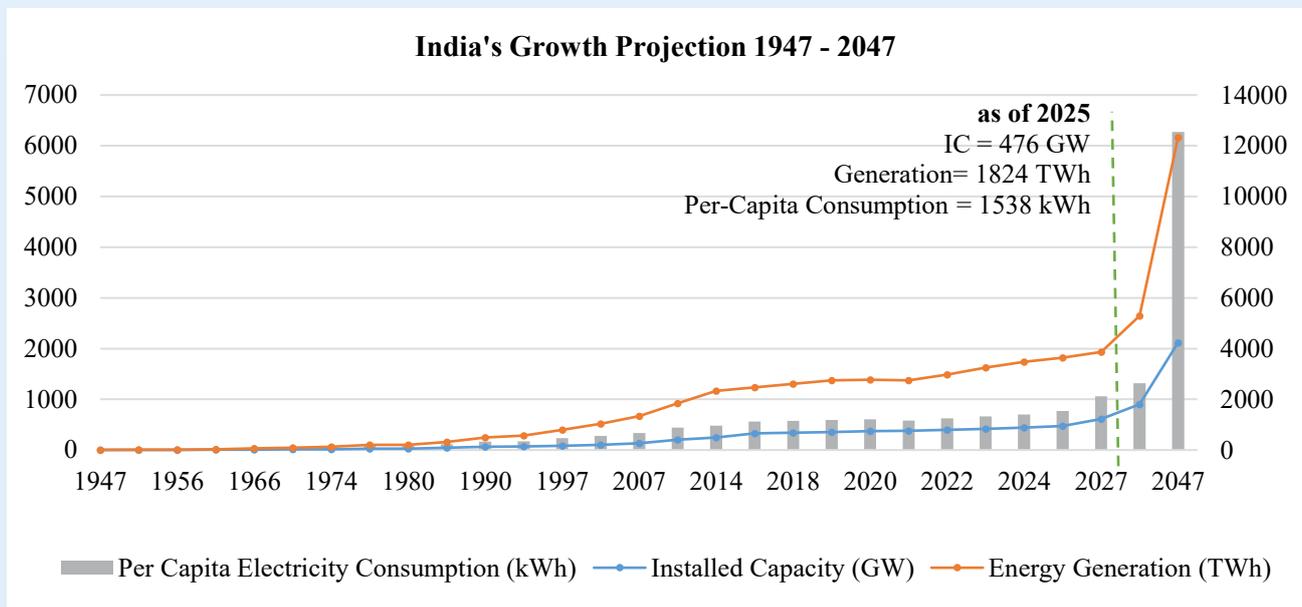


Figure 8 India's Historic Growth and Projection, 1947-2047.

The cleaner generation mix is projected to bring down the average grid emission factor from 0.548 kg CO₂/kWh in 2026-27 to 0.430 kg CO₂/kWh by 2031-32, reflecting a significant reduction in carbon intensity and contributing meaningfully to India's NDC commitments under the Paris Agreement.

1.2 India's Energy Transition: Progress & Imperatives

India's growing prominence in the global clean energy landscape is a testament to its strategic commitment to sustainable development amid rapidly rising energy needs. As the third-largest global energy consumer¹² and the third-largest emitter of greenhouse gases (GHGs), India occupies a pivotal position in the fight against climate change. Its dual identity - as a country with enormous development aspirations and one with vast renewable energy potential - has allowed it to position itself not only as a major beneficiary of the global energy transition but also as a leader helping to shape its direction. According to the NITI Aayog¹³, **Figure 9** illustrates India's power generation mix over the years from FY 2013-14 till FY 2024-25 along with the yearly growth projections.

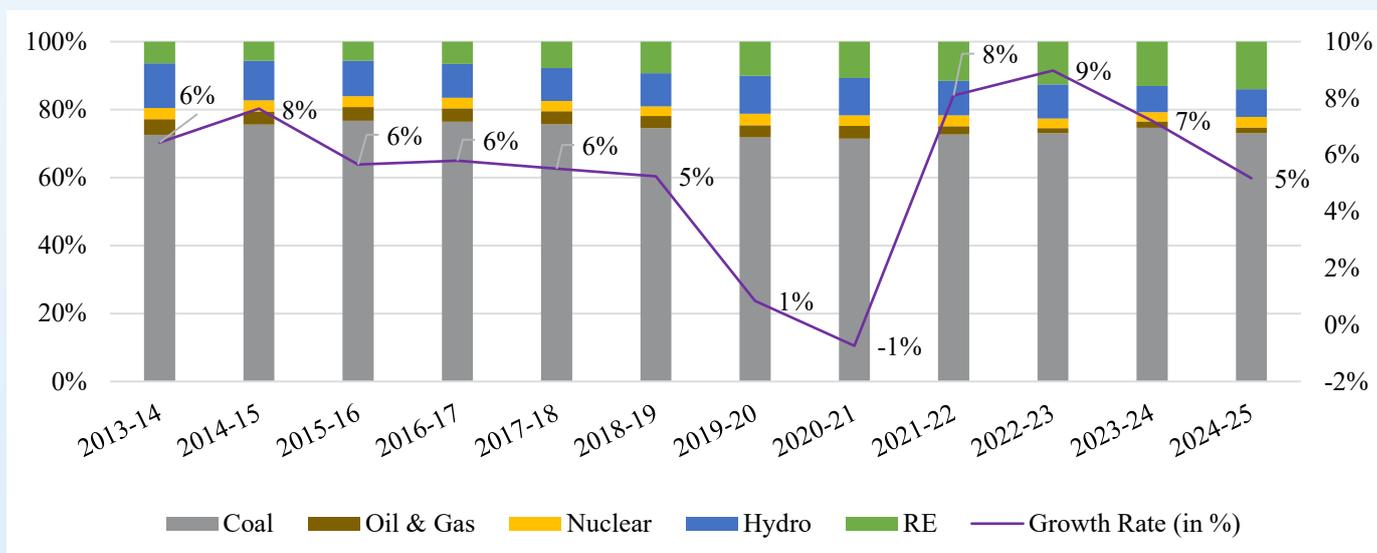


Figure 9 Electricity Generation Mix 2014-2025, NITI Aayog.

Diversification is essential to meet net-zero goals. Over the last decade, India has rapidly climbed the global rankings in renewable energy capacity. According to the 'India Energy Landscape' by the Ministry of Power in June 2025¹⁴, the country stands 4th globally in overall renewable energy installations, 3rd in solar capacity, and 4th in wind power. These numbers are a result of a robust and sustained policy push following the Paris Agreement in 2015¹⁵.

Beyond capacity additions, India has shown global leadership through platforms such as the International Solar Alliance (ISA), which it co-founded to promote solar energy access in the Global South, and the One Sun One World One Grid (OSOWOG) initiative¹⁶, which envisions cross-border solar energy sharing. These initiatives demonstrate India's intent to foster global collaboration in clean energy and reflect its aspiration to emerge as a renewable energy superpower.

- ❖ OSOWOG was launched by India's Prime Minister at the ISA Assembly in October 2018
- ❖ Aims to create a global solar grid under the idea that "The Sun Never Sets"
- ❖ ISA leads implementation: Phase-I study completed and approved
- ❖ A task force (2021) is exploring interconnections with South Asia, Middle East, Africa, and Europe

Despite these achievements, India's emissions footprint remains significant. It contributes approximately 7% of global CO₂ emissions annually. However, contextualizing this value reveals a more balanced narrative:

India’s per capita emissions are just 2 tons per person per year - less than half the global average and far below developed economies like the United States. Furthermore, India’s historical emissions are relatively modest, emphasizing the country’s argument that climate justice and equitable responsibilities must shape the global climate agenda.

The India Energy Security Scenarios (IESS) 2047¹⁷, published by NITI Aayog in 2023 highlights the sectoral analysis in the business-as-usual (BAU) vs. net-zero scenario in India for the year 2047. **Figure 10** captures India’s position and key takeaways.

- By 2047, following the net-zero pathway instead of the BAU scenario is projected to result in a 7% reduction in total energy consumption.
- Energy demand is expected to be 11.30% lower in 2047 under the net-zero pathway compared to the BAU scenario.
- While per capita emission intensity is projected to decline by nearly 50% from 2022 levels, the overall energy supply is expected to triple by 2047 relative to the 2022 baseline along with significant increase in GHG emissions per person.
- These trends underscore the urgency of scaling up energy storage, enhancing grid flexibility, and improving energy efficiency to effectively decouple emissions from growing energy demand.

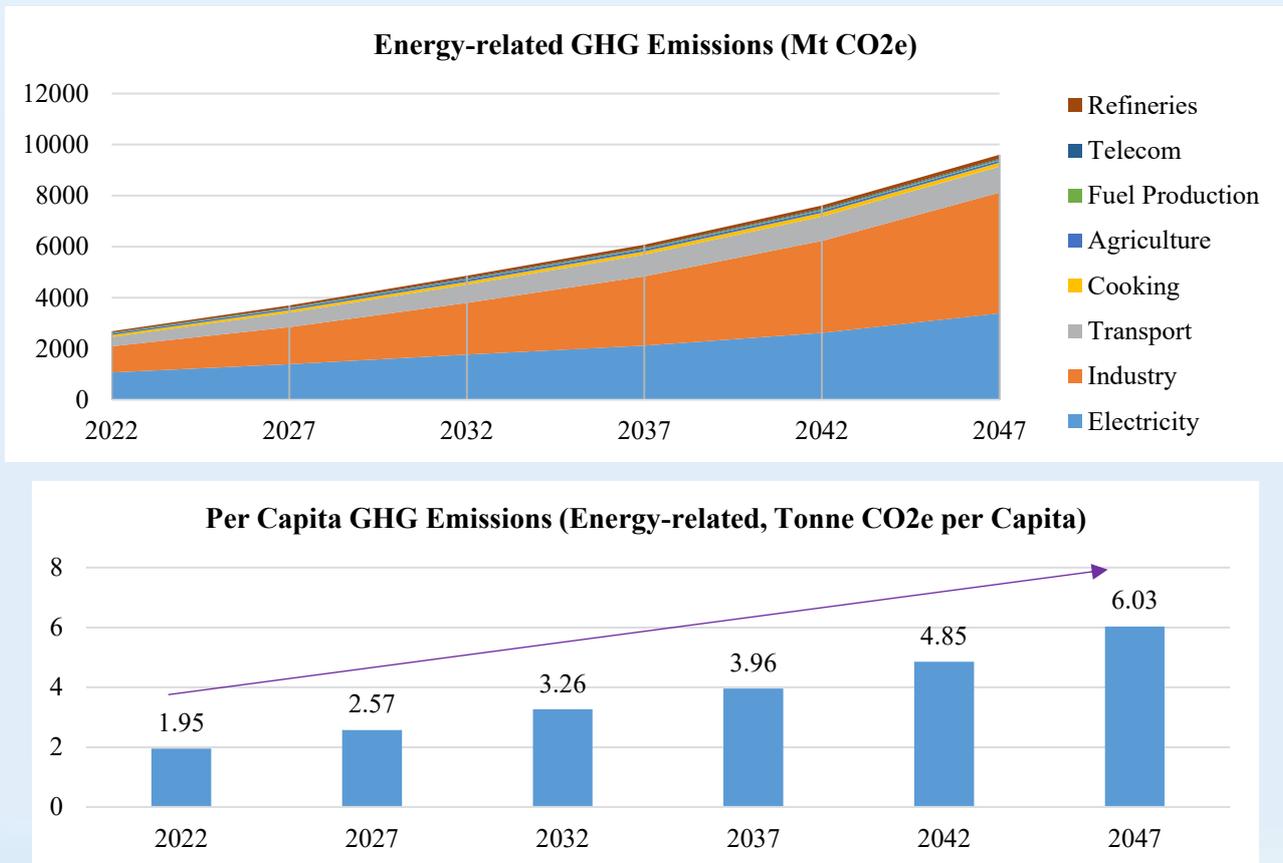


Figure 10 India GHG Emissions Projections vs Per Capita Emissions by 2047, IESS 2047

India’s power sector alone contributes to more than 40% of its GHG emissions, primarily due to its dependence on coal, as per the IMF Working Paper October 2023 report¹⁸. This underscores the importance of

decarbonizing the power sector as a first-order priority in the broader climate strategy. With global ambitions aligned to local needs, India's transition journey offers a critical model for balancing growth and sustainability.

Although India's per capita emissions are among the lowest globally, its status as the third-largest emitter and rising energy demand make decarbonization critical. The country's high vulnerability to climate impacts, floods, droughts, and heatwaves, further underscores the need for urgent action. Decarbonization is thus both a global responsibility and a national imperative for resilience, energy security, and sustainable growth. It presents India with an opportunity to leapfrog to a cleaner, more inclusive energy future, strengthen climate leadership, and ensure long-term intergenerational equity.

1.3. Key Drivers for Renewable Energy Growth

India's energy transition is driven by a confluence of environmental imperatives, developmental needs, and geopolitical realities. As its economy continues to expand - driven by infrastructure development, industrialization and rising urbanization - India's electricity demand is forecasted to more than double by 2040, according to India's Energy Landscape, PiB, June 2025. This makes a sustainable energy pathway not just desirable but essential. Recognizing this, India announced its landmark net-zero commitment at COP26 in Glasgow of the UNFCCC, pledging to achieve carbon neutrality by 2070 and laying out five measurable goals under the "Panchamrit" strategy¹⁹.

This ambitious framework was further detailed in the Long-Term Low Emissions Development Strategy (LT-LEDS) submitted at COP27, which outlines sectoral pathways and the central role of power sector decarbonization in India's broader climate roadmap.

COP3 (1997, Kyoto, Japan):

India supported the Kyoto Protocol, which imposed binding emission reduction targets on developed countries but exempted developing nations like India, emphasizing the principle of "common but differentiated responsibilities" (CBDR).

COP15 (2009, Copenhagen, Denmark):

India was part of the BASIC group (Brazil, South Africa, India, China) that played a pivotal role in shaping the Copenhagen Accord. India agreed to report its voluntary domestic actions for emission intensity reduction, marking its shift toward proactive engagement.

COP21 (2015, Paris, France):

India emerged as a key voice for developing countries, emphasizing climate justice, equity, and the right to development.

- ✔ Submitted its first Nationally Determined Contribution (NDC)
 - ☀ Launched the International Solar Alliance (ISA) with France
 - 🤝 Supported the adoption of the Paris Agreement while securing flexibility for developing nations
-

Five Nectar Elements (Panchamrit) of India's Climate Action, COP-26 at Glasgow

- ⚡ 500 GW of non-fossil energy capacity to be achieved by 2030
 - 😊 50% of total energy requirements to come from renewable sources by 2030
 - 🚫 1 billion tonnes reduction in projected carbon emissions by 2030
 - 📉 45% reduction in carbon intensity of the economy (over 2005 levels) by 2030
 - 🌍 Achieve net-zero emissions by 2070
-

*India submitted its **Long-Term Low Emission Development Strategy (LT-LEDS)** to the UNFCCC at COP27 at Egypt, outlining its vision for low-carbon, sustainable growth while balancing development needs:*

- ⚡ Focus on rational resource use, energy security, and a just transition from fossil fuels
 - 🌱 Green Hydrogen Mission and tripling of nuclear capacity by 2032
 - 🚗 EV adoption, 20% ethanol blending by 2025, and a public transport shift in mobility
 - 🏙️ Smart cities, energy-efficient buildings, and improved urban waste management
 - 🏭 Industrial decarbonization via PAT scheme, electrification, and circular economy
 - 🌳 Forest cover to sequester 2.5-3 billion tonnes of CO₂ by 2030
 - 💰 Calls for scaled-up climate finance; transition to cost trillions by 2050
 - ⚖️ Anchored in climate justice, equity, and India's fair share of the global carbon budget
 - 🌿 Guided by the LIFE mission promoting sustainable lifestyles
-

India has made significant progress toward its 2030 renewable energy target, with around 236 GW of non-fossil capacity already installed - nearly half of total power capacity. Renewable energy's share in electricity generation has risen from 17% in 2015 to over 22% in FY 2024-25. However, the transition is far from complete. The next phase will require not just continued capacity growth, but also major investments in grid flexibility, storage, efficiency, and demand-side solutions. With rising climate risks threatening food, water, and energy security, decarbonizing the power sector is a strategic imperative. It offers environmental gains, strengthens energy security, and creates economic opportunities. The progress so far forms a strong base for building a more ambitious, inclusive, and future-ready energy system.

India's renewable energy landscape has undergone a remarkable transformation over the last 15 years. What began with modest capacity additions in solar and wind has grown into a vast and diversified portfolio of renewable assets. From the **Figure 9**, India's renewable energy capacity (excluding large hydro) has reached approximately 178.8 GW. This includes 110.8 GW from solar, 51.3 GW from wind, and about 16.7 GW from biomass and small hydro.

India's solar power has grown rapidly due to falling costs, strong policy support, and large-scale projects, while wind remains vital in states like Tamil Nadu, Gujarat, and Karnataka. Biomass and small hydro serve niche regional needs. Yet, coal continues to dominate, with 240 GW - around 51% of total capacity - still supplying nearly 70% of electricity. Though newer coal plants use more efficient technologies, this reliance highlights the difficulty of moving away from fossil fuels. Meeting the 2030 target of 500 GW non-fossil capacity will require nearly doubling current renewable capacity, alongside major investments in storage, transmission, and integration. The focus must now shift from merely expanding capacity to ensuring clean energy is reliable, accessible, and resilient.

India's electricity demand has steadily risen due to population growth, urbanization, rising incomes, and industrialization. Per capita consumption jumped from 957 kWh to 1538 kWh over the past decade²⁰, and CEA projects demand to surpass 2,400 BU by 2030, with peak demand exceeding 366 GW²¹, up from ~250 GW in 2025²². Key drivers include rural electrification, sectoral electrification (EVs, electric cooking, agriculture), and new loads like green hydrogen, data centers, and automation. While this growth offers opportunities, it also demands parallel investments in generation, flexible grids, pricing mechanisms, and storage. The shift toward a more interactive power system calls for a coordinated strategy among utilities, regulators, investors, and technology providers.

1.4. Institutional & Regulatory Enablers

India's rapid renewable energy expansion has exposed new challenges in infrastructure, grid management, and policy coherence. The decentralized and intermittent nature of renewables strains a grid built for centralized coal-based power. A key issue is grid readiness - most renewable energy is generated in remote states like Rajasthan, Gujarat, and Tamil Nadu, far from demand hubs. While GEC Phases I and II²³ have added over 30 GW of capacity, more transmission lines, substations, and advanced control systems are urgently needed. Adoption of AI-driven forecasting and SCADA tools remains limited. Land acquisition delays, unclear policies, and environmental clearances continue to hinder project timelines. Additionally, rooftop solar faces persistent barriers due to restrictive net metering, banking limitations, and frequent policy reversals, especially in states with financially weak DISCOMs.

- ❖ *Land acquisition takes 6–12 months or more, delaying RE projects*
- ❖ *Complex laws and varying procedures across states and land types add to the challenge*
- ❖ *Key states like Rajasthan and Jammu & Kashmir lack clear land policies despite having suitable wastelands*
- ❖ *Kerala, Assam, and Punjab also face land-related issues*
- ❖ *Grid proximity is crucial for land suitability*
- ❖ *Rising competition for viable land is pushing up capital costs*

India is experiencing a surge of policy measures that are fostering a more flexible, dispatchable, and investment-friendly clean energy ecosystem. Key developments include:

- ✓ **ISTS Charge Waiver extended till 2030** for solar, wind, hybrid, PSP, BESS, and hydrogen/ammonia projects (*June 2025*)
- ✓ **VGF Support Tranche-II** (*June 2025*), **Tranche-I** (*Revised April 2025*)
- ✓ **Scales Up PLI Budget** to Accelerate ACC Battery Manufacturing (*March 2025*)
- ✓ **Amended TBCB Guidelines** to allow flexible power procurement from wind-solar hybrid projects (*February 2025*)
- ✓ Advisory on **Co-locating minimum 2-hr ESS** with Solar PV projects (*February 2025*)
- ✓ Notification of **Energy Storage Obligation** Trajectory till 2029-30 (*July 2022*)
- ✓ Issuance of **Standard Bidding Guidelines for BESS** (*March 2022*)
- ✓ Clarification on **ESS usage in Various Applications of Power Sector Value Chain** (*January 2022*)
- ✓ Notification of **Ancillary Services Regulations, 2022** (*January 2022*)

Together, such policy measures reflect a deliberate shift towards enabling integrated, dispatchable, and low-carbon power generation while strengthening investor confidence and accelerating the transition to a resilient, sustainable energy future.

1.5. Innovation, Decentralization, and Inclusive Energy Access

The financing of India's energy transition is both a massive opportunity and a complex undertaking. According to the World Energy Investment 2025 by IEA²⁴, India will require an estimated USD 1.3 trillion in clean energy in cumulative investments to 2035, nearly 60% of which must flow into RE generation, grid infrastructure, and ESS. Given the scale, the financing must come from a mix of public funding, private capital, multilateral agencies, and green financial instruments.

As per IBEF estimates, India is projected to invest over US\$ 360 billion in renewable energy and supporting infrastructure by 2030. Of this, US\$ 190-215 billion will be required to reach the 500 GW renewable capacity target, while an additional US\$ 150-170 billion will be needed for transmission and storage²⁵. The sector has already proven its strong appeal to investors. Between FY 2022-23 and FY 2024-25, the Government of India raised ₹57,697 crore through Sovereign Green Bonds (SGrBs)²⁶. According to the FY 2022-23 Allocation Report, around 21% of these proceeds were directed toward renewable energy projects, highlighting the government's commitment to clean power transition.

Budget allocations by the Government of India also reflect growing financial prioritization. In the Union Budget 2025-26, the government allocated:

- **Overall MNRE budget** surged from ₹7,929 Cr in 2023-24 to ₹26,549 Cr.
- **Solar sector** climbed from ₹6,268 Cr to ₹24,224 Cr, driven by scaled-up PM Surya Ghar benefits.
- **Wind and other renewables** saw a slight decline to ₹551 Cr, with wind grid allocations specifically cut to ₹500 Cr.
- **Green Hydrogen Mission** gets boosted to ₹600 Cr for FY 2025-26, up from ₹300 Cr (revised).
- **Bio-energy** funding rose to ₹325 Cr, and green corridors stayed steady at ₹600 Cr.
- **Support programs**, including R&D and capacity building, nearly tripled in two years.

Institutions like the World Bank, AIIB, ADB, USAID, and GCF have supported India's RE expansion with concessional loans and guarantees for transmission upgrades, distributed solar, and municipal energy projects. However, financial risks remain due to DISCOM payment delays, policy uncertainty, and transmission bottlenecks. To attract sustained capital aligned with climate goals, the sector requires long-tenure financing, currency hedging tools, and de-risking instruments such as payment security mechanisms, VGF, and pooled procurement models. In this context, the Government of India has launched two VGF tranches for BESS, each with specific targets, subsidy frameworks, and timelines.

VGF – Tranche I (Cabinet Approved in September 2023, Revised in April 2025)

- Targets development of 13,200 MWh of BESS capacity by 2030–31 (up from 4,000 MWh)
- Applicable to co-located or standalone BESS projects
- Offers central financial support of up to 30% of capital cost or ₹46 lakh/MWh (revised from ₹96 lakh/MWh)
- Total outlay of ₹9,400 crores, including ₹3,760 crores as budgetary support
- Projects must be commissioned within 24 months from the date of agreement signing

VGF – Tranche II (June 2025)

- Supports 30 GWh of standalone BESS projects
- Offers a fixed subsidy of ₹1.8 million/MWh
- 25 GWh allocated across 15 states and 5 GWh through NTPC using existing infrastructure
- Projects to be procured through competitive bidding (BOO/BOOT model for 12–15 years)
- Preferred system configuration: 2-hour discharge with ~1.5 cycles/day
- Project commissioning required within 18 months from PPA signing
- Subsidy disbursement: 20% at financial close, 50% at COD, and 30% after one year

India’s renewable energy push is increasingly shaped by decentralized, inclusive programs fostering innovation and equity. The PM-Surya Ghar: Muft Bijli Yojana (2024) targets 30 GW rooftop solar for 1 crore households with ₹75,021 crore support, aiming to generate 1 lakh crore units and avoid 720 MMT CO₂. The PM-KUSUM Scheme advances solar in agriculture with a 34.8 GW target across solar pumps and decentralized plants, having deployed over 7.7 lakh pumps by March 2025. Solar Parks continue to facilitate utility-scale deployment, while the ₹24,000 crore PLI Scheme has driven 17 GW module and 6 GW cell manufacturing. For remote areas, PM JANMAN is electrifying 1 lakh tribal households via off-grid solar, with 2,057 households already reached.

India Energy Stack (IES) - June 2025

- **Launched by** Ministry of Power to digitize the power sector, support RE integration, DISCOM efficiency, and consumer services.
- **Features:** Unique IDs, real-time data sharing, open APIs for seamless integration
- **Implementation:** 12-month PoC with UIP pilots in Mumbai, Gujarat, and Delhi; guided by a task force
- **Outcomes:** IES White Paper and national rollout roadmap

Technological advancements are opening new avenues in India’s energy transition. Smart meters, AI forecasting, blockchain trading, and cloud-based analytics are enhancing efficiency and demand response. Innovations like green hydrogen, agrivoltaics, floating solar, and hybrid RE-storage systems are scaling up

with policy support and R&D. India is also pushing biofuels, ethanol blending, flex-fuel vehicles, and aims to produce 5 MMT of green hydrogen annually by 2030, as reaffirmed at IEW 2025²⁷. These efforts reflect a broader decarbonization agenda across sectors. Through such innovations, India is fostering a grassroots RE-evolution, empowering citizens as prosumers and linking clean energy to rural development, gender equity, and resilience.

1.6. Objective, Relevance, and Structure of the Theme Paper

India's journey toward a low-carbon future is at once an environmental necessity, an economic opportunity, and a developmental imperative. At the heart of this transition lies the power sector, which, due to its high carbon intensity and systemic centrality, holds the greatest potential for emission reductions. Renewable energy, therefore, is not simply a supplementary source - it is the fulcrum of India's RE-evolution toward a cleaner, more resilient energy future.

The transition underway in India is holistic. It spans utility-scale and decentralized systems, legacy infrastructure and cutting-edge innovation, domestic policy and global diplomacy. It is shaped by complex trade-offs between cost, reliability, equity, and environmental sustainability. However, what is increasingly clear is that India's choices in the energy sector - its policies, investments, and institutional frameworks - will have global ramifications in the race to limit warming to 1.5°C.

This theme paper sets out to explore these interconnected dimensions. Through the chapters that follow, it will examine key areas including Make in India, land acquisition, connectivity and power evacuation, and financing mechanisms. It will also delve into critical integration challenges such as energy storage and hydrogen, planning and state-level issues, flexibility in grid operations, and the development of the Green Energy Corridor. Furthermore, it will investigate emerging innovations - such as rooftop and floating solar, peer-to-peer trading, virtual net metering, biogas, and agrivoltaics - and their role in advancing a climate-resilient and energy-secure future.

By integrating evidence, examples, and projections, the paper aims to provide an informed, balanced, and forward-looking perspective on how renewable energy can transform India's power sector into a cornerstone of national and global decarbonization.

Accelerating Renewable
Energy Deployment -
**CHALLENGES
AND SOLUTIONS**



India's power sector stands at a pivotal juncture in 2025, balancing rising electricity demand with the need for accelerated decarbonization. As of June 2025, the country's total installed electricity generation capacity has reached approximately 476 GW, of which nearly 236 GW (49.5%) comes from non-fossil sources solar, wind, hydro, nuclear, biomass, and waste-to-energy. This aligns with MNRE's stated goal of achieving 500 GW of non-fossil installed power capacity by 2030, as part of India's updated Nationally Determined Contribution on climate action.

Despite this diversification, India's electricity generation remains dominated by coal, which continues to contribute around 70-72% of actual generation, especially during peak periods. This heavy reliance on coal is a key reason why the power sector accounts for 33-35% of India's total GHG emissions as of 2025.

Rapid electrification of transport, digitization of services, and growth in industrial activity are pushing electricity demand higher, with 2025 consumption estimated to exceed 1,750 BUs. India's per capita electricity consumption has reached 1,538 kWh, showing a steady upward trajectory but still below the global average, suggesting significant headroom for growth.

At the same time, transmission infrastructure has expanded, and AT&C losses have declined gradually but remain a challenge, especially in certain states. India's Long-Term Low LT-LEDS, submitted to the UNFCCC, positions the power sector as the anchor for achieving net-zero emissions by 2070, with intermediate targets focusing on renewable energy scale-up, energy efficiency, and storage deployment.

This chapter offers a status update on:

- Electricity consumption patterns
- Power generation and infrastructure trends
- India's progress toward a net-zero aligned power system

Source: Load Generation Balance Report (LGBR) 2025-26²⁸, NITI Aayog - India Energy Security Scenarios (IESS) 2047²⁹ - Updated Dataset (2025)

2.1. Make in India and Domestic Manufacturing

India's renewable energy transition depends not only on expanding generation capacity but also on building a robust domestic manufacturing ecosystem. The "Make in India" initiative, aligned with the Aatmanirbhar Bharat vision, aims to strengthen self-reliance in critical technologies such as solar PV modules, wind turbine components, advanced batteries, and power electronics. While targeted incentives and market-linked obligations have boosted solar module and cell production, upstream inputs like polysilicon, wafers, and metallisation pastes remain import-dependent. In wind, India retains a moderately strong domestic base but still relies on global OEMs for advanced turbine designs and larger capacity models.

As grid flexibility becomes vital, manufacturing gaps in emerging technologies are evident. A key example is Variable Speed Pumped Storage Plants (VS-PSPs), essential for balancing renewable intermittency. Despite several PSP projects announced in states like Maharashtra and Himachal Pradesh, India lacks domestic capability to produce variable-speed drives and converter systems, relying instead on European and East Asian suppliers. Addressing these gaps will require parallel development of ancillary manufacturing capabilities alongside generation technologies. The following sections examine key policy instruments driving RE manufacturing, highlighting their impacts, limitations, and future pathways.

2.1.1. Policy Support for Indigenous Manufacturing

India's flagships push for clean energy manufacturing has revolved around two major schemes:

1. PLI Scheme - Solar PV Manufacturing.
2. PLI Scheme - Advanced Chemistry Cell (ACC) Batteries.

PLI Scheme for Solar (Tranche I & II)

Launched by MNRE and implemented through SECI and IREDA, the solar PLI scheme is designed to catalyse vertically integrated manufacturing of high-efficiency modules.

- **Tranche I (2021)** allocated ₹4,500 crore, awarding around 8.7 GW of capacity across three manufacturers.
- **Tranche II (2023)** scaled up support to ₹19,500 crore, targeting around 39.6 GW of manufacturing capacity across the solar value chain including polysilicon, wafers, cells, and modules.

As shown in **Figure 11**, the PLI scheme has anchored significant solar module capacity additions across India. As of mid-2025, over 25 GW of PLI-awarded capacity is under construction, with commissioning expected between 2025 and 2027.

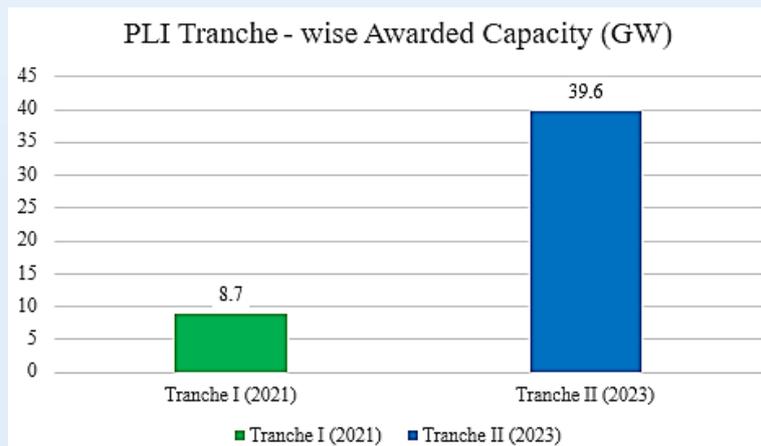


Figure 11 Solar PV Manufacturing Capacity Awarded under PLI Scheme (as of 2025).

PLI Scheme for ACC Batteries

Approved in 2021 by the Department of Heavy Industries, this scheme targets 50 GWh of battery storage capacity with an outlay of ₹18,100 crore. Beneficiaries include Reliance New Energy, Ola Electric, Rajesh Exports, and others. These projects aim to localize the production of lithium-ion cells for EVs and grid storage. Initial production is expected to begin by late 2025 or early 2026³⁰.

Other Policy Enablers

- **Basic Customs Duty (BCD)³¹**: 40% duty on imported modules and 25% on imported cells (effective from April 2022) to protect Indian manufacturing.
- **Viability Gap Funding**: Used selectively for niche technologies such as BESS, round-the-clock RE bids, and offshore wind.
- **State Industrial Policies**: Gujarat, Tamil Nadu, Andhra Pradesh, and Maharashtra offer capital subsidies, SGST reimbursements, and plug-and-play zones for RE manufacturers. These policy

mechanisms have created early momentum, but there is a need for better synchronization between financial incentives and demand certainty. For example, PSP developers seeking to adopt variable-speed configurations continue to face uncertainty due to lack of local suppliers, the absence of economies of scale, and insufficient R&D in heavy electrical machinery. Unless addressed, such gaps could create long-term strategic dependencies even as solar and wind manufacturing mature.

2.1.2. Domestic Content Requirements (DCR) and PLI Scheme

India's domestic content policies have played a strategic role in anchoring early demand for locally manufactured solar equipment. In the absence of large-scale export markets for Indian modules and cells, DCR-based procurement schemes have provided a steady, albeit limited, foundation for industrial capacity utilization.

DCR Frameworks in Operation (2025)

In 2025, the key policy levers sustaining domestic demand for solar components under India's DCR framework are CPSU (Central Public Sector Undertaking) Scheme Phase-II and PM-KUSUM (Components B & C), both mandating use of Indian-made modules, and in some cases cells, for government-backed projects.

Under CPSU Phase-II (12 GW target), about 8.9 GW has been awarded and 5.4 GW commissioned, primarily by public entities like NTPC, NHPC, SECI, and SJVN, which have helped stabilize domestic demand amid global price fluctuations. Similarly, PM-KUSUM has sanctioned 3.2 GW of decentralized solar capacity since 2020, with 1.7 GW operational, implemented largely by state nodal agencies, DISCOMs, and smaller EPC players in rural markets.

While both schemes provide crucial demand signals, they face challenges such as small project sizes, delayed subsidies, and uneven state-level execution. Still, for Tier II/III manufacturers, DCR-linked procurement remains vital for maintaining order-book stability where export orders are limited.

Linkage Between DCR Obligations and PLI Awardees

There is now a clearer convergence between DCR programs and PLI beneficiaries. The MNRE has clarified that projects implemented under DCR obligations can preferentially source from PLI beneficiaries, thereby strengthening capacity utilization for newly awarded units under PLI Tranche I and II.

As per industry disclosures:

- PLI awardees (e.g., Reliance, ReNew, First Solar, Waaree) have committed to producing high-efficiency TOPCon (Tunnel Oxide Passivated Contact), HJT (Heterojunction Technology), and bifacial modules.
- CPSU and KUSUM projects are gradually being encouraged to adopt these higher-efficiency technologies to align with the government's long-term vision of phasing out polycrystalline standards.

The PLI scheme is thus influencing technology stack upgrades across the domestic market, pushing developers to shift from conventional multi-PERC to TOPCon (Tunnel Oxide Passivated Contact) and HJT (Heterojunction Technology) modules. This is particularly relevant given India's plans to participate in global markets where such technologies are becoming the norm.

Technology Adoption Trends (2025)

Figure 12 is the technology mix infographic showing planned solar manufacturing capacities (in GW) by module type under India's PLI Scheme as of 2025. Some key highlights are:

- Mono PERC and Bifacial modules still dominate.
- TOPCon is gaining momentum due to better efficiency and PLI alignment.
- HJT is emerging, led by vertically integrated entrants like Reliance.

Source: MNRE PLI notifications (Tranche I & II), SECI bidding results, and public disclosures from PLI awardees (2023-25)

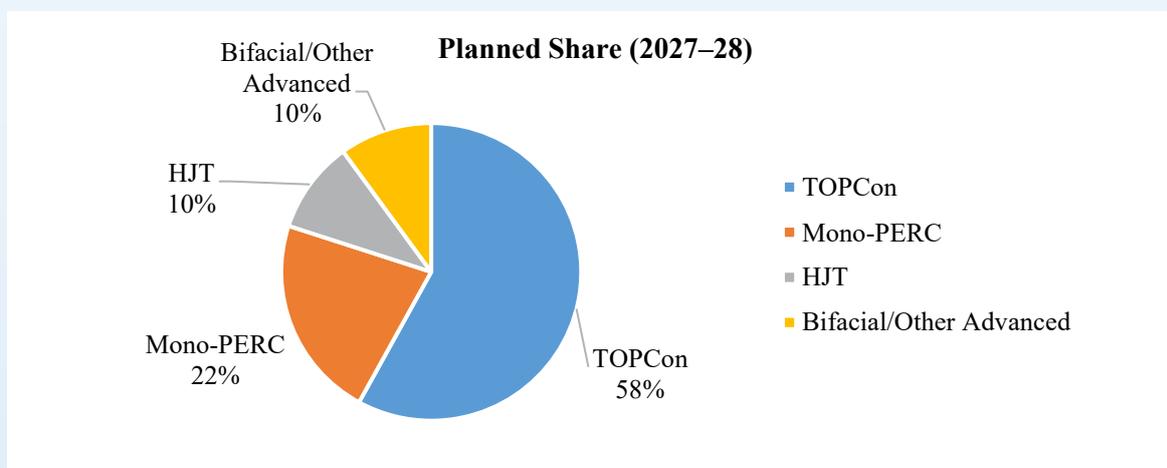


Figure 12 Planned Manufacturing Capacity by Solar Technology Type India.

2.1.3. Solar and Wind Equipment Manufacturing Ecosystem

India's manufacturing ecosystem for renewable energy components has expanded considerably over the last decade, particularly in solar PV and wind turbine segments. However, the structure, scale, and technological depth vary significantly between the two sectors.

In the solar segment, India's installed manufacturing capacity spans across modules, cells, inverters, junction boxes, and mounting structures. As of 2025, module manufacturing capacity has exceeded 50 GW, with around 20 GW of integrated cell capacity operational or under commissioning. However, upstream integration into polysilicon and wafer production remains limited, with most players dependent on imports, especially from China and Southeast Asia, for these critical inputs. Companies like Adani, Waaree, ReNew, and Reliance have initiated projects to vertically integrate the value chain, but full self-sufficiency is still a few years away. **Figure 12** illustrated the distribution of planned manufacturing capacity by technology type, highlighting the shift toward high-efficiency modules. In wind manufacturing, India enjoys a relatively stronger domestic base.

India has developed strong domestic capabilities in wind equipment manufacturing, with global and local OEMs like Vestas, Siemens Gamesa, GE, Suzlon, and Inox Wind operating multiple units across Tamil Nadu, Karnataka, Gujarat, and Maharashtra. Blade and nacelle clusters are typically located near port cities to ease transport challenges, especially for turbine blades exceeding 100 meters in length. Despite this progress, the sector faces challenges due to low auction tariffs, reduced pipeline visibility, and fragmented procurement, leading to underutilized capacity. The transition to larger 3-5 MW turbines also demands retooling, which many domestic players are not financially equipped to undertake. Additionally, while India is scaling up PSPs

for firm power, it lacks domestic manufacturing for essential variable-speed technology. Equipment like variable speed drives, motor-generator sets, and power converters continue to be imported, primarily from Europe, raising costs, timelines, and supply chain risks. To scale and future-proof its renewable manufacturing base, India must invest in upstream integration, advanced R&D, and develop capabilities in grid-supportive technologies such as PSP equipment, advanced inverters, and hybrid power electronics.

2.1.4. Supply Chain and Raw Material Dependencies

While India has made tangible progress in scaling up solar and wind equipment manufacturing, it remains significantly dependent on imported raw materials and sub-components, especially for upstream inputs that are highly specialized and capital-intensive to produce. This dependence introduces both cost volatility and geopolitical risk into the supply chain, particularly as global demand for clean energy technologies accelerates.

In the solar value chain, over 90% of polysilicon, wafers, and metallization pastes are imported, predominantly from China, Taiwan, and South Korea. Despite India's ambitious PLI-linked vertical integration goals, there is currently no domestic polysilicon production facility operational at a commercial scale. Wafer slicing, another energy-intensive and technology-sensitive step, is also fully import-reliant. These upstream components account for roughly 35-40% of the module cost, exposing Indian manufacturers to both foreign exchange fluctuations and trade disruptions. **Table 1** presents the installed manufacturing capacities in India across key segments - solar modules, solar cells, ingots/wafers, and BESS - highlighting the country's growing commitment to scaling up domestic capabilities in clean and emerging technologies.

Table 1 India's Current Manufacturing Capacity.

Manufacturing Segment	Installed/Commissioned Capacity
Solar Module Manufacturing	74 GW
Solar Cell Manufacturing	25 GW
Ingot/Wafer Manufacturing	2 GW
BESS Manufacturing Capacity	5 GWh

India has achieved significant strides in domestic manufacturing, the module capacity nearly doubled from 38 GW to 74 GW between March 2024 and March 2025, while cell production tripled, reaching 25 GW in the same period. Launching the country's first ingot-wafer facility (2 GW) marks a foundational step toward vertical integration³².

In the energy storage segment, the new 5 GWh BESS plant at Bangalore's Bidadi SEZ³³, backed by VGF support, reflects early-stage efforts to build domestic battery manufacturing. However, with India hosting only ~5 GWh of installed capacity and projected at tens of GWh per year, substantial scale-up remains critical.

Key drivers for capacity enhancement include:

- PLI-linked investments targeting high-efficiency cell technologies (TOPCon, HJT).
- Giga-complexes like Reliance's Jamnagar and SAEL's 5 + 5 GW plant in Greater Noida, collectively adding ~10 GW module/cell output³⁴.
- Policy support through ALMM (Approved Lists of Models and Manufacturers of Solar) and MNRE/CEA guidelines for module procurement.
- Inflows of VGF incentives for BESS deployment targeting 30 GWh by 2030-31.

To reduce supply chain dependencies, India must rapidly scale up ingot-wafer manufacturing (currently at 2 GW), expand battery cell production, and develop domestic mineral processing capabilities. Enhancing PLI schemes, offering stronger state-level incentives, and linking joint venture benefits to local sourcing can better align domestic manufacturing with clean tech goals and reduce reliance on imports. In wind manufacturing, while towers, blades, and nacelles are largely produced domestically, critical components like rare earth magnets, high-grade epoxy resins, and precision gears for large turbines (3 MW+) are still imported. Similarly, India’s battery storage sector - especially lithium-ion - relies heavily on imported raw materials like lithium, cobalt, and nickel.

Despite PLI-backed cell manufacturing, companies remain dependent on global supply agreements. To address this, India has signed MoUs with Australia, Argentina, and Chile for mineral access and is developing processing hubs in Odisha, Gujarat, and Rajasthan, though these efforts remain in early stages of commercialization. **Figure 13** highlights India’s critical supply chain dependencies for renewable energy components.

A notable government response to this vulnerability is the National Critical Minerals Strategy (2023-2047)³⁵, which outlines domestic resource mapping, overseas acquisition plans through Khanij Bidesh India Ltd. (KABIL), and incentives for battery recycling. In addition, circular economy approaches such as solar panel and EV battery recycling are beginning to gain policy traction, with pilot initiatives led by Recyclekaro, Attero, and several Indian startups.

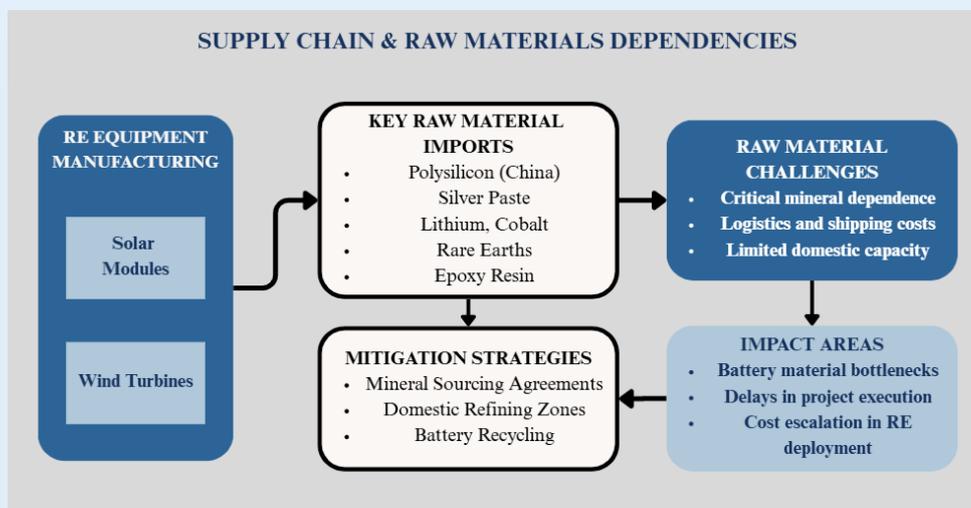


Figure 13 Supply Chain & Raw Materials Dependencies.

Logistics is another structural factor impacting manufacturing viability. High freight costs, inadequate multimodal connectivity to ports, and congestion at SEZ-bound customs points delay equipment movement. The global container shortage in 2021-22 exposed the fragility of Indian module and cell exports, prompting developers to push for localizing not just manufacturing but also bulk materials and electronics.

As India seeks to become a global manufacturing hub for RE technologies, addressing raw material bottlenecks whether through domestic production, recycling, or trade diversification will be critical. These efforts must be accompanied by institutional coordination between MNRE, Ministry of Mines, DPIIT, and industry consortia to de-risk the supply chain.

2.1.5. Role of MSMEs and Startups in RE Manufacturing

India's renewable energy manufacturing ecosystem includes not just large players but also MSMEs and startups that contribute significantly to value addition and innovation. MSMEs, located in clusters like Pithampur, Bhiwadi, Noida, and Pune, manufacture key Balance of System (BoS) components - such as mounting structures, transformers, junction boxes, and safety gear - and supply them to EPCs and OEMs. However, their scale-up is limited by challenges like working capital constraints, lack of certification facilities, and export intelligence.

Simultaneously, energy startups are driving innovation in areas such as AI-based diagnostics, lithium storage systems with integrated BMS, remote asset management, and battery recycling. Companies like BatX Energies, Ecofy, and ExactSpace are already piloting solutions and scaling via tech licensing and joint ventures.

To support these players, government initiatives like SIDBI's Term Loan Scheme, MNRE's Innovation Challenge, and state-level incubation centers in Karnataka, Telangana, and Gujarat have been launched. While progress is visible, further streamlining of funding access, mentorship, and integration into large-scale procurement systems is essential for broader impact.

2.1.6. Challenges in Scaling and Competitiveness

Despite significant progress through policy incentives and industrial commitments, India's renewable energy manufacturing ecosystem continues to face structural and systemic challenges that limit its ability to scale rapidly and compete globally. These issues are especially pronounced when compared to entrenched supply chains in countries like China, which dominate global markets through aggressive pricing, integrated production, and state-backed financing.

Cost Structure and Scale Disadvantage

Indian manufacturers remain at a cost disadvantage of 15-25% compared to Chinese peers across key segments such as solar modules, cells, and lithium battery packs. This is primarily due to smaller economies of scale, higher input costs (owing to raw material imports), higher financing costs, and lower capacity utilization. For instance, while China's top module producers operate at unit costs below 18 cents per watt, Indian Tier I manufacturers report average costs closer to 22-24 cents per watt³⁶. This differential is further exacerbated by supply chain disruptions and currency volatility.

Technology Gaps and Quality Standards

India's manufacturing competitiveness is further constrained by a lag in adopting the latest technologies. While global markets are shifting toward TOPCon, HJT, tandem cells, LFP and sodium-ion chemistries in storage, Indian facilities remain heavily reliant on Mono PERC modules and conventional lithium-ion (NMC) formats. In wind, the shift toward high-capacity (3.5-5 MW) turbines is limited to a handful of joint ventures, with most domestic facilities yet to retool for these platforms.

Quality compliance is another concern. A significant share of low-cost modules and BoS components fail to meet international certification benchmarks (e.g., UL, IEC, BIS). This affects the bankability of Indian-manufactured equipment in global tenders, curbing export opportunities.

Workforce and Skills

Advanced manufacturing of clean energy components requires precision engineering, electronics, material science, and mechatronics skills that are still underdeveloped in India's workforce. While the Skill Council for Green Jobs (SCGJ) and state ITIs offer foundational courses, there is a lack of specialized technical training in areas like electrochemistry (for batteries) and power electronics (for inverters and drives). This talent gap affects both productivity and process control in the next-generation manufacturing units.

Access to Affordable Capital

Indian clean energy manufacturers face steep financing costs often exceeding 10-12% for working capital compared to sub-5% credit lines available to Chinese competitors. Venture capital for hardware-based climate tech startups remains limited, with investors preferring software-heavy solutions. Banks remain conservative in lending to capital-intensive segments like solar polysilicon, wafer slicing, or battery cell production, due to long gestation and perceived technology risks.

Strategic Interventions for Scaling

To enhance the scale, quality, and competitiveness of domestic RE manufacturing, the following interventions are essential:

1. **Market Aggregation:** Consolidated procurement models (e.g., bulk orders through SECI, CPSUs, and DISCOMs) can provide demand certainty, help manufacturers plan capex and improve utilization rates.
2. **Global Technology Partnerships:** India should facilitate joint ventures and licensing agreements with global leaders in advanced solar, wind, and battery technologies to bring high-efficiency designs and process know-how into domestic supply chains.
3. **Public-Private R&D Platforms:** Government-funded research clusters linking PSUs, academia (IITs, NITs), and startups should focus on accelerating indigenization of upstream components (e.g., wafer tech, battery chemistry, variable-speed drives for PSPs).
4. **Support for Legacy Units:** Policy-driven financial and technical assistance programs can help upgrade older units with modern production lines, automation tools, and quality assurance labs. This could be modelled on the lines of the FAME or M-SIPS programs but tailored for RE manufacturing.
5. **Green Finance Channels:** Creating green credit lines, blended finance mechanisms, and risk-sharing instruments under SIDBI, IREDA, and India Exim Bank can ease capital access for MSMEs and mid-sized manufacturers seeking scale.

2.2. Land Acquisition and Regulatory Bottlenecks

Scaling up utility-scale RE deployment depends on timely access to land and simplified clearance processes. This section examines land-related hurdles like availability, acquisition, environmental clearances, and social resistance with an emphasis on decentralized policy responses.

2.2.1. Land Identification and Availability for RE Projects

The availability of suitable land is a foundational precondition for large-scale RE deployment in India. While India's theoretical solar potential exceeds 750 GW, and wind potential surpasses 300 GW at 120m hub height (NIWE), the actual realizable capacity is sharply constrained by land-use pressures³⁷, fragmented tenure systems, and regulatory opacity. Most utility-scale RE projects require contiguous tracts of non-agricultural,

low-productivity land, preferably near grid infrastructure conditions that are increasingly difficult to meet in densely populated states.

Estimates suggest that to meet India's 2030 target of 500 GW non-fossil capacity, an additional 50,000-60,000 hectares of land would be required for ground-mounted solar alone, given the land-intensive nature of such projects, not accounting for wind, BESS, or transmission corridors. These land demands frequently intersect with multi-layered ownership patterns, revenue records with unresolved encumbrances, and ecological sensitivities necessitating a structured and anticipatory land identification framework.

Use of GIS and Spatial Tools

India has begun leveraging spatial intelligence for site screening. The RE Resource Assessment Portal (REMap), developed by NREL and MNRE, overlays solar irradiance, wind speed, topography, forest boundaries, transmission proximity, and land-use categories. As of 2025, REMap includes high-resolution datasets for solar and wind potential across 1 km² grids, aiding central and state planners in identifying viable project zones. Additionally, state GIS portals such as Rajasthan's Bhulekh RE interface and Karnataka's Bhoomi system are integrating RE-specific zoning overlays. These tools are vital for reducing speculative land acquisition, improving transparency in site selection, and shortening pre-bid evaluation windows for developers.

Land Acquisition Models in Practice

Multiple acquisition and facilitation mechanisms are currently being deployed across India's RE landscape including:

- **Government-facilitated land** through public solar parks remains the most streamlined route. SECI and state nodal agencies (like RRECL, GUVNL) aggregate land, provide clearances, and offer plug-and-play infrastructure. Examples include Bhadla (Rajasthan), Pavagada (Karnataka), Dholera (Gujarat).
- **Revenue-sharing and lease models** are gaining prominence, where landowners retain ownership while leasing parcels for 25-30 years. Andhra Pradesh and Maharashtra have piloted such approaches, offering annualized payments indexed to inflation.
- **Land pooling mechanisms**, inspired by urban planning models (e.g., Amaravati Capital Region), are being explored for large solar parks, wherein multiple landowners contribute land and receive proportionate revenue or equity in the RE project.
- **Private-led acquisition** remains an option but faces challenges due to legal risks, consent barriers, and time-consuming mutation processes.

A hybrid model combining government facilitation with voluntary lease has emerged as a promising approach, particularly in politically sensitive or tribal regions where outright land purchase is likely to trigger resistance.

2.2.2. Land Policies and Approvals

The facilitation of land for renewable energy deployment in India is fragmented, as land is a state subject under the Constitution. This leads to inconsistent processes and varying timelines across the country, increasing project uncertainty and cost of capital. At present, there is no unified national mechanism tailored to RE needs, and developers must navigate multiple state-level agencies for clearances, land-use conversions, and tenure regularization.

To address these challenges, there is a growing need for a national land facilitation framework that would

- Provide standardized templates for lease agreements, consent forms, and revenue-sharing mechanisms.
- Establish a centralized RE land repository with GIS overlays for grid connectivity and biodiversity buffers.
- Harmonize Social Impact Assessment (SIA) and Forest Rights Act (FRA) compliance protocols.
- Integrate forest clearance, environmental safeguards, and right-of-way (ROW) approvals into a single digital platform.

As illustrated in **Figure 14** a unified national land facilitation framework can replace today’s fragmented multi-agency approval process with a streamlined digital approach, integrating clearances, GIS-based land repositories, and standardized approvals

A unified approach under MNRE or NITI Aayog could streamline land-related processes, reduce duplication of efforts, and lower transaction costs for developers, particularly in new states scaling up renewable energy capacity. Such a Model Land Facilitation Framework would ensure predictable access to pre-cleared sites, improving investor confidence and accelerating India’s journey toward 500 GW of non-fossil power capacity by 2030.

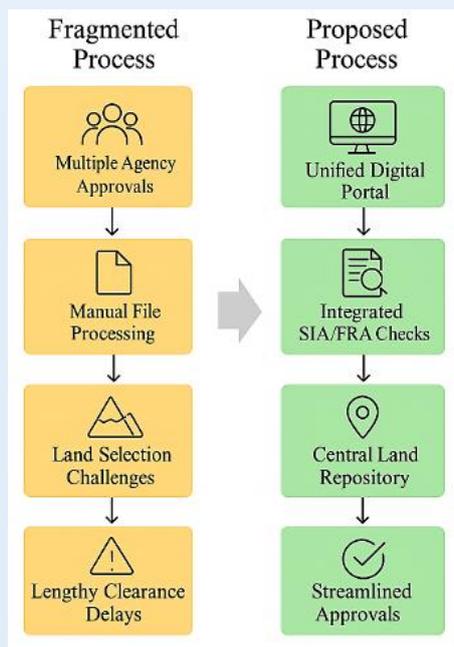


Figure 14 Standardizing Land Access for RE Deployment

2.2.3. Environmental and Forest Clearances

Environmental and forest clearances remain a critical procedural hurdle in the lifecycle of utility-scale RE projects, particularly for wind and hybrid installations that often intersect with forest patches, biodiversity corridors, and Scheduled Areas. While RE projects are generally exempt from full-scale EIAs under current norms, many still require clearances under the Forest Conservation Act (1980), the Environment (Protection) Act (1986), and other region-specific regulations, depending on site.

As India scales towards its 2030 non-fossil capacity targets, friction between RE expansion and ecological stewardship is becoming more visible. This tension is especially acute in states like Rajasthan, Gujarat,

Maharashtra, and Madhya Pradesh, where high solar and wind potential often overlaps with arid-zone biodiversity hotspots, forest edges, and wildlife habitats.

Legal Framework and Recent Changes

As of 2025, India's environmental clearance framework relevant to RE projects includes:

- **Environmental Clearance:** Required for projects located within designated Eco-Sensitive Zones or with capacities exceeding thresholds under MoEFCC's categorization rules.
- **Forest Clearance:** Mandated if the project involves diversion of forest land granted under Section 2 of the Forest Conservation Act.
- **Wildlife Clearance:** Applicable if the site is within 10 km of a protected area or national park; oversight by the Standing Committee of the National Board for Wildlife (NBWL).

A landmark example is the Supreme Court's 2022 order to protect the GIB (Great Indian Bustard) in western India. As per the directive, all transmission lines (66 kV and above) passing through GIB priority areas must be laid underground, unless technically infeasible. This has affected over 20 GW of solar and wind capacity planned in parts of Jaisalmer, Bikaner, and Barmer, due to high costs of underground cabling (~₹6-7 crore/km). Some developers are exploring rerouting options or bird diverter retrofitting on existing lines as alternative mitigation measures, pending MoEFCC and SC committee approvals.

Procedural Challenges Faced by Developers

1. **Long Clearance Timelines:** FC approvals often take 12-18 months, even for small parcels of forest land. The requirement for physical site inspections, Gram Sabha approvals (in tribal areas), and biodiversity surveys introduces delays.
2. **Uncertainty in Applicability:** Many developers remain uncertain about whether certain land tracts fall under the forest category due to ambiguity in land records, particularly in revenue forest or *deemed forest* zones.
3. **Cumulative Impact and Mitigation Burden:** Wind power projects in ecologically sensitive zones often require developers to finance Compensatory Afforestation (CA), biodiversity offsets, or invest in conservation infrastructure (e.g., bird diverters, camera traps) as mitigation measures, which increase project costs.

Source: Forest Clearance Portal, Supreme Court Orders: M.K. Ranjitsinh & Ors. vs Union of India (W.P. 838/2019)

2.2.4. Social Impact and Community Engagement

The deployment of RE infrastructure at scale inherently intersects with local communities, livelihoods, and land-based identities, particularly in rural and semi-rural India. While solar and wind projects are often perceived as low-conflict compared to mining or heavy industry, their land-intensive nature especially for utility-scale installations can generate social resistance, particularly when consent, compensation, and benefit-sharing mechanisms are absent or opaque.

In recent years, several RE developers have faced project stalling or legal challenges owing to weak stakeholder consultation, non-transparent land deals, and perceived inequities in economic gains. This makes

proactive community engagement not just a social imperative, but a risk mitigation strategy for developers and public agencies alike.

Community-Level Concerns

Communities affected by RE projects commonly cite:

- Loss of agricultural productivity (in dryland zones) where pastureland or cultivable revenue land is converted.
- Inadequate compensation or absence of indexed lease payments under land pooling arrangements.
- Marginalization of landless groups, women, and tenants in benefit-sharing schemes.
- Absence of meaningful consultation or Free, Prior, and Informed Consent (FPIC), especially in Scheduled Areas and tribal regions.

In states like Rajasthan, Andhra Pradesh, and Madhya Pradesh, these issues have surfaced in wind park expansions and large solar tenders, especially where revenue land with informal usage rights was acquired without social mapping or compensation to user groups.

Regulatory Landscape and CSR Obligations

Currently, India does not have a national-level Social Impact Assessment (SIA) framework that is specific to RE projects. While SIAs are mandated under the Right to Fair Compensation and Transparency in Land Acquisition Act (2013), they are often waived or diluted when land is acquired through lease or government transfer, as is common in solar parks.

However, large-scale RE developers registered as companies fall under the ambit of Section 135 of the Companies Act (2013), mandating Corporate Social Responsibility (CSR) expenditure. Yet, many CSR initiatives are decoupled from host community needs and are not designed as long-term social investments.

Figure 15 summarizes community engagement models adapted from the best international practices like IAP2

Stage	Description
Inform	One-way communication – awareness campaigns, info brochures
Consult	Surveys, public meetings, verbal inputs with no shared decision rights
Involve	Local stakeholder committees, participatory scoping
Collaborate	CSR MoUs, joint program design with community organisations
Empower	Co-ownership models, cooperatives, land-pooling with revenue shares

Figure 15 Community Engagement Models Applicable to RE Project Development in India (Adapted from IAP2 and Field-level 2025 Practices)

Emerging Good Practices

1. Revenue-Sharing Models: Projects in Maharashtra and Gujarat have piloted annual lease payments indexed to inflation for landowners, which provide more sustained income than lump-sum compensation.

2. Joint Ownership and Cooperatives: In Karnataka and parts of Telangana, small-scale solar irrigation and off-grid installations have been successfully implemented via community-based cooperatives, where users hold equity stakes.
3. CSR-Linked Energy Access: Some developers (e.g., ReNew, Tata Power) have begun aligning CSR with off-grid electrification, water access, and education infrastructure in project-affected areas, creating reputational and operational co-benefits.
4. Digital Grievance Portals: A few states (like Rajasthan) now require developers to maintain grievance redress portals, monitored by nodal agencies such as RRECL or SNA.

Source: Land Conflict Watch database (2024), Companies Act (CSR section)

Case Study: Bhadla Solar Park, Rajasthan

- **Location:** Jodhpur, Rajasthan; **Capacity:** ~2,245 MW (Phases I-IV); **Lead Agencies:** RRECL, SECI, NTPC
- **Land Aggregation:** RRECL secured 10,000+ hectares of wasteland with minimal displacement and no forest diversion, easing legal and social challenges
- **Single-Window Clearances:** Integrated portal streamlined environmental, land, and grid approvals; evacuation managed via pre-laid infrastructure by RVPN and PGCIL
- **Investor-Friendly Tariffs:** Risk-mitigated setup enabled record-low ₹2.44/unit tariff in 2017, attracting major players like Adani, SoftBank, and Fortum
- **Community Benefits:** Developers funded water access and education in nearby villages as part of CSR efforts

2.3. Connectivity and Power Evacuation Infrastructure

Robust transmission is vital for integrating high shares of variable renewables. This section delves into the preparedness of India’s grid infrastructure national, state, and regional to meet RE targets.

2.3.1. Transmission Infrastructure Readiness

A robust and forward-looking transmission system is the backbone of India’s energy transition. As RE penetration deepens especially from remote zones like Kutch, Ladakh, and southern Tamil Nadu, the need for long-haul, high-capacity, and flexible evacuation infrastructure has become more urgent than ever. While India has made significant progress through initiatives like the GEC and the National Transmission Plan (NTP 2023), the scale and speed of future deployment demand even greater synchronization between RE zoning, transmission planning, and financial closure of projects. As depicted in **Figure 16**, key RE zones is connected through planned and operational transmission corridors.

Green Energy Corridor: Achievements and Gaps

The Green Energy Corridor project, conceptualized in 2013, was India’s first transmission program tailored to RE evacuation. It was divided into:

- GEC Phase I: Covered 8 RE-rich states including Tamil Nadu, Rajasthan, Gujarat, Maharashtra, Himachal Pradesh, Karnataka, Andhra Pradesh, and Madhya Pradesh.
- Targets: 9,400 circuit kilometers (ckm) of transmission lines and 19,000 MVA of substations.

- Status (as of 2024): Over 97% of substations and 85% of lines commissioned. Funded via a combination of KfW loans, PFC/REC disbursements, and state equity.

GEC Phase II was sanctioned in 2022 with a ₹12,000 crore outlay, targeting another 10,750 ckm of lines and 27,500 MVA in substation capacity by 2026, focused on intra-state strengthening. This includes critical links in Ladakh, Koppal, Tirunelveli, and Bhuj, as well as a modernization component involving STATCOMs and PMUs for better RE integration.

National Transmission Plan (CEA, 2023)

The CEA's NEP for Transmission (NEP-Tx), 2023 outlines a clear blueprint to evacuate 500 GW non-fossil capacity by 2030, based on granular forecasts of RE zones and load centers (refer **Figure 16**). Key highlights include:

- Addition of 51 transmission corridors for 8 RE zones.
- Creation of transmission capacity for 500 GW RE, of which ~200 GW is targeted by 2027.
- Estimated investment of ₹2.44 lakh crore for the proposed expansion between 2023-2030.
- Focus on High Voltage Direct Current (HVDC), Gas Insulated Substations (GIS) in urban growth areas, and dynamic line ratings in high-wind zones.

The plan also advocates "transmission before generation" – a significant shift from reactive to anticipatory grid development especially in remote RE clusters like Ladakh, offshore Gujarat, and desert Rajasthan.

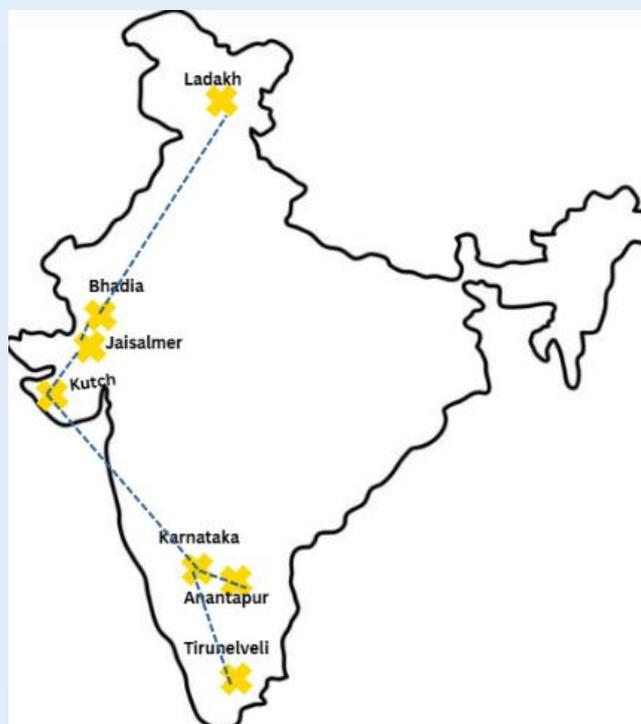


Figure 16 Key RE Zones and Transmission Corridors (2023-2030).

Planning RE Zones and Grid-Forming Substations

Inadequate transmission capacity has historically led to project underutilization, curtailment, and delays in financial closure for developers. The NEP-Tx proposes a coordinated spatial framework, integrating CEA zoning, ISTS projections, and real-time load forecasts.

Grid-forming substations which can stabilize frequency and voltage autonomously are being piloted in select zones of Tamil Nadu and Gujarat. These substations, paired with synchronous condensers and battery banks, can replace spinning reserves traditionally provided by thermal plants.

2.3.2. Inter-State and Intra-State Grid Access

India's federal grid architecture operates on a layered framework, where ISTS are managed by central entities like PGCIL and regulated by the CTU, while intra-state systems fall under the purview of STUs and SERCs. While ISTS networks have seen considerable expansion in recent years particularly through ISTS waivers and CTU-led planning the intra-state infrastructure often lags in readiness, contributing to a growing disconnect between generation zones and demand centers.

This section evaluates the status, structural asymmetries, and emerging integration pathways for both ISTS and STU systems in the context of RE evacuation.

CTU vs STU Infrastructure: Uneven Development

Over the past decade, the central government has prioritized ISTS investments through schemes such as the GEC, Inter-State Transmission System Waiver for RE Projects (2018-2025), and TBCB-led private participation. As of 2024:

- The ISTS network spans over 114,000 ckm, enabling bulk transfer of RE from resource-rich zones (Gujarat, Rajasthan, Ladakh, Tamil Nadu) to load centers (Maharashtra, Delhi-NCR, West Bengal).
- Grid connectivity for ISTS-connected RE projects enjoys waiver of transmission charges till 2025, reducing delivered cost of power and encouraging large-scale developers to locate in remote regions.

In contrast, STUs often face financing constraints, procurement delays, and limited technical forecasting capacity, particularly in Tier-II states. For example:

- Tamil Nadu, Rajasthan, and Andhra Pradesh despite high RE generation have faced curtailments due to intra-state bottlenecks.
- In Odisha and Jharkhand, the lack of upstream STU readiness has delayed commissioning of over 1.5 GW of installed wind and solar capacity.
- Banking charges, outdated grid codes, and absence of digital substations further exacerbate integration delays.

Congestion and Curtailment Trends

Curtailment remains a critical operational challenge for integrating high shares of renewables into India's grid. The POSOCO National RE Curtailment Report (2023) highlights that grid congestion, inadequate intra-state transmission redundancy, and limited substation capacity collectively lead to renewable energy curtailment of 4-6% at the national level (refer **Figure 17**). This translates into lost generation revenue, weakens the enforceability of PPAs, and creates investment uncertainty for developers.

To mitigate this, India has deployed Renewable Energy Management Centers (REMCs) in major regional load dispatch centers and introduced mandatory forecasting and scheduling protocols for variable renewable energy. However, full operational integration of REMCs with SLDCs and CTUIL remains incomplete, limiting their real-time curtailment mitigation potential.

Nationally, addressing congestion requires faster execution of Green Energy Corridors, expansion of digital substations, and flexible ancillary markets to absorb renewable variability. A unified national congestion management framework - combining proactive transmission planning with dynamic dispatch protocols - can help reduce renewable curtailment and improve investor confidence.

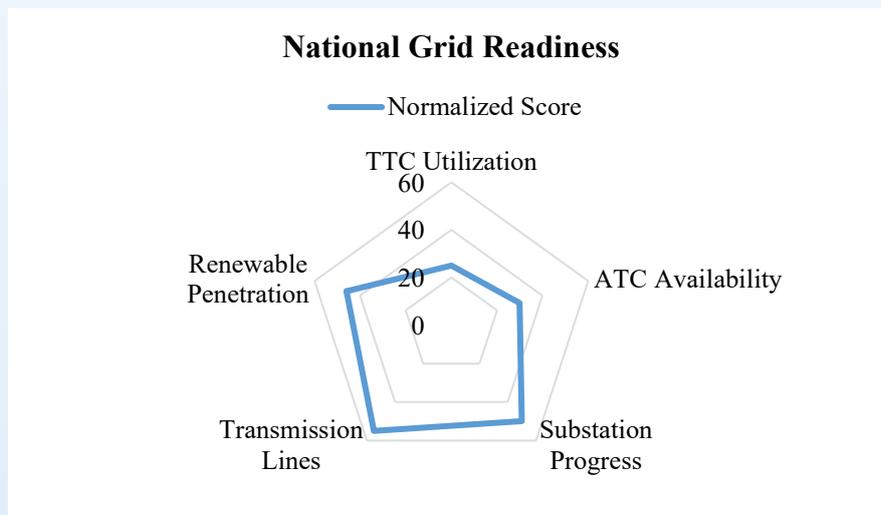


Figure 17 National Grid Readiness Score.

Need for Integration: CTU-STU Coordination

Going forward, seamless integration between CTU and STU systems is vital. Some emerging policy measures include:

- Joint transmission planning exercises between CTU (under POWERGRID/CEA) and STUs, now mandated annually for RE-rich states.
- Single Window Connectivity Portals (e.g., CTUIL's revamped GNA portal, Gujarat STU dashboard) to align timelines and connectivity criteria.
- Financial support from PFC and REC for STU upgrades under the RDSS (Reforms-Based Distribution Sector Scheme), with grid-linked performance indicators.
- Unified digital load flow modelling across ISTS and STU nodes for real-time balancing and congestion forecasting.

2.3.3. GNA (General Network Access) and Connectivity Frameworks

The launch of General Network Access by CERC represents a major shift in India's transmission connectivity. Moving away from project-specific, location-bound approvals, GNA offers renewable energy (RE) developers greater flexibility to inject power anywhere in the grid within contracted capacity limits. Implemented through the Connectivity and GNA Regulations, 2022 (effective July 1, 2023), this framework aims to improve long-term planning, reduce litigation, and ease business in the RE sector.

Key Features of the GNA Regime

GNA unifies generation and withdrawal access, replacing fragmented instruments like Long-Term Access (LTA) and Medium-Term Open Access with a single-window system applicable uniformly to ISTS users. It allocates capacity as a quantum (MW) not tied to specific grid nodes, enabling dynamic scheduling when feasible. Transmission capacity is offered on a rolling basis based on system availability and congestion forecasts by CTUIL. GNA rights are transferable and bankable with regulatory approval, enhancing liquidity and aiding refinancing.

Transition Challenges Since July 2023

Early implementation has exposed challenges, including a backlog of legacy LTA applications facing uncertainty on tariff locks and node assignments. CTUIL’s GNA portal rollout has experienced delays and data sync issues with STUs and SLDCs. Lenders worry about revenue security under non-location-specific injection, prompting MNRE and MoP to clarify policies. Hybrid and storage-linked projects face ambiguity on how GNA will handle variability and firm capacity.

Impact on Developers and Investors

GNA reduces lead times and removes node constraints, benefiting utility-scale RE developers. For instance, in Gujarat and Rajasthan, SECI auction winners secured GNA within 45-60 days versus prior LTA waits of up to six months. However, in Tamil Nadu and Andhra Pradesh, poor STU coordination has led to uncertainty on injection limits and curtailments. The framework’s effect on project bankability depends on regulatory refinements around injection priorities, dispute resolution, and hybrid/storage asset treatment.

Source: CERC GNA Regulations, 2022; CTUIL GNA Portal Dashboard (2024); SECI Tranche-XIV Bid Guidelines.

2.3.4. Substation Availability and Expansion Plans

Substation infrastructure is the critical last-mile interface between RE generation and bulk transmission networks. The availability, capacity, and geographic alignment of substations particularly in RE-dense zones play a direct role in determining the feasibility, bankability, and timeline of solar, wind, and hybrid projects. While transmission line development has gained pace under national and state-level schemes, substation deployment has often lagged due to land bottlenecks, inter-agency delays, and inadequate geospatial planning.

Current Status of Substation Infrastructure in RE Zones

As of 2024, India has approximately 1,100 substations under the ISTS and STU frameworks catering to RE evacuation. However, many of these are geographically misaligned with renewable energy-rich regions, especially in western Rajasthan, southern Tamil Nadu, and the Kutch peninsula in Gujarat. A snapshot of critical RE regions shows the following **Table 2** below:

Table 2 Critical RE Regions.

Region	RE Potential (GW)	Operational Substation Capacity (MVA)	Identified Gaps
Kutch, Gujarat	~80	~13,500 MVA	Delay in Bhuj II, lack of redundancy
Bhadla, Rajasthan	~40	~8,200 MVA	Curtailment due to transformer limits
Tirunelveli, Tamil Nadu	~30	~5,800 MVA	Limited STU grid upgrades

Region	RE Potential (GW)	Operational Substation Capacity (MVA)	Identified Gaps
Anantapur, Andhra Pradesh	~20	~3,700 MVA	No nearby pooling substations
Ladakh	~10	~1,000 MVA (planned)	High-altitude logistics, land acquisition

Source: CEA Transmission Plan (2023), SECI Zone Readiness Tracker, CTUIL Substation Reports

Challenges in Substation Deployment

Substation projects face delays mainly due to difficulties in acquiring contiguous land parcels, especially near forests and tribal areas. Many State Transmission Utilities (STUs) still rely on static planning without GIS overlays of renewable resource zones, causing misaligned infrastructure and costly rerouting. In several SECI auctions, such as Gujarat ISTS-IV, projects were ready before substations became operational, resulting in stranded capacity and force majeure claims. While transmission lines have attracted private investment through TBCB projects by players like Sterlite and Adani Transmission, substation development remains predominantly public sector-led, limiting innovation and speed.

Expansion Plans under CEA & GEC-II

Several substation projects are fast-tracked under Green Energy Corridor Phase II and the 2023 NEP (Transmission). These include the Koppal 765/400 kV pooling substation in Karnataka for wind-solar hybrids, targeted for 2025 commissioning, Bhuj-II GIS substation in Gujarat linked to a 30 GW solar-wind park, accelerated under TBCB after delays; Tirunelveli 400 kV substation with STATCOMs in Tamil Nadu funded by RDSS and GEC-II, and the Leh-Alusteng 220 kV grid link with step-up to 400 kV from Ladakh to Kashmir³⁸, facing ongoing logistical challenges. These projects will incorporate advanced technologies like GIS, STATCOMs, and remote telemetry units to enhance grid reliability and flexibility.

2.3.5. Challenges in RE-Rich States

India's top renewable energy states - Rajasthan, Gujarat, and Tamil Nadu - show strong ambition but face challenges from transmission congestion, regulatory inconsistencies, and planning gaps. Rajasthan's Bhadla region experiences seasonal curtailment due to delayed ISTS upgrades and limited pooling. Gujarat's Kutch clusters suffer from policy volatility and fragmented right-of-way norms. Tamil Nadu's legacy wind fleet faces intra-state congestion and dispatch issues. These problems stem from disjointed RE-transmission planning, unclear central-state roles, and right-of-way hurdles, calling for coordinated national-level solutions.

Policy Recommendations

1. State-Centre Coordination Forums: Institutionalize a quarterly RE Evacuation Coordination Taskforce under MNRE and MoP, with CTUIL, SLDCs, STUs, and developers.
2. Performance-Linked Incentives for STUs: Tie a portion of central funding (e.g., via PFC/REC, RDSS) to STU-level metrics like dispatch efficiency, curtailment reduction, and substation commissioning timelines.
3. Model RoW Guidelines & Fast-Track Approvals: Update RoW compensation norms across states and introduce a digitized portal for RoW tracking and redressal, modelled on PM Gati Shakti.

4. **Banking Policy Harmonization:** Develop uniform banking principles across RE-rich states under a national open access policy to improve project economics and remove market distortions.

2.3.6. Role of CTU, STUs, and Private Transmission Licensees

India's transmission system is becoming more decentralized and market-driven. While the Central Transmission Utility (CTU) and State Transmission Utilities (STUs) remain key for inter- and intra-state transmission, private transmission licensees have grown notably through the Tariff-Based Competitive Bidding (TBCB) model. Their collaboration is vital for efficiently evacuating 500 GW of non-fossil capacity by 2030.

Role of the CTU

Carved out from PGCIL in 2021, CTUIL serves as the nodal agency for planning, connectivity, and development of the inter-state transmission system (ISTS). Since July 2023, CTUIL administers General Network Access (GNA), replacing earlier LTA/MTOA systems. It prepares medium- and long-term transmission plans aligned with the NEP and SECI auctions, and scopes ISTS projects for competitive bidding. By 2024, CTUIL oversees over 40,000 circuit km of transmission lines, fast-tracking ISTS for RE zones like Gujarat (Kutch), Rajasthan (Bhadla), and Ladakh.

Challenges for STUs

STUs face delays in upgrading RE hotspots causing curtailment and underutilization, limited forecasting and slow digitalization especially in SLDC-STU coordination, and capital constraints relying on state budgets or PFC/REC funds. However, states like Gujarat and Karnataka are advancing substation automation and real-time dispatch to better integrate with CTU.

Rise of Private Transmission Licensees

Since TBCB's launch in 2011, private players have expanded their share, with over 60 projects awarded by 2024. Major players include Sterlite Power (over 13,700 ckm portfolio), Adani Transmission Ltd (integrated T&D with ISTS corridors), and IndiGrid (first InvIT-backed transmission owner). These firms have introduced innovations in execution timelines, GIS substation tech, and asset management, cutting construction times by up to 30%.

Regulatory and Policy Enablers

CERC's 2020 Tariff Regulations clarified tariff discovery and returns. Standard Bidding Documents for TBCB projects are regularly updated to improve risk sharing and dispute resolution. The Draft Electricity (Transmission System Planning, Development and Recovery of Inter-State Charges) Rules, 2022³⁹, offer guidance on system cost recovery and PoC charge rationalization.

Coordination Challenges

Despite progress, coordination gaps persist between CTU, STUs, and private players, causing route planning duplication, right-of-way delays, lack of shared GIS data, and disputes over asset ownership in overlapping zones. Addressing these requires a unified Transmission Coordination Portal, shared digital tools, and stronger regulatory oversight by CERC and SERCs.

Source: CEA National Transmission Plan (2023); CERC Tariff Regulations (2020); Sterlite & Adani Transmission Annual Filings (2024); CTUIL Portal

2.3.7. Inter-continental Power Grids - Realistic Assessment

India's ambition to emerge as a global clean energy hub is increasingly reflected in its strategic push for cross-border and intercontinental power connectivity frameworks. Initiatives like the One Sun One World One Grid (OSOWOG) and its affiliation with the Global Green Grids Initiative (GGI) signal a vision of transnational electricity exchange rooted in solar diplomacy, grid decarbonization, and energy equity.

However, translating these aspirations into operational power corridors involves deep technical harmonization, geopolitical coordination, and robust institutional architecture. This section critically evaluates the progress, potential, and structural barriers to realizing such intercontinental grid frameworks.

OSOWOG and GGI: Vision and Architecture

Launched by India at COP26 under its G20 and ISA (International Solar Alliance) leadership, the OSOWOG initiative envisions a “Sun never sets” model of global electricity sharing through seamless regional interconnections. The key objectives are:

- Efficient sharing of renewable energy resources, especially solar, across time zones.
- Stabilizing demand-supply mismatches via regional balancing and seasonal complementarity.
- Reducing fossil dependency through clean electricity trade.
- Promoting energy equity by linking renewable surplus zones with energy-deficit economies.

The initiative is supported by the GGI-OSOWOG Joint Secretariat, anchored by India and the UK, with technical backing from the International Solar Alliance (ISA) and the World Bank.

Technical and Geopolitical Challenges

Despite its compelling vision, implementation faces the following complex hurdles:

- **Grid Synchronization:** Varying frequency, voltage, and grid codes across national boundaries (e.g., SAARC vs ASEAN) require synchronous/asynchronous converter stations and stable HVDC backbones.
- **Cybersecurity & System Control:** Cross-border grid flows pose higher risks of cyber-attack propagation, necessitating secure SCADA/EMS systems and AI-based intrusion detection.
- **Infrastructure Redundancy:** Long-distance lines across oceanic or desert zones must be fortified with redundancy loops and stable baseload buffers difficult in solar-dominated corridors.
- **Energy sovereignty and trade dependencies:** Nations remain cautious of relying on neighbors for critical energy flows, especially amid regional tensions (e.g., India-China-Nepal or India-Pakistan).
- **Regulatory alignment:** Different electricity market structures and cost-recovery principles hinder the creation of unified trade corridors.
- **Financing of long-distance interconnectors:** With estimated costs exceeding \$1.5 million/km for HVDC subsea cables, multilateral financial coordination is essential.

In conclusion, while India's RE transition is accelerating, systemic challenges across manufacturing, land, regulatory frameworks, and transmission must be addressed. A whole-of-government approach, coupled with investor confidence, robust infrastructure, and social acceptance, is essential to realize the clean energy vision.

2.4. Financing Renewable Energy Projects

The transformation of the global energy sector has now placed financing in the center of RE transition. In India, the scale and complexity of clean energy deployment have increased considerably in view of long-term decarbonization goals, constantly evolving policy frameworks, and the urgent need for ensuring energy security. Today, financing renewable energy projects goes beyond the traditional utility-scale solar and wind assets to encompass a wide range of technologies, business models, and infrastructure segments—from green hydrogen and battery storage to distributed generation and transmission upgrades.

As the sector matures, financial instruments and capital structures have evolved and are bringing together domestic and international investors, public institutions, and multilateral agencies. These emerging risks—off taker creditworthiness, long-term debt availability and cost volatility—continue to slow down investment. Addressing these requires a coordinated approach involving financial innovation, regulatory certainty, and risk-sharing arrangements.

2.4.1 India's Investment Needs and Financing Gap

India needs to significantly boost its investment in green energy to close the funding gap and reach its clean power goals by 2030. India's commitment to achieving 500 GW of non-fossil fuel-based power capacity by 2030 stands as a cornerstone of its broader climate and energy transition strategy. Realizing this target requires unprecedented investment across multiple renewable energy technologies, supported by enabling infrastructure in transmission, storage, and grid integration.

2.4.1.1 Capital requirement for 500 GW non-fossil energy target by 2030

According to estimates published by FICCI, the total capital requirement to achieve 500 GW of non-fossil capacity by 2030 is projected to be approximately ₹30 lakh crore (USD 360 billion). This reflects the aggregate capital expenditure (CAPEX) for generation assets alone, covering solar, wind, hydro (both large and small), and nuclear power installations.

A detailed segment-wise investment breakdown indicates the following:

- **Solar Energy:** With a planned capacity of ~292 GW, solar constitutes the largest share of the target, requiring an estimated ₹12.6 lakh crore in investments.
- **Wind Energy:** Projected at ~93 GW, wind capacity is expected to draw capital investments of approximately ₹5.5 lakh crore.
- **Hydropower:** Including both large and small hydro, an estimated 63 GW is planned, corresponding to a funding requirement of around ₹5.7 lakh crore.
- **Nuclear Power:** With a projected capacity of ~22 GW, nuclear energy investments are estimated at ₹5.75 lakh crore.

2.4.1.2 Estimates for Net Zero 2070 investment

Reaching net zero by 2070 means India will need to invest over \$10 trillion in everything from power generation and storage to transmission and other key infrastructure making this one of the biggest investments challenges the country has ever faced in its energy transition.

The Long-Term Financing Challenge

Achieving India’s commitment to net-zero emissions by 2070 will require a fundamental, multi-decade transformation of its energy, transport, and industrial systems. This transition will be capital-intensive, involving sustained financial flows into renewable power generation, electrified mobility, green hydrogen, energy storage, and carbon management infrastructure.

Investment Projections from CEEW-CEF

To reach its net-zero goal, India will need to mobilize a total capital of nearly USD 10.1 trillion between 2020 and 2070, according to modelling done by the Council on Energy, Environment and Water - Centre for Energy Finance (CEEW-CEF). This is assuming that **low-cost** international climate finance is available. Investment in both core infrastructure and enabling systems is included in this estimate, which also accounts for changes throughout the economy.

Sector-Wise Investment Distribution

According to the report, the power sector alone would require approximately 83% of the total investment, or approximately USD 8.4 trillion. This involves establishing energy storage devices, expanding renewable energy production, and improving transmission infrastructure. Additional capital needs include:

- **Electric mobility:** ~USD 1.2 trillion for EV adoption and charging infrastructure.
- **Green hydrogen:** ~USD 0.5 trillion for production and industrial applications.

Role of affordable climate finance

The total amount of investment needed could increase dramatically to USD 13.7 trillion in a high-cost financing scenario where concessional capital and blended finance mechanisms are scarce. This presents a compelling argument for increasing access to low-cost foreign capital, de-risking strategies, and institutional advancements that can facilitate the large-scale channeling of long-term funding.

2.4.1.3 Current funding availability and financing gap

To support its energy transition objectives, India has made significant progress in mobilizing green finance. The current rate and scope of capital deployment, however, are still insufficient to reach the country's clean energy goals (refer **Figure 18**).

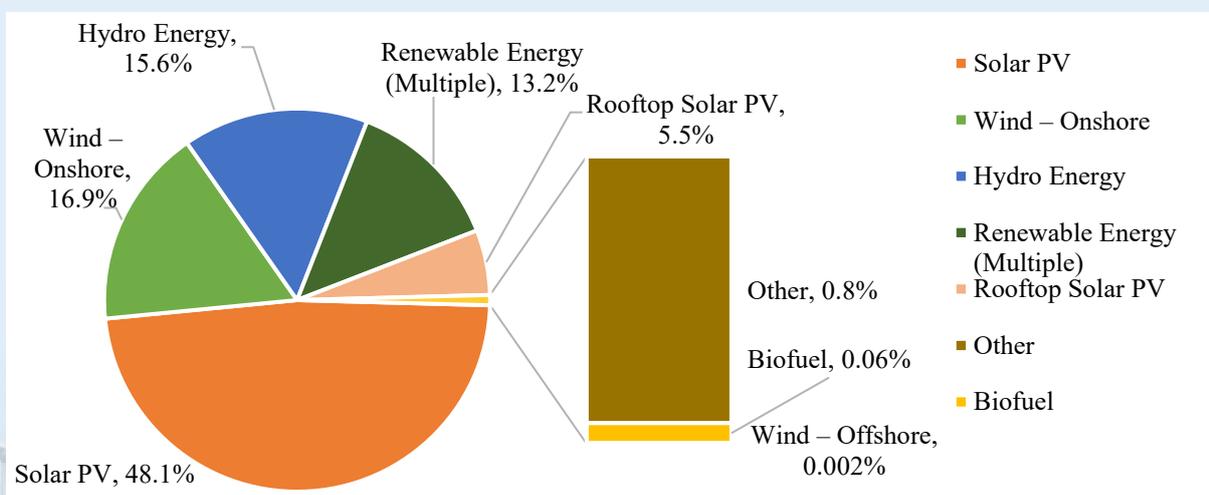


Figure 18 Breakdown of Clean Energy Finance by Subsector in India (FY 2021-22).

In FY 2021-22, total clean energy finance in India amounted to ₹1,768 billion (refer **Figure 19**). Of this, the Solar PV segment received the highest allocation at ₹850 billion, followed by Wind (Onshore) at ₹299 billion and Hydro Energy at ₹275 billion. Investments directed toward multiple renewable energy technologies total ₹233 billion. Rooftop Solar attracted ₹97 billion, while smaller allocations were made to segments such as Biofuel (₹1 billion), Offshore Wind (₹0.04 billion), and other technologies (₹14 billion). This distribution reflects a strong concentration of financing in utility-scale solar and wind projects.

According to the Indian government, it will take ₹11 trillion (USD 170 billion) a year until 2030 to meet its NDC targets. However, only ₹4.25 trillion (USD 57 billion) in tracked green finance flows in FY 2021-2022 met roughly 30% of the requirement. This gap emphasizes the necessity of greatly increasing capital mobilization for renewable energy and related infrastructure.

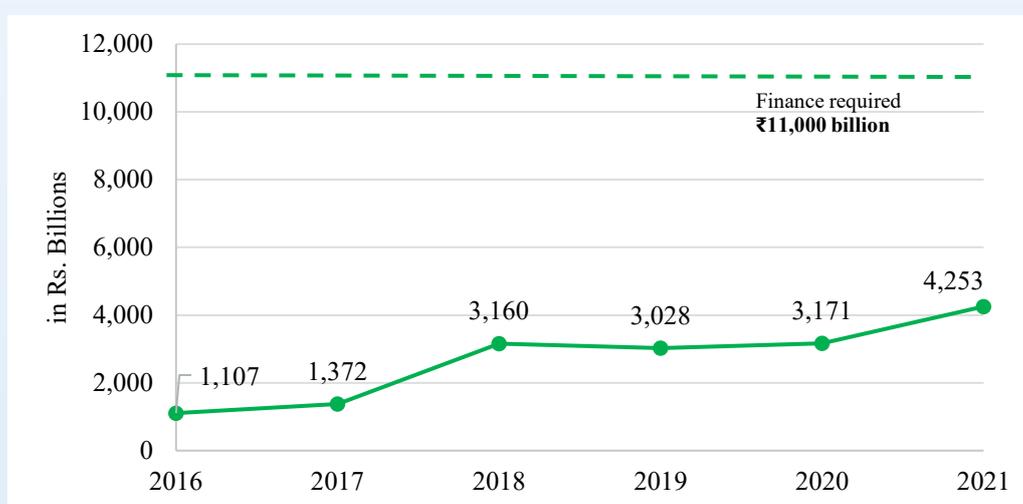


Figure 19 Green Investment and Estimated Requirements to Meet Current NDC (INR Bn).

Financing Gap

There is a persistent and steadily increasing gap between the required and actual financial flows. Only 30 to 35 percent of yearly requirements are met by green finance flows as of FY 2021-2022. Underinvestment in wind, grid-scale storage, and grid modernization is the main cause of the ₹650 billion annual gap in the clean energy sector, according to CPI.

Although there have been comparatively strong capital inflows into the solar sector, other sectors like transmission infrastructure, BESS, and hybrid or round-the-clock (RTC) power solutions have had difficulty obtaining comparable funding. India's larger decarbonization plan, which depends increasingly on integrated and dispatchable renewable energy, is threatened by this imbalance.

Several factors contribute to this persistent financing gap:

- Limited availability of long-term, low-cost debt instruments.
- Perceived credit risk is associated with off-takers, especially state DISCOMs.
- Regulatory uncertainties affect cost recovery and project viability.
- Delays in project approvals and financial closure in some SECI-conducted bids.
- Weak investor appetite for segments with uncertain or multi-stakeholder revenue models (e.g., storage, green hydrogen).

2.4.1.4 Role of public, private, and blended capital in closing the gap

India must invest an average of ₹11 trillion (USD 170 billion) annually to meet its 2030 NDC targets. However, in FY 2021-22, green finance flows reached only ₹4.25 trillion (USD 57 billion), covering about 38% of the need. Closing the yearly gap of over ₹6.5 trillion requires coordinated capital from public, private, and blended sources.

Public Capital: Essential but Insufficient

Public finance is crucial for early-stage investments and project bankability. In FY 2021-22, public sources contributed 28% of green finance (₹1.05 trillion). Organizations like IREDA, REC, and PFC provided over ₹400 billion in debt for grid and renewable infrastructure. Key enablers include funding for the Green Energy Corridor (₹10,141 crore for GEC-2), payment security mechanisms, and viability gap funding. Yet, public funds alone cannot meet the scale needed, especially for emerging technologies like hydrogen, offshore wind, and storage.

Private Capital: Largest but Selective

Private players such as ReNew, Greenko, and Adani Green use InvITs to raise equity and debt. Commercial banks and NBFCs finance established solar and wind projects with signed PPAs. In 2023, Indian firms raised over USD 9 billion in green bonds and sustainability loans. Despite this, private capital mainly targets low-risk, mature sectors, with limited exposure to newer technologies due to tariff uncertainties, lack of long-term contracts, and evolving regulations.

Blended Capital: Unlocking Risk-Averse Markets

Blended finance helps de-risk investments by combining commercial funds with concessional or philanthropic capital. India's National Infrastructure Investment Fund (NIIF) commits equity and subordinated debt to renewable platforms. Multilateral institutions like the World Bank, ADB, AIIB, and KfW provide credit lines, guarantees, and first-loss coverage. Platforms like the Solar Risk Mitigation Initiative (SRMI) and SECI's aggregation model pool risk and capital effectively. Blended finance is especially critical for markets with uncertain commercial viability such as standalone BESS, green hydrogen pilots, and large hybrid dispatchable projects.

2.4.2 Domestic Financing Landscape

In the past, India's renewable energy sector has relied on money from within the country to build and grow projects. As energy markets mature and policy frameworks change, more types of financing tools and institutions are now helping to raise capital. This part talks about the main trends and channels that are changing the way people get money in their own country.

2.4.2.1 Role of PSU banks, private banks, and NBFCs (IREDA, REC, PFC)

Public and private sector banks, along with sector-specific non-banking financial companies (NBFCs), play a central role in financing RE assets. Among them:

- A. **PSU Banks** (like SBI and Bank of Baroda) are still the main lenders for utility-scale solar and wind projects, especially those that have central PPAs.
- B. **Private banks** like HDFC Bank, Axis Bank, and ICICI Bank are more involved in financing C&I rooftop projects, corporate RE platforms, and term loans with ESG-aligned covenants.

C. NBFCs like IREDA, REC, and PFC offer customized financing options like construction loans, refinancing, and interest subvention schemes for RE developers. Many private NBFCs offer special products for funding RTS projects and green projects

- **IREDA set a record in FY 2023-2024** by sanctioning ₹37,354 crores in loans and disbursing ₹25,089 crores, which represented 14.6% and 15.9% annual growth, respectively. Its loan book increased by 26.7% annually to ₹59,650 crore. This highlights how IREDA, India's largest green finance NBFC is growing and supporting a wide variety of renewable energy technologies. Together with REC, PFC, and large banks, it makes up most of the domestic renewable energy lending. Release finance for developing technologies, better support mechanisms are necessary as financing is still primarily focused on traditional solar and wind.

2.4.2.2 Green Bonds, InvITs, and Infra Debt Funds

Market-based instruments are being used more often by developers and financial institutions to diversify funding sources outside of traditional bank loans as India's renewable energy sector grows. These include Infrastructure Debt Funds (IDFs), Infrastructure Investment Trusts (InvITs), and green bonds, which have become significant avenues for long-term fund mobilization.

Green Bonds: Growth and Dominance

By December 2024, India's cumulative aligned GSS+ debt reached USD 55.9 billion, with green bonds accounting for USD 46.6 billion (83%). In 2024 alone, USD 6.4 billion was raised through 22 green debt deals, averaging USD 292 million each. Key issuers include ReNew Power (USD 11 bn), Adani Group (USD 5.4 bn), and Greenko (USD 4.2 bn), with issuances mainly in USD (55%) and INR (44%). Since 2023, the Government of India has issued ₹477 billion (~USD 5.8 billion) in sovereign green bonds, helping establish a green yield curve. SEBI has also tightened disclosure norms, mandating independent reviews from April 2025.

Infrastructure Investment Trusts (InvITs)

Infrastructure Investment Trusts (InvITs) offer renewable energy developers a way to monetize operational assets and recycle capital. Green InvITs like Virescent Renewable Energy Trust and India Grid Trust (IndiGrid) have attracted long-term investments from pension and sovereign wealth funds, providing stable, infrastructure-grade returns. Initially used for roads and transmission, InvITs are now scaling up for solar and wind assets, aligning with India's RE growth.

Infrastructure Debt Funds (IDFs)

IDFs are designed to refinance mature RE projects with lower rates and longer tenors. However, uptake remains limited due to low deal visibility and high risk perception for new asset pools. SEBI's revised framework and NaBFID's role as a long-term infra financier may boost IDF deployment in RE and grid infrastructure.

2.4.2.3 RBI's Green Deposit Framework and ESG-linked lending

Institutional reforms in the financial sector's approach to capital allocation and environmental risk are necessary for India's shift to a low-carbon economy. Considering this, the RBI has promoted the expansion of ESG-linked loan products in domestic markets and established regulatory frameworks to support green finance, most notably the Green Deposit Framework.

A. RBI Green Deposit Framework (Effective April 2023)

Under this framework, Scheduled Commercial Banks (excluding Regional Rural Banks) and deposit-taking NBFCs must offer green fixed deposits, with proceeds exclusively allocated to environmentally sustainable activities like renewable energy, clean transport, energy efficiency, sustainable water and waste management, and green buildings. Regulated entities are required to implement Board-approved policies and strong internal controls to ensure compliance. The allocation of funds must undergo independent third-party verification to maintain transparency and investor confidence. Additionally, annual disclosures on funds mobilized, deployment status, and environmental impact are mandatory.

B. ESG-Linked Lending: Emerging but Gaining Traction

Sustainability-linked loans (SLLs), where interest rates depend on meeting predefined ESG performance targets, are increasingly adopted in India. Corporates in sectors such as energy, manufacturing, and infrastructure are linking borrowing costs to decarbonization goals, water usage, or ESG governance metrics. Lenders are integrating ESG scoring into credit appraisals, particularly for long-term debt and refinancing renewable energy projects. There is also growing interest from foreign banks and multilateral institutions in offering concessional or ESG-linked credit lines to Indian corporates.

2.4.3 Global Capital and Climate Finance

Global capital plays a vital role in supporting India's renewable energy transition. It comes through foreign direct investment, multilateral and bilateral development finance and international climate funding. These sources complement domestic finance and often help reduce project risks by offering longer tenures, concessional terms or structured guarantees. Their importance continues to grow as India moves into more complex and capital-intensive segments of clean energy.

2.4.3.1 Foreign Direct Investment (FDI) and Leading Global Investors

- In Q2 FY24, India received USD 505 million in FDI into the renewable energy sector, reflecting a 9% year-on-year increase.
- The total FDI for H1 FY24 (April-September 2023) stood at USD 938 million (refer **Figure 20**).
- Despite the modest growth, this is the second consecutive quarterly decline from Q4 FY23, when FDI stood at USD 848 million.
- The solar sector continued to attract the largest share of FDI, followed by wind and emerging clean technologies.
- Top international investors included Brookfield, GIC, CDPQ, and ADIA, mainly through platform investments and asset acquisitions.

Although equity has been the dominant form of FDI, there is a growing interest in structured debt and sustainability-linked instruments from global financial institutions. FDI continues to play a crucial role in both greenfield development and the refinancing of mature assets.

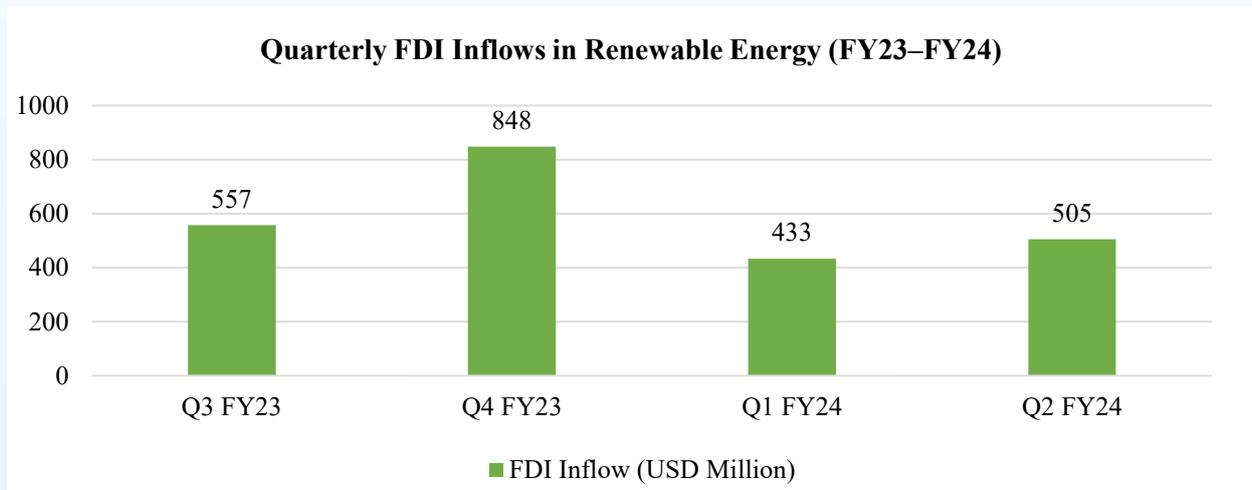


Figure 20 Quarterly FDI Inflows in Renewable Energy (FY23-FY24).

2.4.3.2 Role of Multilateral and Bilateral Development Banks

- Development finance institutions bring long-term capital and help crowd in private investment by reducing project risk. They also contribute to institutional reforms, capacity building, and project design.
- The World Bank has partnered with SECI and state utilities to support solar parks, transmission upgrades, and payment security systems. ADB and KfW have provided lines of credit to IREDA and REC for rooftop solar and grid connected RE projects.
- AIIB has supported utility-scale solar and wind projects developed by firms such as ReNew and Greenko.
- These institutions often function as anchor lenders in blended finance structures. They also help extend the tenor of project loans, which is especially important for capital-heavy assets like wind-solar hybrids and storage-integrated systems.

2.4.3.3 Climate Finance Platforms: GCF, CIF, and Just Energy Transition Partnership (JETP)

India has received support from several climate finance platforms that focus on decarbonization and energy transition. The Green Climate Fund (GCF) has backed rooftop solar aggregation programs, guarantee schemes for private developers, and credit facilities through institutions such as IREDA and NABARD.

The Climate Investment Funds (CIF), especially the Clean Technology Fund have provided concessional capital for projects like grid integration, solar parks, and smart metering. These programs aim to lower the cost of capital while supporting technology demonstrations and system-wide reforms.

India is also in discussions to access support through the Just Energy Transition Partnership. This framework is expected to bring in concessional finance for coal transition, grid strengthening, and energy access, especially in states that depend on fossil fuel-based generation.

While these funds offer valuable support, their effectiveness depends on aligning financial terms, technical requirements and reporting processes with India’s domestic policy and market needs.

2.4.4 Financing for Emerging RE Technologies

India's energy transition is shifting away from traditional solar and wind power and towards a more diversified combination that incorporates technologies such as distributed rooftop solar, offshore wind, green hydrogen, and battery storage. Although these sectors have the potential to decarbonize overall, they present funding difficulties because of their high capital intensity, changing regulatory environments, and short records. It will take a combination of blended finance, governmental incentives, and creative project structure to raise money for these new fields.

2.4.4.1 Green Hydrogen: investment outlook and support schemes

Green hydrogen is becoming an important part of India's long-term plan to cut carbon emissions in hard-to-abate sectors like fertilizers, refining, steel, and heavy mobility. The market is still new but there is a lot of momentum thanks to central policy frameworks and state-level incentives that work well with them. However, big investments are still hard to make because of high upfront costs, changing technology economics, and a lack of long-term offtake visibility.

National Policy Framework

The **National Green Hydrogen Mission (NGHM)** was launched in 2023 that marks India's first comprehensive step towards establishing a green hydrogen economy. The total outlay of **₹19,744 crore** is directed toward (refer **Figure 21**):

- Production-linked incentives through the SIGHT (Strategic Interventions for Green Hydrogen Transition) program (₹13,000 crore).
- Electrolyze manufacturing support.
- Pilot projects and demand aggregation across priority sectors.

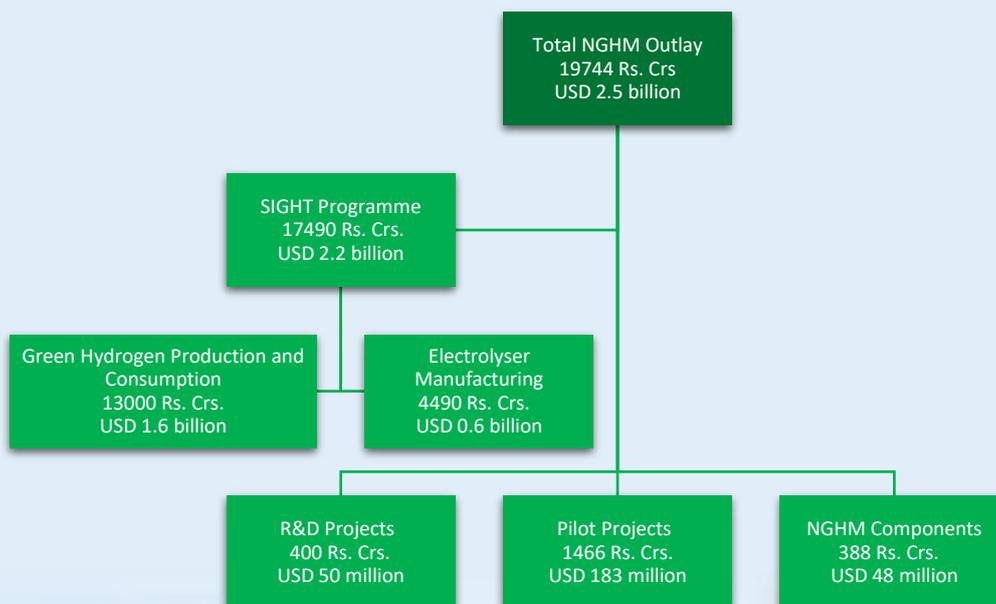


Figure 21 SIGHT Program Accounts for the Largest Share of the NGHM Outlay.

Investment Challenges and Capital Requirements

Green hydrogen initiatives include downstream applications, storage, electrolyze systems, and renewable energy. This results in a lengthy development phase and a setup that requires a lot of capital. The following still restricts financing:

- It is costly to integrate electrolyzers and RE supply.
- Uncertain offtake agreements and unbankable revenue models.
- Underwriting projects of this nature is not something that domestic lenders have much expertise in.

2.4.4.2 Energy Storage: co-location, revenue stacking, tariff design

Co-location

Co-location means building BESS next to wind or solar plants, enabling shared use of personnel, transmission infrastructure, and land. This improves project bankability, boosts transmission capacity utilization, and lowers capital costs. For example, NTPC Renewable Energy Ltd. is developing co-located solar plus storage projects in Rajasthan, Auraiya, and Uttar Pradesh, combining solar capacity with 250 MW/500 MWh BESS to provide round-the-clock power.

Revenue Stacking

Revenue stacking uses a single BESS asset to generate income from multiple value streams, enhancing cash flow since a single stream like energy arbitrage alone may not be viable. Typical streams include energy arbitrage (buy low, sell high), ancillary services (grid frequency and voltage support), capacity payments (availability during peak demand), and renewable firming (smoothing solar/wind variability). In SECI's 2023 1000 MWh BESS auction, developers such as JSW and Greenko bid with models offering fixed capacity payments (₹10.84 lakh/MWh/year) plus flexibility to earn from open access markets through arbitrage or frequency support.

2.4.4.3 Floating Solar and Offshore Wind: early-stage financing

India is expanding clean energy beyond land with emerging technologies like Floating Solar Photovoltaic (FSPV) and Floating Offshore Wind (FOW), which unlock opportunities in land-scarce or sensitive areas. Floating solar, deployed on reservoirs and lakes, saves land and improves efficiency but has higher capital costs (₹7-8 crore/MW) due to specialized structures and cabling. NTPC's 100 MW plant at Ramagundam leads current projects, with more planned by SECI and state utilities. Challenges include limited domestic suppliers, lender unfamiliarity, and lack of standardization. Floating offshore wind, anchored on deep-sea platforms in India's vast 2.3 million km² EEZ, offers clean energy near coastal hubs without land use. It benefits from stronger offshore winds and reduces transmission constraints but is still at an early stage. Financing both technologies faces hurdles from high upfront costs and infrastructure needs.

2.4.4.4 C&I Rooftop and Open Access: business models and Capex/Opex financing

The C&I sector drives India's decentralized renewable energy growth, with rising grid tariffs, volatile energy prices, and sustainability goals pushing C&I consumers toward rooftop solar and open access (OA) contracts. As per Mercom's Q1 2025 analysis, this segment accounts for over 70% of new rooftop solar capacity. Financing depends on the chosen business model - opex or capex - and is influenced by policy risks, contract availability, and state-level regulatory clarity.

By Q1 2025, India’s total rooftop solar capacity surpassed 13 GW, with over 9 GW from the C&I sector. Growth is concentrated in high-tariff industrial states like Maharashtra, Karnataka, Gujarat, Tamil Nadu, and Haryana. Key enablers include declining EPC costs (₹4.0–4.5 crore/MW in capex), payback periods of 3–4 years, net and gross metering in about 20 states, and corporate decarbonization commitments such as RE100 and Science-Based Targets.

In OA, large C&I users (typically >1 MW load) buy renewable power directly from developers, bypassing DISCOMs - especially in Karnataka, Maharashtra, Tamil Nadu, Gujarat, and Andhra Pradesh. However, OA adoption varies due to cross-subsidy and additional surcharges that raise tariffs, inconsistent banking policies across states, and regulatory resistance from DISCOMs in surplus areas.

The financing of rooftop solar projects typically follows two primary models - Capex and Opex (RESCO) - each catering to different consumer profiles and ownership structures, as summarized in **Table 3** below.

Table 3 Capex vs. Opex Financing Models.

Model	Description	Consumer Profile
Capex	Consumer owns the system; invests upfront	Large corporates, captive users
Opex (RESCO)	Developer owns and operates; consumer pays per unit (PPA)	SMEs, tenants, ESG-mandated corporates

De-risking Mechanisms and Policy Enablers

- Investors and lenders are focusing more on project-level risks as India expands renewable energy across utility-scale, distributed, and emerging technologies.
- Key risks include currency exposure, merchant revenue volatility, DISCOM payment delays, and high upfront costs for offshore wind, battery storage, and green hydrogen.
- Financial and policy de-risking mechanisms are vital to attract private capital at scale.
- These include payment security systems, sovereign-backed VGF programs, credit guarantees, and hedging tools.
- Carbon markets and regulatory frameworks are creating new opportunities to monetize renewable energy attributes.

2.4.4.5 Viability Gap Funding: Support for Offshore Wind, Storage, and Green Hydrogen

The Government of India uses VGF as a crucial fiscal instrument to bridge the commercial viability gap for early-stage, capital-intensive renewable energy technologies. For sectors such as offshore wind, grid-scale battery storage, and green hydrogen - which remain financially unviable at their current maturity - VGF reduces developer risk, enhances tariff competitiveness, and attracts institutional capital.

Offshore Wind: ₹7,453 Crore VGF Approved

In June 2024, the Union Cabinet sanctioned a ₹7,453 crore VGF scheme for the country’s first commercial offshore wind projects. Of this, ₹6,853 crore is allocated for the installation and commissioning of 1 GW offshore wind capacity - 500 MW each in Gujarat and Tamil Nadu. An additional ₹600 crore is earmarked for upgrading port infrastructure at two key locations to support heavy-lift logistics and turbine handling.

Battery Storage: Tariff-Linked Support Emerging

While a dedicated VGF for BESS is yet to be formally approved, India's first standalone BESS tender by SECI in 2023 discovered a benchmark capacity charge of ₹10.84 lakh/MWh/year. The government is currently evaluating VGF for hybrid solar-storage projects, standalone grid-integrated storage plants, and BESS deployments focused on ancillary services at the state level. This support is essential to meet the CEA's projected requirement of 47 GW / 236 GWh of BESS by 2030. Complementary mechanisms such as long-term contracts, concessional finance, and revenue stacking will be crucial alongside future VGF schemes.

Green Hydrogen: Incentives via SIGHT

Though not explicitly termed VGF, the Strategic Interventions for Green Hydrogen Transition (SIGHT) program under India's National Green Hydrogen Mission offers similar financial support through performance-linked incentives. It allocates ₹13,050 crore for green hydrogen production (with Tranche I auctions concluded in 2024) and ₹4,490 crore for domestic electrolyzer manufacturing.

2.4.4.6 Payment security mechanisms: SECI, Tripartite, and state-level efforts

One of the persistent challenges to financing renewable energy in India is the risk of DISCOM payment delays or defaults. Investor confidence has been impacted by DISCOMs' weak financials, high AT&C losses, and tariff under-recoveries - particularly under long-term PPAs. To address this, federal and state-level payment security mechanisms have been introduced to reduce lender risk perception and ensure timely payments to RE developers.

SECI's Tripartite Agreement Framework

A key central de-risking tool is the Tripartite Agreement signed by the Reserve Bank of India, Ministry of Power/MNRE, and the respective State Government, ensuring payment security for central agencies like SECI.

Electricity (Late Payment Surcharge) Rules, 2022

Under these rules, DISCOMs must:

- Maintain a Letter of Credit (LC) equal to one month's average billing.
- Face power curtailment if payments are delayed beyond 75 days.

These measures enforce payment discipline and reduce financial risk for bulk RE power buyers.

2.4.4.7 Electricity Derivatives

After nearly two decades of regulatory discussions, India has launched electricity derivatives⁴⁰, marking a new phase in its power market reforms. These financial instruments allow market participants to hedge against the increasing price volatility in the spot electricity market, which is driven by the growing share of intermittent renewable energy.

Regulated by the Securities and Exchange Board of India (SEBI), these derivatives are designed primarily as tools for risk management rather than speculation.

Verticals and Product Details:

The electricity derivatives market consists of several key participants and products:

- **Market Participants (Verticals):**
 - **Hedgers:** These include power generation companies (Gencos), distribution companies (Discoms), and large industrial consumers who use derivatives to lock in future prices, ensuring revenue predictability and cost stability.
 - **Speculators:** Traders who bet on future price movements, providing essential liquidity to the market.
 - **Arbitrageurs:** Entities that capitalize on price differences between the physical and derivatives markets, helping to align prices and improve market efficiency.
- **Derivative Products:** The National Stock Exchange (NSE) and Multi Commodity Exchange (MCX) have launched Monthly Electricity Futures contracts. These are currently the primary derivative products available. Key specifications include:
 - **Settlement:** They are cash-settled, meaning there is no physical delivery of electricity.
 - **Lot Size:** The standard contract size is 50 MWh.
 - **Underlying Index:** The settlement price is based on the volume-weighted average price of the Day-Ahead Market (DAM) across all three of India's power exchanges.
 - **Contract Availability:** Contracts are listed for the current month plus the next three calendar months, allowing for short-to-medium-term hedging.

Hedging Prices and Market Activity

The market has seen robust activity since its launch. In the initial week of trading in July 2025, the total traded value on the NSE crossed ₹450 crore. For the August 2025 contract, prices on July 17, 2025, were trading in the range of ₹4,356/MWh to ₹4,364/MWh. These prices serve as a forward indicator, allowing businesses to hedge their electricity costs for the coming months. The introduction of these derivatives is expected to attract investment and bring greater stability and maturity to India's dynamic power sector.

2.4.4.8 Credit enhancement tools: guarantees, currency hedging

As renewable energy markets mature, financial risks are diversifying - from offtaker payment delays to power price volatility and currency exposure. To reduce financing costs and attract wider institutional investment, credit enhancement tools like hedging instruments, insurance wraps, and partial guarantees are becoming essential.

Partial Risk Guarantees and Blended Risk Cover

- **IIFCL Credit Enhancement:** Originally for toll roads and transmission InvITs, IIFCL's Partial Credit Guarantee (PCG) is now being extended to green bonds and RE portfolios.
- **World Bank-SECI Risk Sharing:** Under the India Solar Risk Mitigation Program, the World Bank, SECI, and IREDA protect developers from DISCOM payment delays and defaults.
- **First Loss Default Guarantees (FLDG):** USAID-PACT, SIDBI, and CEWE-CEF are piloting FLDGs for rooftop and distributed solar in the MSME sector to reduce NBFC lending risk.

Currency and Interest Rate Hedging

- Currency Hedging: Concessional foreign loans face high INR hedging costs of 5-6% annually, impacting ECB viability.
- Interest Rate Swaps: As global lending benchmarks shift to SOFR, RE borrowers increasingly use swaps to lock in long-term borrowing costs.

2.4.4.9 Virtual Power Purchase Agreement (VPPA)

A VPPA⁴¹ is a financial contract that allows organizations, typically large corporations, to invest in renewable energy and meet sustainability targets without taking physical delivery of the power. It functions as a long-term financial hedging instrument between a renewable energy generator (like a solar or wind farm) and a buyer.

The core of a VPPA is structured as a "Contract for Difference" (CfD). The two parties agree on a fixed price for electricity, known as the "strike price". This price is then compared to the variable wholesale market price where the generator actually sells its power. The financial settlement works as follows:

- If the market price is lower than the fixed strike price, the buyer pays the generator the difference, ensuring the project receives its guaranteed revenue.
- If the market price is higher than the fixed strike price, the generator pays the excess revenue back to the buyer, allowing the buyer to benefit from high market prices.

Through this arrangement, the buyer does not use the actual electricity from the project but receives the associated Renewable Energy Certificates (RECs). These certificates are the primary tool that allows the company to claim the environmental benefits and make progress on its renewable energy and decarbonization goals.

VPPAs offer several key advantages:

- Geographic Flexibility: Since no physical power is delivered, a company can support a renewable project located anywhere on the grid, regardless of its own operational footprint.
- Financial Predictability: They provide a hedge against volatile electricity prices for both the generator, who gets a stable revenue stream, and the buyer, who can offset their own energy costs.
- Enables New Projects: The long-term revenue certainty provided by a VPPA is often crucial for developers to secure the financing needed to build new renewable energy capacity.

In India, VPPAs are being formally recognized within the power market regulations, providing a structured pathway for large commercial and industrial consumers to fulfill their renewable purchase obligations and support the country's energy transition.

2.4.4.10 Contract for Difference (CfD)

CfDs are financial instruments used by governments and private entities to manage price volatility in various markets, including energy⁴². A CfD is an agreement between a seller (such as a power generator) and a buyer to settle the difference between a pre-agreed "strike price" and the actual market price of an asset.

This mechanism effectively provides revenue certainty.

- If the market price is below the strike price, the buyer pays the generator the difference, protecting the generator's income.

- If the market price is above the strike price, the generator pays the excess back to the buyer, protecting the consumer from high prices.

As derivative instruments, CfDs hedge against price movements and can be structured as purely financial contracts or linked to the physical delivery of the asset.

For India's renewable energy sector, two-sided CfDs are particularly valuable. By guaranteeing a stable revenue stream for renewable generators, they can significantly enhance investor confidence, de-risk projects, and accelerate the addition of new clean energy capacity.

2.4.4.11 Carbon markets and monetization of RE attributes

India's Domestic Carbon Market (CCTS)

Operationalized under the amended Energy Conservation Act (2022), the Carbon Credit Trading Scheme (CCTS) is India's first official domestic carbon market. Administered by the Bureau of Energy Efficiency (BEE), it follows a hybrid compliance + voluntary model with sectors added in phases. Under the voluntary track, small-scale solar, wind, and biomass projects can earn and trade credits, offering RE developers - especially those without long-term PPAs - a new revenue stream

Renewable Energy Certificates (RECs)

RECs have long enabled RE generators to monetize power not directly sold to obligated entities. In February 2024, Avaada Energy sold surplus solar power from its Madhya Pradesh plant - partially tied to a long-term PPA - on the Indian Energy Exchange (IEX) via REC trading. The excess generation was registered as RECs and auctioned, mainly purchased by DISCOMs and open access users to meet their Renewable Purchase Obligation (RPO). The non-solar REC clearing price was ₹1,100 per certificate, equivalent to 1 MWh of clean energy.

Renewable Energy
Integration Challenges -

PLANNING AND STORAGE SOLUTIONS



As India scales up its renewable energy (RE) capacity towards the 500 GW target by 2030, integrating such a large volume of variable and intermittent sources into the grid presents a set of complex technical, market, and policy challenges. This chapter explores the evolving landscape of RE integration, the critical role of energy storage and green hydrogen, flexibility needs, planning tools, and state-level implementation nuances. It also analyses key infrastructure initiatives such as the Green Energy Corridor and their readiness to support large-scale integration.

3.1. Role of Energy Storage and Green Hydrogen

3.1.1. Utility-Scale Storage Deployment in India

India's ambition to achieve 500 GW of non-fossil fuel capacity relies heavily on solar and wind power, which are inherently variable and intermittent. The Energy Storage Systems (ESS) - especially BESS & PSP are pivotal in managing this variability, ensuring grid stability and reliability. By storing surplus renewable energy during periods of high generation and releasing it during peak demand or low generation hours, BESS minimizes curtailment, reduces reliance on conventional peaking sources, and optimizes overall generation and dispatch costs **Figure 22** illustrates the typical role of Energy Storage Systems (ESS) in enhancing power system stability and reliability, while **Figure 23** complements this by showcasing the diverse use cases of ESS across the power system. Moreover, BESS enables round-the-clock (RTC) power supply, making renewable energy a viable continuous power source. It also strengthens resource adequacy by ensuring energy availability when it is needed most, thereby supporting system reliability. In the context of growing electricity demand from electric vehicles, urbanization, and industrial development, BESS plays a critical role in enhancing India's energy security and accelerating its transition towards a clean, resilient, and self-reliant energy future.

Grid Stability	• Balances supply-demand fluctuations
Energy Arbitrage	• Buys low, sells high
Renewable Integration	• Reduces curtailment and smoothens output
Ancillary Services	• Supports frequency and voltage control
Peak Shaving	• Reduces demand during peak hours
Grid Deferral	• Avoids costly T&D upgrades
Backup Power	• Ensures supply during outages

Figure 22 Typical Role of Energy Storage - BESS & PSP.

The Ministry of Power (MoP), through its order dated January 29, 2022⁴³, formally recognized ESS as an essential component of the power system under clause (50) of Section 2 of the Electricity Act, 2003⁴⁴. ESS, especially BESS and PSP, can operate as a standalone generating system or in conjunction with generation, transmission, or distribution functions. Its regulatory classification depends on its application area, and it can be developed, owned, leased, and operated by a range of entities including generating companies, transmission and distribution licensees, system operators, and independent storage providers. ESS has also been designated as a delicensed activity, like generating stations, and is eligible for grid connectivity under the Electricity (Transmission System Planning, Development and Recovery of Inter-State Transmission Charges) Rules, 2021⁴⁵.

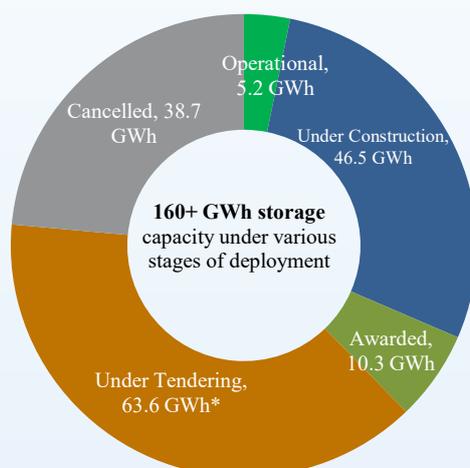


Figure 23 Typical Use Case for of ESS - BESS & PSP.

As of April 2025⁴⁶, India’s operational battery storage capacity stands at just 0.5 GWh, but deployment is accelerating. In 2025 alone, over 16 GWh of standalone BESS tenders have been issued by agencies like NTPC, NHPC, GUVNL, NVVN, SJVN, and TGGENCO, raising the cumulative tendered volume to nearly 24 GWh. Around 7.5 GWh is under construction, expected to be commissioned by late 2026 or early 2027. Another 50 GWh is in the tendering phase, potentially entering construction by end-2026, taking the total pipeline beyond 50 GWh. CEA’s NEP 2023 highlights the increasing role of both BESS and PSP in enabling renewable energy integration, grid reliability, and system flexibility.

Figure 24 presents the current status of energy storage projects in India as of May 2025, drawing from sources including CEA⁴⁷, the Press Information Bureau (PiB)⁴⁸, and NEP 2023⁴⁹. **Table 4** presents projected BESS and PSP capacities (GW/GWh) for 2026–27, 2029–30, and 2031–32, underscoring India’s strong policy push for a flexible and resilient power system. As per NEP 2023, India will require 38.5 GW/201.5 GWh of battery storage by 2031–32 to support grid balancing, RE integration, peaking, and frequency regulation. The plan also anticipates a drop in grid emission intensity from 0.548 kg CO₂/kWh in 2026–27 to 0.430 kg CO₂/kWh by 2031–32, enabled partly by storage-backed clean energy dispatch.

To accelerate this transition, MNRE has introduced measures such as the VGF scheme (Tranche-1 and 2) for battery projects and central/state tenders promoting hybrid RE+storage models. These are supported by updated guidelines for BESS and PSP, which emphasize their role in long-duration and seasonal balancing (see **Figure 25** for policy and regulatory evolution).



Source: CEA PiB, * includes PSP of 7.5 GW DPR concurred by CEA

Figure 24 Status of ESS projects in India (PSP + BESS) (As of May 2025) in GWh.

Table 4 NEP 2023 Generation Projections for ESS - BESS & PSP.

YEAR	BESS (GW/GWh)	Pumped Storage (GW/GWh)	TOTAL (GW/GWh)
2026-27	8.68 / 34.72	7.45 / 47.65	16.13 / 82.37
2029-30	41.6 / 208.2	19.0 / 128.2	60.6 / 336.4
2031-32	47.2 / 236.2	26.7 / 175.2	73.9 / 411.4

3.1.2. Economics and Tariff Design for Storage

BESS are becoming crucial for managing renewable energy variability and ensuring grid stability. The total deployment cost is around \$120/MWh, with \$80 attributed to batteries and containers, mainly imported from China, highlighting the need for domestic manufacturing and supply chain localization. Lithium, while critical, forms only a small part of battery costs and is also largely sourced from China.

Though lithium-ion battery recycling is technically feasible, it remains costly, about twice the value of recovered materials. The ecosystem is further limited by the early stage of large-scale BESS deployment. To scale adoption, end users should be incentivized alongside generation and distribution companies, supported by regulatory frameworks.

Solar-plus-storage costs ₹6-7/unit, higher than standalone solar at ₹2.5/unit, but still competitive during peak hours. The Indian Energy Exchange (IEX) has reported sharp price spikes during the 5-6 PM transition, driven by solar dips and ramping needs, where BESS can help stabilize prices. Compared to the costlier and less mature CSP with Thermal Energy Storage (TES), BESS offers greater viability, though technology choice should depend on use case, not just cost.

Despite growing momentum, the sector faces challenges from rapidly falling tariffs. In Solar + BESS projects, L1 tariffs dropped 53% from ₹6.99/kWh in 2018 to ₹3.09/kWh by 2024⁵⁰, even as storage needs increased. For standalone BESS, tariffs declined nearly 75% from ₹10.8 lakh/MW/month⁵¹ in 2022 to ₹2.16 lakh/MW/month⁵² by 2025. Such declines, coupled with stricter specs and deeper market penetration, have raised concerns about commercial viability, with stakeholders warning of possible delays or project failures due to unrealistic tariff expectations.

3.1.3. Energy Storage for Ancillary Services and Peaking Power

India is advancing rapidly in integrating Energy Storage Systems (ESS) for ancillary services and peaking needs, with the Central Electricity Regulatory Commission (CERC) recognizing ESS as vital for grid stability, flexibility, and renewable energy integration.

ESS now supports frequency regulation, ramping, and black-start functions. Under the CERC Ancillary Services Regulations 2022, ESS qualifies for Secondary (SRAS) and Tertiary Reserves (TRAS), requiring AGC compliance, SCADA connectivity, a minimum 1 MW capacity, and fast response - making ESS ideal for these services. Procurement is structured where SRAS is acquired through nodal agencies using cost and ramping-based participation factors, while TRAS is procured via day-ahead and real-time markets. Both receive capacity and variable charges, settled weekly through the DSM pool based on SCADA performance.

Pilot projects confirm ESS readiness. The 150 MW/300 MWh Fatehgarh BESS⁵³ delivers multiple reserve services at ₹1.08 million/MW/month, with parameters like 85% efficiency and two cycles/day. It features single-point metering, SCADA integration, and is operated via SECI. Fast Response Ancillary Services (FRAS) pilots are also evaluating hydro and RE assets for AGC-based real-time dispatch, testing system flexibility and ESS performance.

To scale ESS, India will need improved automation (AGC, SCADA), transparent reserve pricing, and secure settlements. ESS participation in ancillary markets signals a shift from thermal to fast-response, clean energy systems - crucial for building a stable, resilient, and affordable grid.

3.1.4. Green Hydrogen as a Long-Term Storage Solution

Green hydrogen is emerging as a vital long-duration energy storage solution for India, complementing BESS by addressing inter-day to seasonal balancing needs while enabling decarbonization across power, industry, and transport sectors. Unlike BESS suited for short-duration use, green hydrogen offers storage flexibility over longer timescales.

Launched in January 2023, India's National Green Hydrogen Mission targets 5 MMT annual production by 2030, supported by 125 GW of RE and a ₹19,744 crore budget. It includes manufacturing incentives (SIGHT), pilot projects, R&D, and infrastructure for hydrogen hubs, pipelines, and storage.

Green hydrogen helps manage seasonal RE-demand mismatches by converting surplus solar/wind into hydrogen via electrolysis. This hydrogen can be re-electrified or supplied directly to end-use sectors, displacing fossil fuels.

Key Use Cases:

- **Grid Integration:** Converts midday solar surplus into hydrogen, improving grid stability; hydrogen turbines/fuel cells supply power during peak hours.
- **Industrial Decarbonization:** Replaces grey hydrogen in sectors like refineries, ammonia, and steel (DRI), enabling 24x7 RE use.
- **Hydrogen Blending:** Injects 10–20% hydrogen into gas pipelines for cleaner heating, cooking, and industrial processes using existing infrastructure.
- **Energy Hubs:** Co-located RE and hydrogen facilities can streamline production, storage, and export, serving as grid balancing points.

Challenges remain, high costs, low round-trip efficiency (30–40%), lack of infrastructure, and safety concerns. India must scale pilots integrating RE, electrolyzers, and fuel cells; incentivize hydrogen-compatible power assets; develop markets for long-duration flexibility; and ensure inter-ministerial coordination on blending norms and infrastructure.

Green hydrogen thus complements BESS, offering a clean, scalable pathway for seasonal storage and deep decarbonization.

3.1.5. Policy and Regulatory Landscape for Storage and Hydrogen

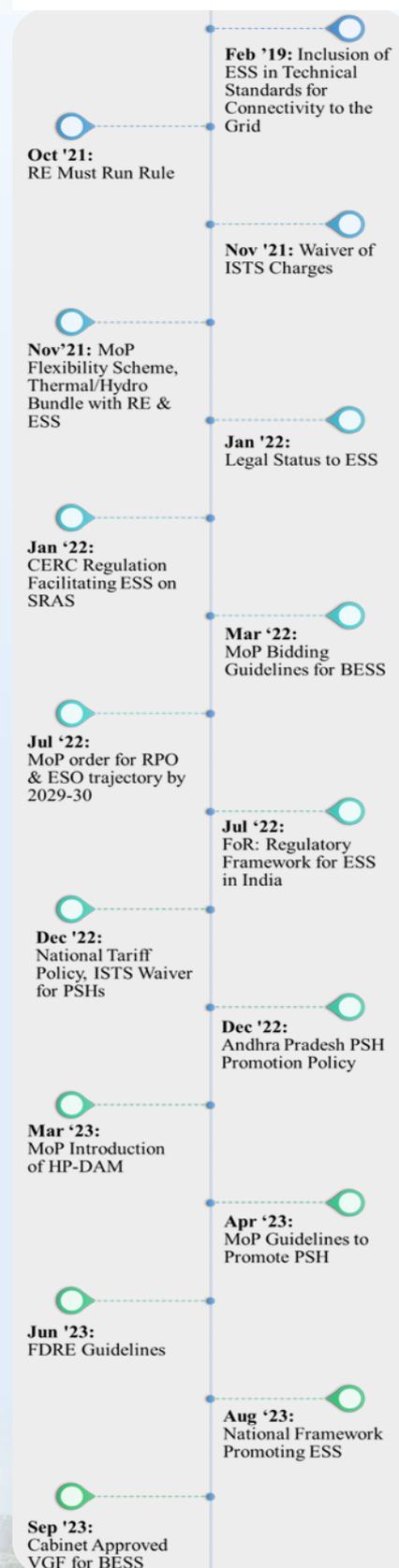
India’s policy and regulatory framework for ESS has evolved to support grid flexibility, renewable energy integration, and reliability enhancement. The CEA has incorporated storage norms into its generation planning frameworks, reflecting the growing recognition of ESS as a critical infrastructure element. The MNRE has actively supported the deployment of standalone and co-located BESS through capital grant-based tenders, especially for RTC and peak power applications.

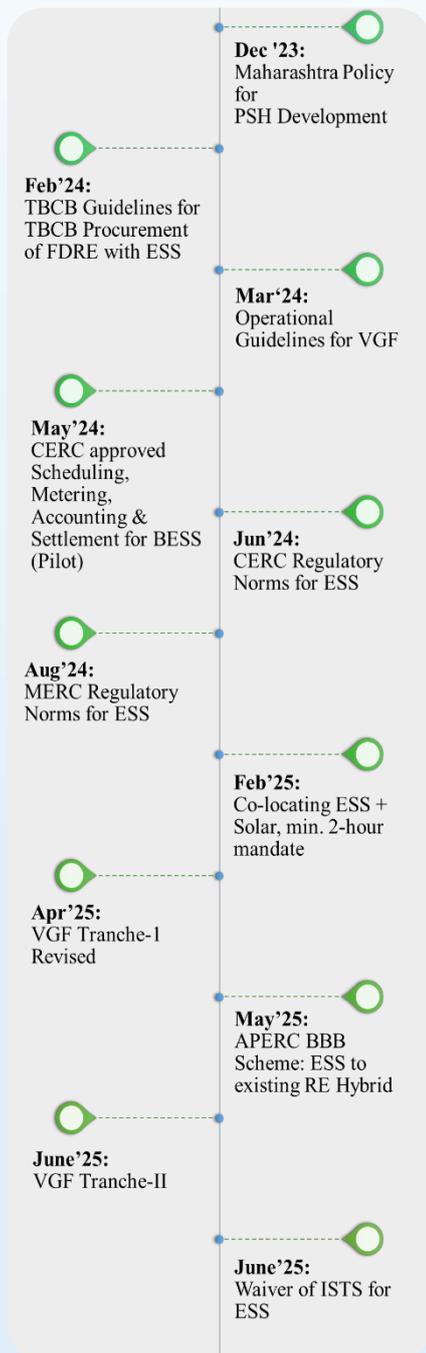
To boost viability, the GoI has undertaken various schemes, orders, policies & regulatory steps (refer **Figure 25**) like a recent order on ISTS waiver for co-located BESS projects commissioned before June 2028. This incentive has significantly improved the economic case for RE + Storage hybrid projects. However, regulatory clarity is still evolving on several operational dimensions such as interconnection standards, grid connectivity, scheduling protocols, and cost recovery mechanisms - especially for standalone BESS.

Ancillary service markets remain underdeveloped. While POSOCO and CERC have introduced limited mechanisms (like Fast Frequency Response using BESS), broader participation of ESS in ancillary procurement remains constrained. Moreover, India lacks proper tariff structures or flexible pricing signals (such as time-of-day pricing or ramping incentives) that would allow ESS to monetize multiple value streams like arbitrage, peaking, and reserves.

India’s hydrogen policy landscape is anchored in the Green Hydrogen Policy (2022) and the National Green Hydrogen Mission (2023), and various policy measures have been undertaken in the last five years (refer **Figure 26**). The NGHM defines green hydrogen, sets a target of 5 MTPA of green hydrogen by 2030 (with a stretch target of 10 MTPA including exports), and outlines a roadmap for demand creation in priority sectors like refineries, steel, fertilizers, shipping, and heavy transport. It also supports electrolyzer manufacturing, infrastructure development (including hydrogen hubs, pipelines, and storage), and R&D.

Figure 25 Policy & Regulatory Evolution of ESS in India.





To accelerate adoption, the IH2A (India Hydrogen Alliance)⁵⁴ has submitted a final proposal to the Government of India, recommending the introduction of 10% Hydrogen Purchase Obligations (HPOs) for existing facilities and 100% HPOs for new refineries and ammonia plants by 2030, in line with the National Green Hydrogen Mission (NGHM) 2030 targets. These are intended to ensure long-term demand visibility for producers, especially in refining and fertilizer sectors. However, implementation remains uneven across states.

At the sub-national level, as of March 2024⁵⁵, six Indian states (Maharashtra, Uttar Pradesh, Andhra Pradesh, Rajasthan, Odisha, and West Bengal) have announced dedicated state green hydrogen policies. States like Madhya Pradesh and Karnataka have included green hydrogen provisions within broader RE policies. Meanwhile, Gujarat, Kerala, Punjab, and Haryana are preparing dedicated policies. These regional policies offer location-specific incentives, demand targets, and provisions for low-cost renewable energy access. (refer **Figure 27** for hydrogen demand sites in India CEEW).

The PNGRB (Petroleum and Natural Gas Regulatory Board)⁵⁶ is playing a central role in enabling hydrogen blending into gas networks. It has approved India's first hydrogen blending project in the Gujarat Gas network, supplying NTPC's Kawas Township. PNGRB is currently developing regulatory norms around hydrogen blending thresholds, pipeline tariff methodologies, safety standards, and open access rules - essential for scaling commercial hydrogen transport.

Despite notable progress, India's policy framework for ESS and green hydrogen still has key gaps that hinder market growth and investment:

- **No capacity or flexibility markets** to compensate ESS or hydrogen for reliability, limiting long-term contracts and investor confidence.
- **Lack of carbon pricing** prevents environmental benefits from being reflected in cost analyses or dispatch decisions.

- **Limited ancillary service mechanisms**, with pilots in place but insufficient scale or inclusion of hydrogen technologies.
- **Inadequate tariff structures**, lacking dynamic pricing, peak/off-peak differentiation, or locational signals needed to value flexibility.
- **Regulatory fragmentation**, with uneven state-level adoption and poor coordination with central mandates.
- **Incomplete infrastructure and standards**, including grid codes for ESS and safety/purity norms for hydrogen.

To address these, India must develop frameworks for stacked revenue streams, implement carbon and time-of-day pricing, and finalize interoperable standards. A coordinated national-state policy approach is essential to unlock scale, bankability, and a just energy transition.

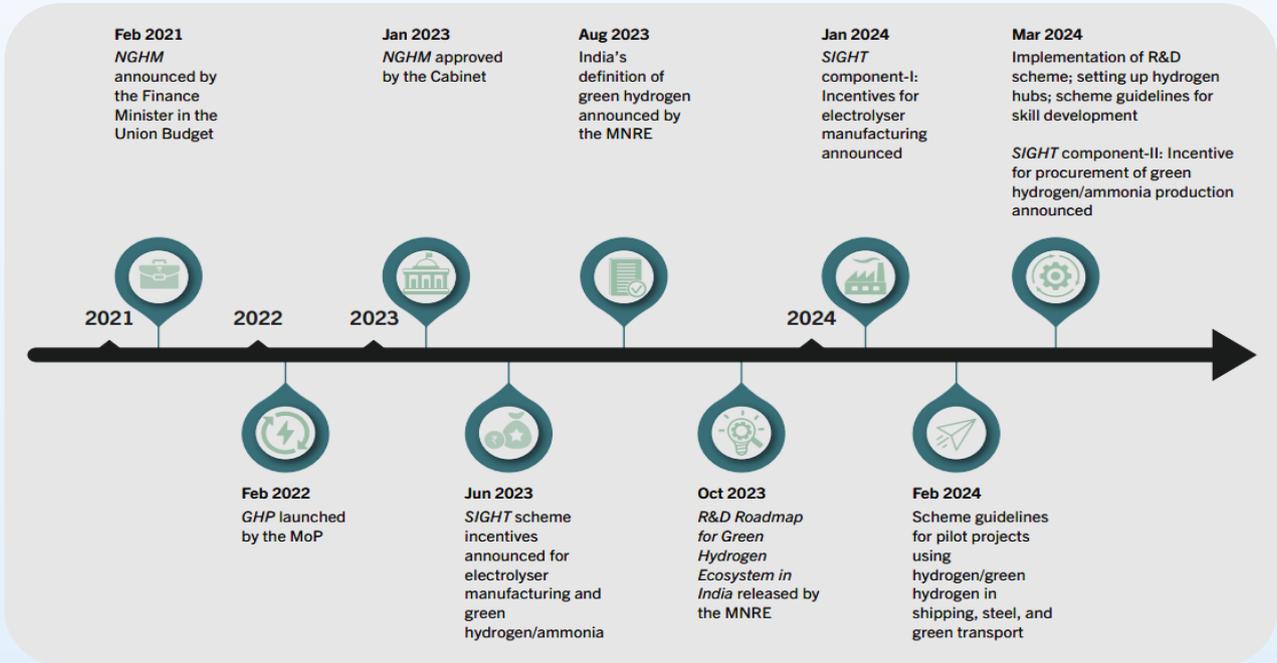


Figure 26 Green Hydrogen Related Policy Milestones, CEEW.

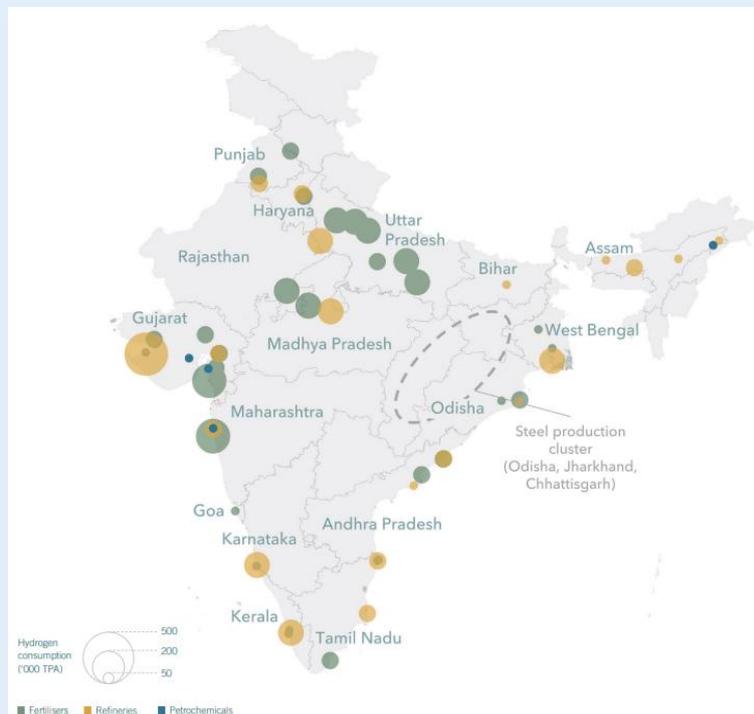


Figure 27 Hydrogen Demand Sites in India (FY 2020, in TPA), CEEW.

3.2. Need for Flexibility in Power Systems

India's transition to a high renewable energy future is transforming power system operations. The rising share of variable renewables like solar and wind has increased generation variability, making system flexibility essential for ensuring reliability, affordability, and security. This section examines the key aspects of flexibility - its definition, supply- and demand-side sources, market enablers, and the growing role of distributed technologies.

3.2.1 Defining and Quantifying Flexibility Needs

In power systems, flexibility is the grid's ability to respond efficiently to changes in net load - total demand minus variable renewable energy (VRE) - across timescales ranging from milliseconds to seasons. It involves key operations like ramping generation, maintaining frequency and voltage stability, and tracking load variations. The rising need for flexibility is mainly due to two factors: the timing mismatch between midday renewable generation and evening.

As the share of VRE in the power mix continues to grow, the inherent intermittency and variability of such sources have led to a substantial rise in system flexibility requirements. This is evident in the form of sharper ramping demands, larger forecast deviations, and the need for increased reserve margins. In response, India has, over the past decade, initiated a series of modelling studies, regulatory measures, and operational frameworks aimed at understanding and addressing these emerging challenges (refer **Figure 28**). Together, these efforts form a strategic foundation for enabling the reliable integration of higher levels of VRE into the national grid.

Among the key modelling studies, TERI's 2020 report *Renewable Power Pathways: Modelling the Integration of Wind and Solar by 2030 in India*⁵⁷ was one of the first high-resolution, India-specific simulations assessing system-wide flexibility needs. In its Baseline Capacity scenario, solar generation frequently exceeded the turndown limits of coal plants, typically bound by a 55% technical minimum, forcing many into two-shifting operations - particularly in April, when up to 16 GW of capacity was affected, and similarly in March, May, and June.

To mitigate this, TERI modelled a *High Thermal Flexibility* scenario where coal plants could operate at 30–40% minimum load, significantly reducing the need for shutdowns. Even under a *Transmission Flexibility* scenario, high two-shifting persisted, underscoring that flexibility challenges were systemic, not regional. The study also emphasized the role of flexible hydropower with storage for peak and intra-day balancing.

Complementing these findings, a 2030 scenario with large-scale battery deployment showed VRE curtailment dropping from 4% to <0.2%, two-shifting halved, and extreme coal ramping events (>500 MW/min) reduced from over 50% of days to 32%. These results, echoed by the 2020 NREL–Grid India report⁵⁸, reinforce the need to retrofit coal plants, optimize hydro, and scale battery storage with clear targets and enabling policies by 2030 to build a flexible, low-carbon power system.

Over the past decade, India has conducted extensive studies and introduced policies to address the growing flexibility needs of its power system amid rising VRE integration. These include detailed modelling and regulatory guidelines to support system planning.

Flexibility requirements differ by region - Rajasthan faces steep daily solar ramps, while Tamil Nadu needs intra-day wind balancing. Karnataka⁵⁹ presents a unique challenge, with solar expected to meet 40% of capacity by 2026-27. By 2030, it will face a sharp 11 GW ramp in one hour, 30% of peak demand, double the

national average. This underscores the need for a balanced mix of short-term solutions like storage and demand response, alongside long-term options such as hydro, thermal, and inter-regional transfers.

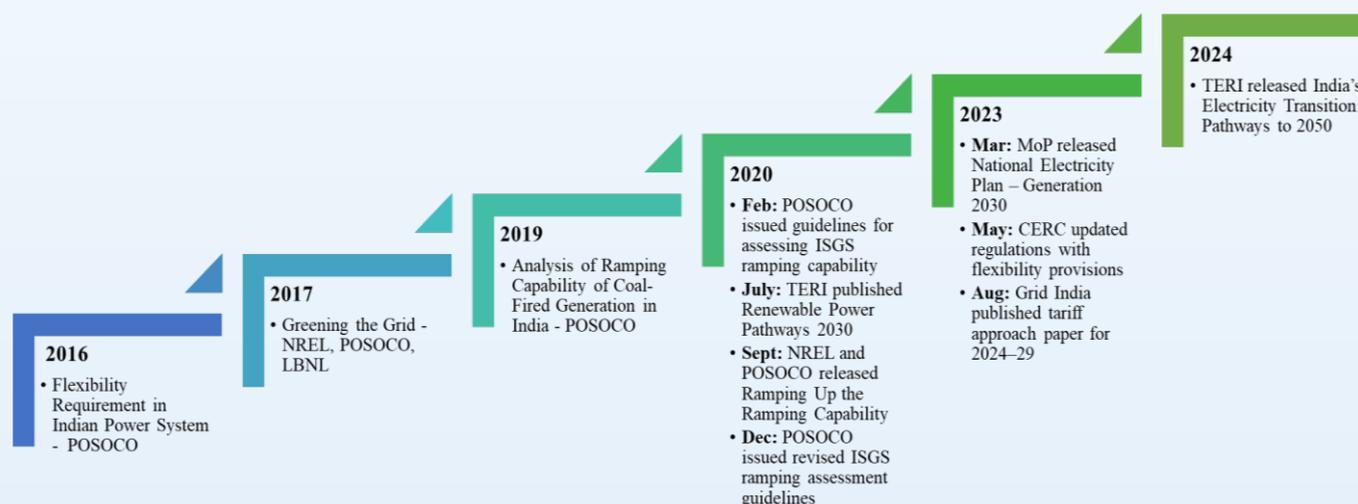


Figure 28 Studies and Policies for Flexibility Needs of the Indian Power System.

3.2.2 Conventional Generation Flexibility and Retrofit Challenges

As India rapidly expands renewable energy, coal-based generation remains a key pillar of the power system. However, these thermal plants, designed for steady baseload operations, are now being pushed to operate flexibly to manage VRE variability. Flexible operations pose technical and economic challenges. Most plants need retrofits to improve part-load efficiency and ramping. Reforms like coal linkage aggregation have helped optimize fuel supply. Gas-based plants, though underutilized, offer fast ramping and are well-suited for short-term balancing.

Key challenges in enhancing coal plant flexibility include low ramp rates (typically 1–2% per minute), which are inadequate to meet steep evening demand surges. Operating below 55–60% load leads to inefficiencies and elevated emissions, while frequent two-shift operations accelerate wear and tear on equipment. Additionally, increased auxiliary power consumption and higher startup fuel costs further impact economic viability.

Pilot projects offer valuable insights:

- **NTPC Dadri⁶⁰** achieved 3% ramping and stable 40% load operations with digital upgrades.
- **USAID GTG-RISE⁶¹** pilots at NTPC and GSECL showed reduced technical minimums, cutting RE curtailment from 3.7% to 0.76%.
- **Additional pilots** at Mauda, Sagardighi, Vindhyachal, Anpara, Ukai, and Mouda demonstrated operations at 40% load, involving partners like BHEL, JCOAL, TEPCO, JERA, and IGEF.
- **Others⁶²:**
 - BHEL conducted flexible operation pilot tests at Mauda TPS of NTPC and Sagardighi TPS of WBPDC.

- Vindhyachal STPS, NTPC and at Anpara B TPS, UPRVUNL by JCOAL, Japan.
- Unit-6 (500 MW) of Ukai Thermal Power Station, operated by GSECL, was scheduled by CEA and successfully executed by BHEL on 4th March 2020.
- Efficiency test at Mouda Thermal Power Station, NTPC has been conducted between 6th January 2020 to 10th January 2020 by TEPCO Power Grid Inc. and JERA, Japan under the observation of CEA.
- Flexible operation (up to 40% load) test has been conducted at Unit-2 500MW MPL, Maithon (Unit-2) of JV DVC & TATA Power under IGEF from 19-29th July, 2021.
- Further, Unit-7 Ramagundam TPS NTPC and Unit-3 Raichur TPS KPCL are under flexible operation study/test in association with Denmark.

The long-term viability of flexible thermal operations will require policy support, including capacity compensation, differentiated tariffs for flexible operation, and retrofitting cost recovery mechanisms.

3.2.3 Role of DSM and Demand Response Mechanisms

Demand-side interventions like Demand Side Management (DSM) and Demand Response (DR) are gaining traction as scalable, cost-effective tools to boost power system flexibility. By adjusting consumption in response to grid conditions or price signals, these measures help reduce peak load, shift demand, and lower balancing costs.

Smart grid infrastructure - featuring advanced metering, outage management, and automated controls - enhances grid responsiveness and enables consumer participation in real-time operations.

Key interventions include:

- **Time-of-Day (ToD) tariffs:** Adopted across most states for HT consumers; DISCOMs like MSEDCL, TANGEDCO, and APSPDCL report 5-10% load shifting.
- **Smart meters & AMI:** Rolled out under RDSS, enabling granular consumption data and targeted DR programs.
- **Automated DR (ADR):** Uses systems like BMS to respond automatically to grid signals. BESCOM's smart grid pilot showed up to 15% peak reduction.

Case studies:

- **Haryana:** Industrial consumers reduced non-critical loads during peak RE periods.
- **BESCOM:** Residential consumers used smart meters and alerts to reduce usage during high-demand times.

Scaling DSM/DR requires not only technology but also customer engagement, standardized protocols, and incentive structures in both regulated and market-based programs

3.2.4 Market-Based Solutions for Flexibility Procurement

The evolution of electricity markets in India is enabling flexibility procurement through market-based mechanisms, which help match supply and demand more efficiently.

Key developments include:

- **Real-Time Market (RTM):** Launched in 2020 by IEX and PXIL, RTM allows 15-minute interval trading closer to actual demand-supply situations. It improves grid balancing and RE integration by allowing last-minute adjustments. RTM volume reached 4,770 MU in May 2025⁶³, indicating growing utility participation.
- **Ancillary Services Market (ASM):** Operational under CERC's Ancillary Services Regulations 2022⁶⁴, it enables procurement of secondary and tertiary reserves from thermal, hydro, and in the future, BESS and DR providers. Performance-based payments encourage faster response.
- **Future Flexibility Procurement:** CERC Discussion Paper: Market-Based Economic Dispatch (MBED), 2018⁶⁵ proposed evolution of electricity markets, relevant for future flexibility procurement.
- **Flexibility tenders:** Some states and utilities (e.g., Delhi, Gujarat) have issued pilot tenders to procure fast ramping or peak support capacity, particularly during RE surplus or deficit periods.

However, market maturity is still evolving:

- **Liquidity constraints** in early morning or high-RE periods can limit effectiveness.
- **Price caps and inadequate compensation** deter participation from BESS and other flexible providers.
- **Lack of forecasting transparency**, curtailment practices, and grid code ambiguities restrict advanced participation.

A more robust framework - including nodal agencies for flexibility auctions, portfolio-based RE + storage contracts, and value stacking mechanisms - can unlock the full potential of market-based flexibility.

3.2.5 Wholesale Market Design for High RE: The Role of Market Coupling

In a landmark order on July 23, 2025, CERC announced⁶⁶ its decision to implement market coupling for India's power exchanges. Market coupling is a mechanism that pools all buy and sell bids from multiple power exchanges and matches them through a unified system to discover a single, uniform clearing price for electricity. This initiative is expected to increase market depth, reduce price disparities between exchanges, and lower the overall cost of power by optimizing the use of generation and transmission resources.

Key Aspects of the CERC Notification:

- **Phased Implementation:** The rollout will occur in stages. The CERC has directed the coupling of the DAM segment across all power exchanges to begin by January 2026.
- **Future Scope:** The decision to couple other market segments, such as the Real-Time Market (RTM) and Term-Ahead Market (TAM), will be considered at a later stage after assessing the operational experience from the DAM coupling.
- **Operational Framework:** Power exchanges will take turns acting as the Market Coupling Operator in a "round-robin" model. Grid-India, the national grid operator, will serve as a supplementary and auditing entity.

- **Pilot Program:** The decision follows a successful shadow pilot program conducted from December 2024 to March 2025, which demonstrated an overall welfare increase and a reduction in price volatility.

This reform is considered a strategic move to create a more efficient and integrated national power market. However, it is expected to impact the dominance of the Indian Energy Exchange (IEX), which currently handles nearly 90% of electricity trading volumes.

3.2.5 Flexibility from Distributed Energy Resources and BESS

Distributed Energy Resources (DERs) and BESS are emerging as key enablers of both local and grid-level flexibility in India's evolving power system. DERs, such as rooftop solar, behind-the-meter storage, and EVs, offer decentralized flexibility, aiding real-time grid balancing, load flattening, and system resilience, especially across distribution networks. BESS plays a central role in VRE integration by smoothing generation, storing excess energy, providing fast-response ancillary services, and improving transmission and distribution efficiency. Policy measures now support BESS deployment across use cases like grid stability, generation support, and market-based services, accelerating its adoption. India's planning framework includes a 5% spinning reserve norm⁶⁷, reinforcing the need for ramp-capable assets like BESS. The ancillary services market is expanding to accommodate BESS and responsive loads, diversifying grid flexibility. Pumped hydro storage (especially off-river PSPs) complements BESS by offering long-duration flexibility at lower capital costs and quicker timelines. These plants provide peaking power, reserves, and black-start capability.

To enable deeper renewable integration, the Ministry of Power has introduced a bundling framework pairing RE and storage with thermal/hydro sources⁶⁸. This helps DISCOMs meet RPOs economically while encouraging flexible generation.

Key DER-based flexibility options include:

- Rooftop solar + storage: Allows self-consumption and demand flattening.
- EVs with V2G: Enable services like peak shaving and voltage control.
- Community-scale RE + storage: Microgrids and peer networks boost local resilience.

Challenges to scale include:

- Lack of aggregation frameworks for market participation.
- Inadequate metering and telemetry in residential DERs.
- Unclear ownership and compensation for DER services.

Pilots in Delhi (solar + battery net metering)⁶⁹, Kerala (energy communities)⁷⁰, and V2G demonstrations by KSEB⁷¹ show technical feasibility. Scaling DER flexibility will require dynamic tariffs, regulatory recognition of aggregators, and interoperable digital infrastructure.

3.3. Planning Challenges in Grid Integration

India's ambitious renewable energy goals and the growing variability from solar and wind have highlighted key planning challenges for smooth grid integration. These include the need for accurate forecasting, strengthened transmission networks, resource adequacy, appropriate market incentives, and the use of advanced planning tools. Successfully managing high RE penetration requires an integrated planning approach that bridges technical, regulatory, and market frameworks.

3.3.1. Forecasting and Scheduling of Variable RE

Accurate forecasting and scheduling of variable renewable energy (RE) are essential for grid stability, with SLDCs mandated to monitor day-ahead and intra-day forecasts. While compliance has improved, wind forecast accuracy remains a challenge due to high variability. Advances in AI and machine learning are enabling more precise 15-minute predictions by combining meteorological and plant-specific data, as seen in pilots across Tamil Nadu, Gujarat, and Karnataka⁷². The F&S and DSM framework has helped enforce discipline through deviation penalties, though enforcement remains inconsistent, especially for smaller generators. Strengthening coordination among SLDCs, REMCs, and RE developers, alongside improved state regulations, is key to making forecasting a reliable grid management tool.

3.3.2. Transmission System Planning under High RE Scenarios

With growing RE capacity, often far from demand centers, India's transmission planning faces spatial and temporal alignment challenges. The CEA's National Electricity and Transmission Plans provide a long-term framework, while Renewable Energy Zones (REZs) and Dedicated RE Corridors under ISTS support bulk power evacuation from regions like Rajasthan, Gujarat, and Tamil Nadu. However, delays in transmission due to clearances and EPC issues often misalign with RE project timelines, causing curtailment and stranded assets. A "plug-and-play" approach with synchronized development is needed, along with better coordination between state and central planning to ensure integrated infrastructure rollout.

3.3.3. Long-Term Resource Adequacy and Reserve Planning

Resource adequacy planning is critical to ensuring reliable electricity supply during peak demand. India's *Resource Adequacy Planning Guidelines*⁷³ mandate DISCOMs to plan procurement of generation, storage, and flexible resources in advance through a multi-level institutional mechanism spanning national to DISCOM levels. However, the absence of a unified national framework limits consistency, though some states and system operators have initiated independent efforts.

In 2023, CEA released *Guidelines for Resource Adequacy Planning Framework for India*⁷⁴, outlining methodologies to estimate the capacity contribution of different technologies using metrics like Effective Load Carrying Capability (ELCC) and Capacity Credit - key to valuing VRE and storage during peak periods. NEP 2023 also introduced a 5% spinning reserve norm⁷⁵, but actual deployment often falls short due to lack of compensation and enforcement. As demand evolves with electrification and climate risks, India must adopt a probabilistic, multi-scenario resource adequacy framework that includes storage adequacy metrics. Institutionalizing this process through the Forum of Regulators (FoR), Regional Power Committees (RPCs), with guidance from CEA and POSOCO, will be essential to prevent capacity shortfalls and stranded investments.

3.3.4. Role of ISTS Waiver and Congestion Signals

The Inter-State Transmission System (ISTS) waiver policy, which exempts solar, wind, and hybrid (solar-wind) projects from transmission charges, has been instrumental in driving large-scale RE deployment by reducing delivered power costs. The recent extension of this waiver until June 2028 has further improved investment visibility, especially for PSPs and BESS. However, the policy has also led to project siting being influenced more by incentive structures than by locational efficiency, contributing to congestion in RE-saturated regions and increasing the risk of curtailment and grid reliability issues.

To address these concerns, India must transition toward cost-reflective, location-sensitive pricing mechanisms. Introducing Locational Marginal Pricing (LMP) or zonal congestion pricing would signal the true value of injecting power at specific nodes, directing investment toward underutilized corridors⁷⁶. Moreover, a coordinated review of waiver extensions, based on grid availability and proximity to load centers, is essential to ensure optimal infrastructure use. The adoption of dynamic congestion maps and improved transparency in curtailment data would further support risk-informed planning and efficient siting decisions by project developers.

3.4. State-Level Integration Issues and Best Practices

India's transition to a RE-dominated power system is being led by state-level efforts, given the decentralized nature of planning, scheduling, and grid operations. However, integration challenges differ widely across states due to variations in institutional capacities, RE penetration levels, regulatory preparedness, and infrastructure readiness. This section evaluates these differences, highlights emerging issues, and draws attention to replicable best practices.

3.4.1. Varying State Capacities and Institutional Readiness

States vary widely in their ability to manage and integrate VRE, influenced by SLDC capabilities, RE penetration, and policy responsiveness. States like Tamil Nadu, Gujarat, and Karnataka show greater readiness due to REMCs, integrated forecasting, real-time SCADA, and skilled staff. In contrast, states with emerging RE pipelines - such as Bihar, Jharkhand, and parts of the Northeast - face challenges like limited technical capacity and weak enforcement. Addressing this requires targeted capacity building in RE operations, automated dispatch, regulatory compliance, and planning tools, supported by platforms like the Forum of Regulators (FoR) and POSOCO-led workshops.

3.4.2. Curtailment Trends and Causes

Curtailment of wind and solar energy remains a major concern in several states, driven by grid congestion, low demand during high RE generation periods, and occasional violations of must-run status. States like Tamil Nadu, Rajasthan, and Andhra Pradesh report higher curtailment levels⁷⁷. NREL's *India 2030 Wind and Solar Integration Study*⁷⁸ estimates annual RE curtailment could reach 12.4 TWh by 2030, about 2.3% of total available RE generation. Curtailment levels vary widely: Punjab could see up to 44%, Odisha around 16%, while even high-potential states like Tamil Nadu and Karnataka face transmission constraints that limit full RE utilization. **Figure 29** shows total curtailment in TWh by state.

Curtailment of renewable energy is primarily driven by transmission capacity falling behind RE growth, localized grid bottlenecks, thermal plant minimum load limits, and weak load forecasting or demand-side participation. Mitigating these issues requires proactive REZ-based transmission planning, faster implementation of Green Energy Corridors, better RE visibility at SLDCs, and stricter must-run compliance. Transparent, standardized curtailment reporting, detailing reasons, duration, and magnitude is essential for accountability and informed investment, and should be backed by regulatory mandates.

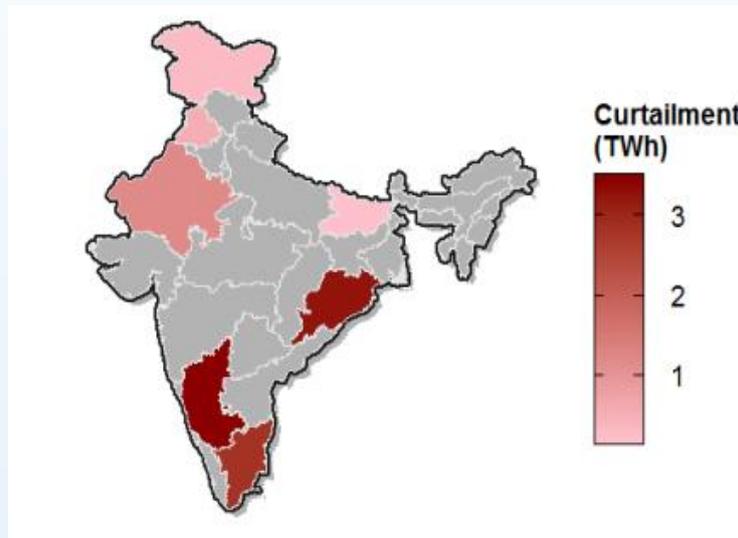


Figure 29 State-wise Annual RE Curtailment (TWh), 2030 estimate by NREL.

3.4.3. Regulatory and Tariff Design Gaps at the State Level

Regulatory gaps across states continue to hinder effective RE integration. Many SERCs have yet to enforce deviation penalties for forecasting and scheduling, and Time-of-Day (ToD) tariffs, though approved, often lack dynamic or seasonal pricing. Net metering and banking policies face frequent reversals and restrictive provisions, creating uncertainty for distributed RE. Additionally, weak DSM regulations and limited consumer engagement delay demand-side flexibility. Greater harmonization, driven by CERC and the Forum of Regulators, is needed to align forecasting penalties, ToD tariffs, and DSM frameworks, ensuring regulatory consistency, reducing investor risk, and enabling smoother market operations.

3.4.4. Coordination between SLDCs and RLDCs

Effective SLDC–RLDC coordination is essential to prevent grid disturbances and ensure smooth operations, especially with rising VRE. Key gaps include inconsistent visibility of intra-state RE, scheduling conflicts from siloed decisions, and limited unified data systems. Addressing this requires integrated SCADA systems, shared real-time dashboards for RE corridors, and joint training exercises. These steps will strengthen coordinated decision-making and enhance real-time response during contingencies.

3.4.5. Best Practice in State-Level Grid Integration

States like Tamil Nadu, Gujarat, and Karnataka offer strong models for RE integration. Tamil Nadu led in establishing REMCs and aligning forecasting with dispatch to reduce wind curtailment. Gujarat’s proactive transmission planning for RE parks helped minimize curtailment risks, while Karnataka’s demand-side pilots, including ADR with smart meters, supported RE balancing. These examples highlight the value of integrated planning, regulatory clarity, and consumer engagement - key elements for replication across other states to support India's energy transition and ensure grid reliability.

3.5. Green Energy Corridor: Progress and Way Forward

3.5.1. Physical Progress of GEC Phases I and II

The Green Energy Corridor (GEC) was launched in 2015 to address the critical need for dedicated transmission infrastructure that supports the evacuation of large-scale renewable energy (RE) from RE-rich zones. Conceived based on a 2012 study by Power Grid Corporation of India Limited (PGCIL), the GEC comprises Inter-State (ISTS) and Intra-State (InSTS) Transmission Systems, along with Renewable Energy Management Centers (REMCs), reactive power compensation systems, and energy storage infrastructure. Its purpose is to strengthen grid readiness for high RE penetration and ensure reliable, real-time integration of variable power sources. As of January 2025,⁷⁹, the physical progress of GEC phases I and II are represented in **Table 5**:

Table 5 Physical Progress of GEC Phases-I & II, as of January 2023.

Component	Inter-State GEC Phase I	Inter-State GEC Phase II (Ladakh)	Intra-State GEC Phase I
Implementing Agency	The ISTS GEC project was implemented by POWERGRID (PGCIL)	POWERGRID	State Transmission Utilities (STUs)
Year of Approval	Approved in 2015	FY 2022-23	2015
Commissioning / Target Timeline	Commissioned in March 2020	Targeted for completion by FY 2029-30	Under implementation (partial completion as of Oct 2024)
Transmission Lines (ckm)	3,200 ckm of inter-state transmission lines were constructed to evacuate RE power	1,268 ckm	Target: 9,700 ckm; Completed: 9,135 ckm
Substation Capacity (MVA)	Substations with a capacity of 17,000 MVA were established	2 x 5,000 MW HVDC terminals	Target: 22,600 MVA; Completed: 21,313 MVA
RE Evacuation Target	~6 GW of RE evacuation capacity created - Ananthapur (1500 MW), Pavagada (2000 MW), Rewa (750 MW), Bhadla-III (500 MW), Bhadla-IV (250 MW), Essel (750 MW), Banaskantha (700 MW), and Fatehgarh (1000 MW); commissioned by POWERGRID or through TBCB routes	13 GW RE + 12 GWh BESS	24 GW target; 18.72 GW already integrated
Project Cost	₹11,369 crore. Funded through 30% equity by PGCIL, and 70% loan from KfW (EUR 500 million) and ADB (approx. ₹2,800 crore)	₹20,774 crore (excluding IDC of ₹2,169 crore); Grant: ₹8,309 crore	₹10,142 crore
Funding Mechanism	30% Equity (PGCIL), 70% Loan (KfW & ADB)	40% Central Grant, 60% loan (likely from PFC/REC)	40% Grant (MNRE), 40% Loan (KfW), 20% STU Equity

Component	Inter-State GEC Phase I	Inter-State GEC Phase II (Ladakh)	Intra-State GEC Phase I
Solar Parks Covered (Phase I)	All 7 solar parks assigned by MoP to POWERGRID were commissioned successfully Also includes Fatehgarh solar park by M/s FBTL under TBCB	Not applicable	Covered in state evacuation plans
REMC Deployment	Installed at 11 locations: 1. REMC-SR (TN, AP, KA SLDCs & SRLDC) 2. REMC-WR (GJ, MH, MP SLDCs & WRLDC) 3. REMC-NR (RJ SLDC, NRLDC & NLDC)	-	-
Status of States	Commissioned successfully with national-level impact	Covers Ladakh and J&K	RJ, MP, KA, TN: Completed; AP, HP (extended to Jun 2025); MH (Dec 2024); GJ (Mar 2025)

The InSTS GEC-II scheme, approved by the Cabinet Committee on Economic Affairs (CCEA) in January 2022, targets the development of 10,750 circuit kilometers (ckm) of intra-state transmission lines and 27,500 MVA of substation capacity. The total project cost stands at ₹12,031 crore, with the MNRE providing central financial assistance (CFA) of ₹3,970 crore - amounting to 33% of the total cost. The remaining 67% is to be financed through loans from KfW, REC, or PFC. The transmission schemes will be executed by the State Transmission Utilities (STUs) of seven renewable energy-rich states: Gujarat, Himachal Pradesh, Karnataka, Kerala, Rajasthan, Tamil Nadu, and Uttar Pradesh, to evacuate approximately 20 GW of renewable energy. At present, STUs are in the process of issuing tenders for project implementation, with March 2026 set as the targeted commissioning deadline.

3.5.2. Integration with Renewable Energy Parks and ISTS

The success of the Green Energy Corridor (GEC) is closely tied to the timely development of Renewable Energy Parks and ISTS infrastructure in states like Gujarat, Rajasthan, and Karnataka. However, delays in park readiness, land acquisition, and timeline mismatches have led to underutilized GEC assets in some areas. Strengthening coordination between SECI, park developers, state agencies, and PGCIL through regular reviews, real-time dashboards, and flexible contracting is crucial to align timelines and avoid stranded investments.

3.5.3. Funding and Financial Sustainability of GEC

Despite support from KfW and GoI through concessional finance and VGF, the long-term financial sustainability of GEC assets remains challenging. States face fiscal constraints, and delayed DISCOM payments hamper cost recovery. To address this, alternative models like RESCOs, InvITs, and green bonds should be explored, along with user-pays principles and lease-operate-transfer approaches for transmission assets to attract private capital and ensure financial viability.

3.5.4. Coordination Across Central and State Agencies

Multiple institutions involved in GEC implementation - CTU, STUs, MNRE, SECI, and SERCs - often result in duplication, delays, and inefficiencies. Establishing a structured coordination mechanism, such as a National Renewable Transmission Coordination Task Force or integrated command center, can streamline decision-making. A single-window digital dashboard co-managed by CTU and MNRE would improve transparency on transmission readiness, RE park progress, and interconnection status.

3.5.5. Future Directions and Expansion Strategy

To meet India's 2030 target of 500 GW non-fossil capacity, the Green Energy Corridor (GEC) must evolve into a future-ready platform. This includes enabling cross-border RE trade with Nepal, Bhutan, and Bangladesh, integrating offshore wind from Tamil Nadu and Gujarat via subsea HVDC lines, and developing hybrid corridors for solar, wind, and storage dispatch. Incorporating smart grid features like dynamic line rating and grid-forming inverters will enhance reliability. A GEC 2030 masterplan - backed by techno-economic studies and involving POSOCO, states, developers, and financiers - will require strong coordination and regulatory alignment for effective implementation.

Distributed Renewable
Energy and
**INNOVATIVE RE
TECHNOLOGIES**



Distributed Renewable Energy (DRE) projects are small-scale units of local generation connected to the grid at the distribution level. These include solar PVE systems, wind turbines, battery storage and EVs. Unlike centralized power plants, DRE are often located close to the point of consumption, such as homes or businesses. DRE are transforming energy systems by enabling bidirectional electricity flows and empowering consumers to become "prosumers" - both producers and consumers of energy. Between 2019 and 2021, 167 GW of distributed PV systems were installed globally, exceeding the combined peak electricity consumption of France and Britain. Whereas in India, the installed capacity of distributed solar generation has increased from 493 MW as on March 31, 2017, to around 21.76 GW of rooftop solar capacity (78.20%) and off-grid solar capacity (21.80%).

Decentralized Renewable Energy (DRE) systems offer significant advantages, including enhanced resilience when paired with storage for backup during outages, improved affordability through reduced grid dependence and lower electricity costs, and meaningful contributions to decarbonization by replacing fossil fuel-based generation and supporting the electrification of transport and heating. This chapter explores a range of DRE technologies that are gaining prominence, such as Rooftop Solar, Building-Integrated Photovoltaics (BIPV), Agrivoltaics (APV), Floating PV (FPV), and Rail and Road Integrated PV (RaIPV and RoIPV).

4.1 Rooftop Solar

Rooftop solar (RTS) systems are a form of distributed renewable energy where solar panels are installed on residential, commercial, or industrial rooftops to generate electricity locally. Rooftop Solar systems are important from the perspective of decentralizing energy production and reducing reliance on fossil fuels. Rooftop solar contributes significantly to global decarbonization. As of 2020, distributed PV installations accounted for around 40% of total PV use globally, with residential systems making up a substantial portion. India has set an ambitious target of 40 GW of rooftop solar capacity under its broader goal of achieving 175 GW of renewable energy capacity by 2022, later revised to 500 GW of non-fossil fuel capacity by 2030. The installed capacity of RTS projects in FY 2024-25 was 5,147.81 MW, with the cumulative capacity of RTS projects reaching 17,071.44 MW. The latest data notified by MNRE states that the cumulative installed capacity of RTS projects has reached 18,842.83 MW as on June 30, 2025. Year-on-year installed rooftop solar capacity is illustrated in **Figure 30**.

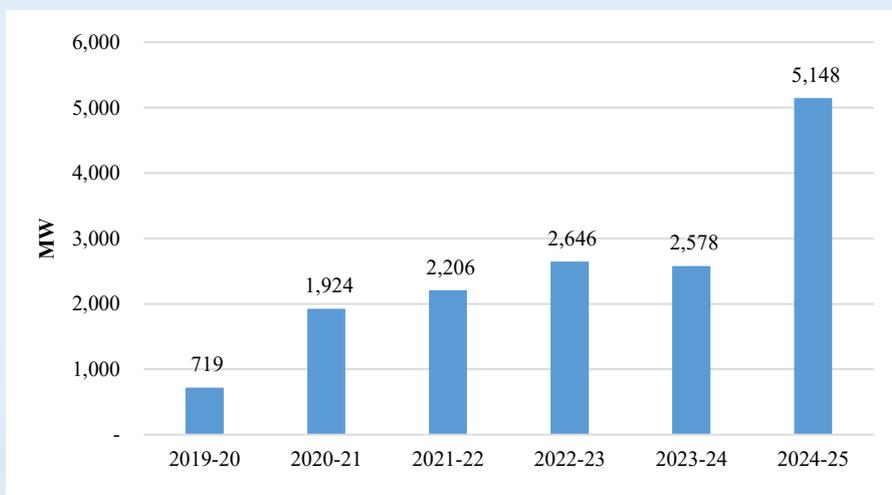


Figure 30 Installed capacity of RTS project

4.1.1 Business Models

India has adopted multiple business models to scale rooftop solar (RTS) deployment, guided by regulatory frameworks from Electricity Regulatory Commissions (ERCs) and implemented with DISCOMs. These models address land, cost, and operational challenges and include:

RESCO Model (Opex)

A third-party Renewable Energy Service Company (RESCO) invests in the project, and the rooftop owner pays per unit of electricity consumed. A long-term Power Purchase Agreement (PPA) defines tariff and supply terms. Excess energy can be exported via net metering. Post-PPA, the customer may retain the RESCO for O&M or choose another operator.

Capex Model

Here, the rooftop owner invests in the system and bears performance risk. The owner either manages O&M directly or hires the EPC contractor for maintenance.

DISCOM-Facilitated Models

DISCOMs may act as a facilitator, mediator, or investor. As investors, they lease rooftops or provide energy credits to consumers. As facilitators or mediators, they support either a customer-owned or RESCO-owned model, with corresponding O&M roles.

4.1.2 Projection

MNRE is aiming to reach 30 GW of RTS capacity by 2027. As of June 2025, 18.8 GW RTS capacity was installed. The CEA reports that rooftop solar contributed 4,716 MUs of electricity generation during FY 2023-24, which indicates growth of Rooftop Solar, but also indicates the need for accelerated growth for Rooftop Solar to meet National Targets. As of March 2025, the PM Surya Ghar scheme, which was introduced to increase the adoption of the RTS project for residential consumers, achieved 1 million installations milestone leading the addition of 3 GW installation. The installations under this scheme are expected to grow in 2025.

CEA, through its 20th Electric Power Survey (EPS), projects India's rooftop solar installed capacity would reach approximately 50 GW by FY 2031-32, generating around 55.8 billion units (BU) of electricity annually - that is, on an assumption of 17% capacity utilization and 75% on-site utilization. Meanwhile, the NEP of the CEA envisages India reaching 364 - 365 GW of solar capacity by 2031-32, of which approximately 60 GW of rooftop solar capacity is projected. The difference between the projections undertaken by the reports is due to the difference in the methodology adopted by them to arrive at the numbers. The EPS projections employ a partial end-use method, which is bottom up and consumption-focused, whereas the NEP projections employ a top-down approach focused on grid planning.

4.1.3 Policy and Regulatory Framework

India aims to deploy 40 GW of rooftop solar (RTS) capacity by 2027, contributing to its broader goal of 500 GW non-fossil power by 2030. To support this, MNRE has launched initiatives like the Phase II RTS scheme and PM Surya Ghar Muft Bijli Yojana. States have also set individual targets and issued policies and regulations to accelerate RTS adoption.

A key regulatory feature is the metering mechanism, with options such as net metering, gross metering, behind-the-meter, virtual net metering, and group net metering. Most SERCs have notified net metering, gross metering, or net billing frameworks. Innovations like group and virtual net metering enable shared RTS use,

benefitting consumers without individual rooftops. State regulations also define capacity limits. While some states cap RTS at 1 MW, others allow more, Maharashtra permits up to 5 MW and Karnataka up to 2 MW. Most states limit installation to sanctioned load, except Gujarat, which allows higher capacities for residential consumers.

Further support includes charge exemptions and simplified approvals. Following the 2024 MoP Consumer Rules amendment, RTS projects up to 10 kW are exempt from feasibility studies, and many states have updated their regulations accordingly.

4.2 Building Integrated Photovoltaics

Building-Integrated Photovoltaics represents an advanced technological solution wherein photovoltaic modules are integrated directly into the structural elements of a building envelope. These systems fulfil a dual role: they function as essential architectural components while concurrently facilitating the on-site generation of renewable electricity. As delineated in **Figure 31**, various elements of the building envelope - such as roofs, façades, and other exterior features - can be systematically adapted or designed to incorporate the installation of BIPV, which would increase the efficiency and be architecturally innovative.

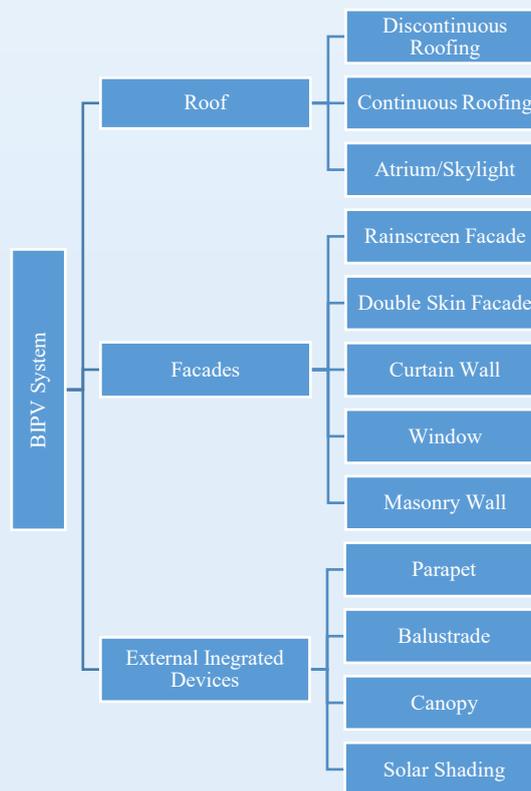


Figure 31 Classification of different BIPV systems.

BIPV systems represent a distinct approach compared to conventional solar photovoltaic (PV) installations, which are typically mounted on rooftops or ground surfaces (refer **Figure 32**). BIPV technologies are integrated directly into the architectural elements of a building - such as façades, roof tiles, and windows - thereby serving both functional and aesthetic purposes. These systems offer several significant advantages, including a reduction in electricity-related operational expenditure, an improvement in overall energy efficiency, and a meaningful decrease in the building’s carbon footprint.

BIPV projects are not new to our country, however the installation of BIPV projects has been rather low. The first BIPV installation in India was commissioned in 2007 by Tata Solar. This pioneering project was implemented at the Samundra Institute of Maritime Studies in Maharashtra and had a cumulative capacity of 90 kW. The country’s largest BIPV installation to date was completed in 2020 in Mumbai for the U-Solar CtrlS Data Center. This project featured an installed capacity of 863 kW and involved the deployment of over 2,000 photovoltaic modules, covering a total façade area of approximately 51,500 square feet.

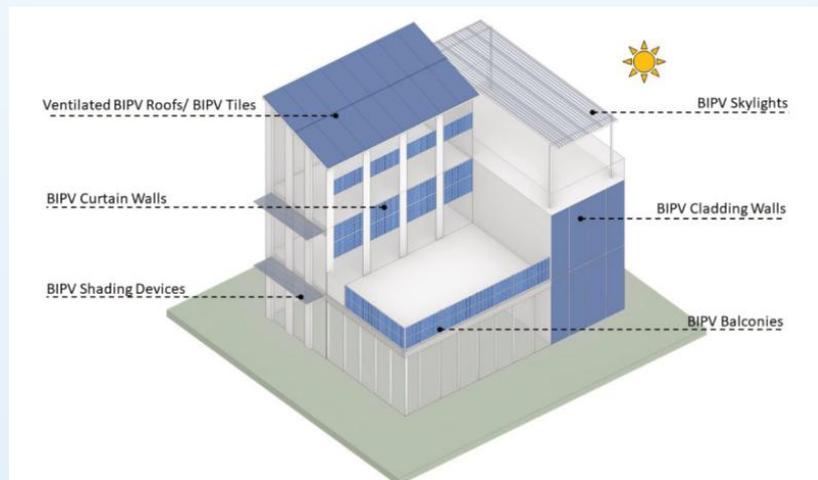


Figure 32 Different categories of BIPV.

Source: SUPSI Switzerland

4.2.1 Business Models

1. Capex business model

Under the capital expenditure (CAPEX) business model, the building owner directly invests in the deployment of the BIPV system. This model offers several strategic benefits, including long-term reductions in operational energy costs, enhanced energy autonomy, and potential increases in asset value. **Figure 33** presents a schematic representation of the key stakeholders involved in the CAPEX business model, along with the nature of their interactions and roles within the value chain.

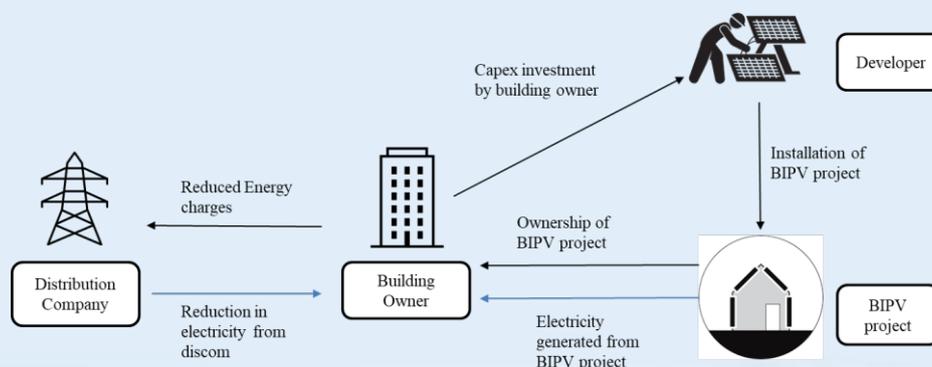


Figure 33 Capex business Model.

As depicted in **Figure 33**, the successful implementation of a BIPV project requires coordinated collaboration among all relevant stakeholders. The building owner engages a qualified project developer, who assumes full responsibility for the comprehensive execution of the installation. Additionally, the developer is generally

accountable for the operation and maintenance of the BIPV system throughout the initial operational period. The overarching objective of the project is to enable the building owner to partially offset electricity consumption supplied by the distribution licensee through on-site renewable energy generation. This substitution of conventional electricity supply with renewable generation may consequently lead to a reduction in revenue for the distribution utility.

2. Opex business model

In an operational expenditure (OPEX) business model, the capital investment required for the BIPV system is undertaken by the project developer rather than the building owner. Under this arrangement, the building owner leases or rents the building space to the developer, who, in turn, supplies the electricity generated by the BIPV installation at a tariff mutually agreed upon by both parties. **Figure 34** illustrates the relationships among the stakeholders involved in the BIPV project within the OPEX framework.

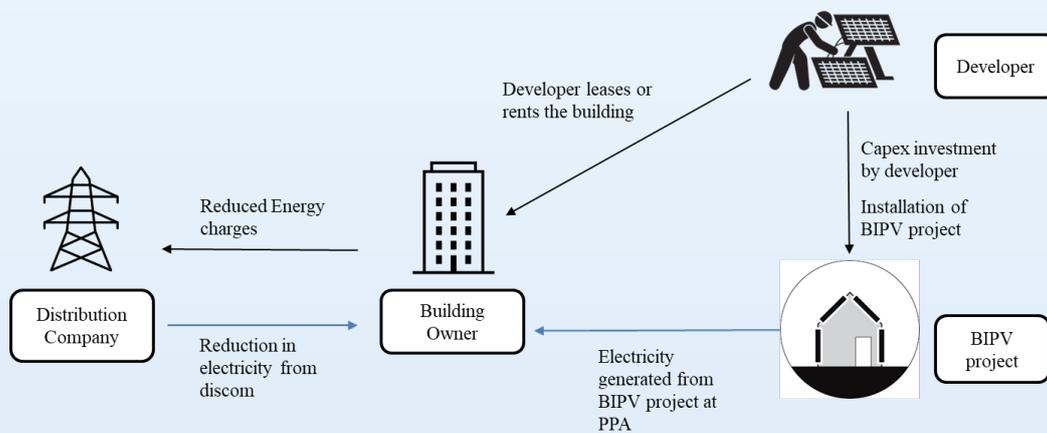


Figure 34 Opex Business Model

4.2.2 Policy and Regulatory framework

The National Building Code (NBC) provides a nationwide framework for building construction, including provisions for Building-Integrated Photovoltaics (BIPV) under Part 11: “Approach to Sustainability.” It outlines the following key guidelines:

- **Building Integration:** BIPV must not compromise the building’s structural integrity, safety, or durability.
- **Electrical Safety:** Installations must comply with Indian electrical safety codes and standards.
- **Performance:** Systems should be designed to minimize losses and optimize generation.
- **O&M:** BIPV should ensure long-term operation and maintenance support.
- **Permits:** All local codes must be followed, and necessary approvals secured.
- **Grid Interconnection:** Must comply with CEA’s technical and safety regulations.

Despite these technical guidelines, India currently lacks specific policies, incentives, or mandates to promote BIPV. High upfront costs further hinder its adoption among building owners.

4.3 Agrivoltaics (APV)

Agrivoltaics (APV), also known as solar farming or agro-photovoltaics, involves the simultaneous use of land for agriculture and solar power generation. APV enhances crop conditions by shielding them from excessive sunlight, high temperatures, and strong winds.

Key benefits for farmers include:

- **Revenue:** Income from selling generated electricity.
- **Savings:** Reduced electricity bills through self-consumption.
- **Water Usage:** Panel shading improves soil moisture retention.
- **Land Use:** Dual-purpose land use by combining crops and solar panels.

In India, APV systems typically follow one of three design configurations. While several pilot projects exist, there are currently no utility-scale deployments. As an emerging solution, APV requires a strong, incentivizing policy framework to scale up and contribute meaningfully to India’s net-zero goals.

4.3.1 Arrangements for APV

Overhead Stilted

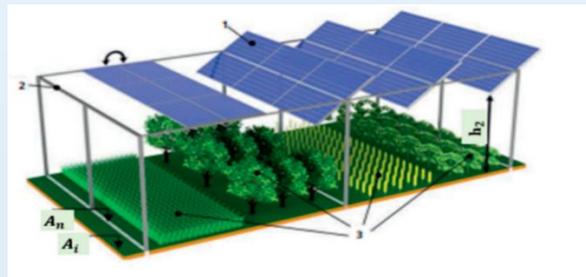


Figure 35 Overhead Stilted Arrangement.

Note: A_n : cultivated agriculture land, A_i : cultivated agriculture land, h_1 : installation height greater than 2.1 m, h_2 : installation height less than 2.1 m, 1: modules, 2: mounting structure, 3: crops

In this arrangement (refer **Figure 35**), APV modules are installed on raised structures to allow continued agricultural use of the land below. The installation height is critical, as it affects crop growth. Industry norms recommend a minimum height of 2.1 meters to enable machinery movement and ensure uniform sunlight distribution under the panels.

Module orientation is another key design factor:

- **South Orientation:** Panels face south to maximize sunlight exposure, boost electricity generation, and minimize shading on crops.
- **East-West Orientation:** Panels are aligned east to west, allowing denser installation per land area. This setup suits low sunlight-requirement crops, such as orchard plants.

Inter-row

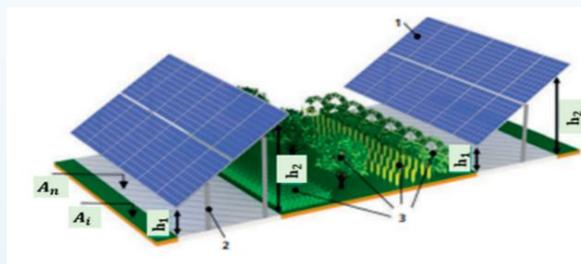


Figure 36 Inter-row Arrangement.

In this arrangement (refer **Figure 36**), the area between the rows of solar modules is utilized for agricultural purposes. For this, the spacing between the solar modules should be designed in such a way to ensure unobstructed movement of machinery, equipment and humans required for the installation and maintenance of the project.

Interspace

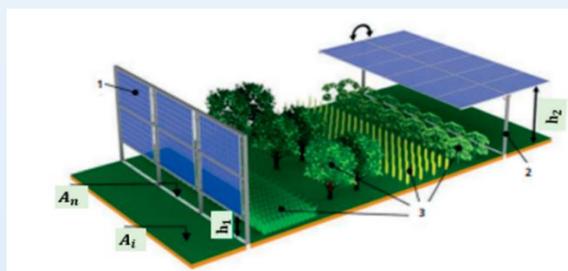


Figure 37 Interspace Arrangement.

In this arrangement refer **Figure 37**, the solar modules are designed along the boundary of the agricultural land. Here, the solar modules are attached to a vertical pole acting as a wall.

4.3.2 Business Models

To frame viable business models for Agrivoltaics (APV), it is essential to understand farmer classifications in India. The Reserve Bank of India categorizes them based on landholding size: Marginal (up to 1 ha), Small (1–2 ha), Medium (4–10 ha), and Big (above 10 ha). Notably, over 82% of Indian farmers fall under marginal and small categories, while medium and big farmers make up just 18%.

Accordingly, two business models are considered - one for farmers owning less than 2 ha and another for those with more. Small farmers, typically reliant on staple crops and the government's Minimum Support Price (MSP) program, may either cultivate their land or engage a caretaker. In their case, a Renewable Energy Service Company (RESCO) can lease the land to install APV systems, with generated electricity directly exported to the grid.

Larger farmers, more inclined toward cash crops and equipped with capital and machinery, often appoint caretakers as well. They are usually less dependent on subsidized electricity and more open to paying standard energy charges, making them more financially viable partners for APV adoption (refer **Figure 38**).

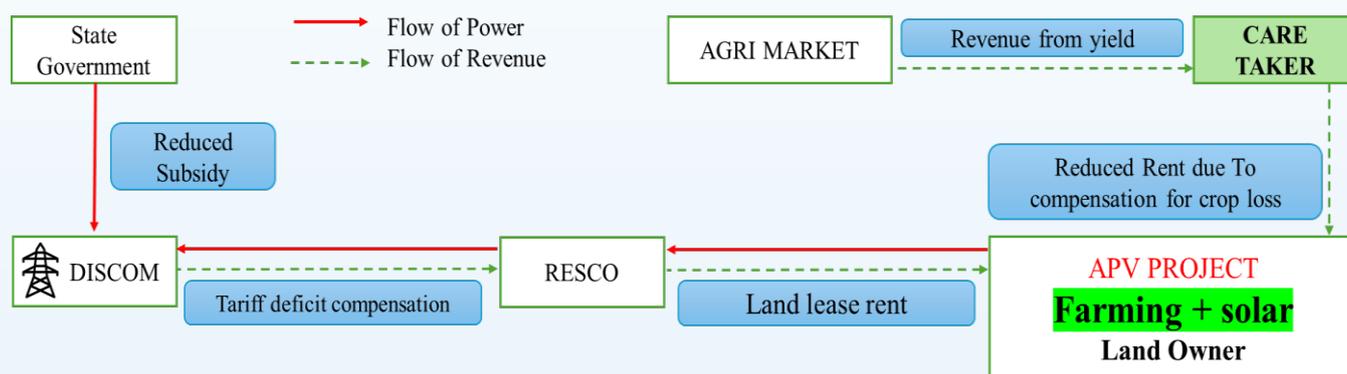


Figure 38 Business Model for Farmers.

The operational details for stakeholders involved in the installation of APV project for small farmers is elaborated in the **Table 6** below.

Table 6 Operation Framework for Business Models for Small Farmers

Stakeholders	Operation for Farmers
State Government	<ul style="list-style-type: none"> Electricity subsidies for farmer can be redirected The subsidy can be used to make APV commercially viable
Discom	<ul style="list-style-type: none"> Procure the electricity generated from APV Savings in power purchase cost
RESCO	<ul style="list-style-type: none"> Installation of APV project O&M of the APV project
Landowner	<ul style="list-style-type: none"> Consume electricity Lease agreement with RESCO Rental income from Caretaker
Caretaker	<ul style="list-style-type: none"> Carries out farming activities

4.3.3 Policy and Regulatory Framework

Agrioltaics (APV) offers a dual solution to clean energy generation and food security, making its adoption vital for sustainable development. While countries like Germany, France, and Italy are piloting APV projects, India has initiated similar efforts through the PM-KUSUM scheme. Under Component A, farmers can install solar systems on farmland and sell power to DISCOMs at mutually agreed tariffs, while Component C promotes solarization of agricultural feeders. Although PM-KUSUM incentivizes decentralized solar generation, much of the implementation has focused on barren or uncultivable land, conflicting with the core principle of APV, which involves active agricultural land use.

Integrating APV with PM-KUSUM could offer farmers supplemental income and boost land productivity. However, regulatory reforms are necessary. A key hurdle is land-use classification, many states prohibit commercial use, such as power sale, on agricultural land. Since APV involves electricity sales, it may be reclassified as commercial, preventing its deployment on cultivable land. Moreover, State Electricity Regulatory Commissions lack dedicated tariff mechanisms for APV, although some have addressed tariff

petitions under PM-KUSUM. A well-designed regulatory framework is essential to mainstream APV while preserving agricultural viability.

4.4 Floating PV

Floating Solar PV or Floating PV (FPV) is a type of solar plant where solar photovoltaic modules are mounted on a structure that floats on a water body such as a lake or a reservoir (refer **Figure 39**). FPV projects contribute to a lot of benefits, such as reduction in the rate of evaporation from the water bodies, which leads to cooling in the surrounding areas and the generation of renewable energy. The electrical components of the FPV should be resistant from water damage. FPV projects are gaining attraction especially in countries who are short on land resources.

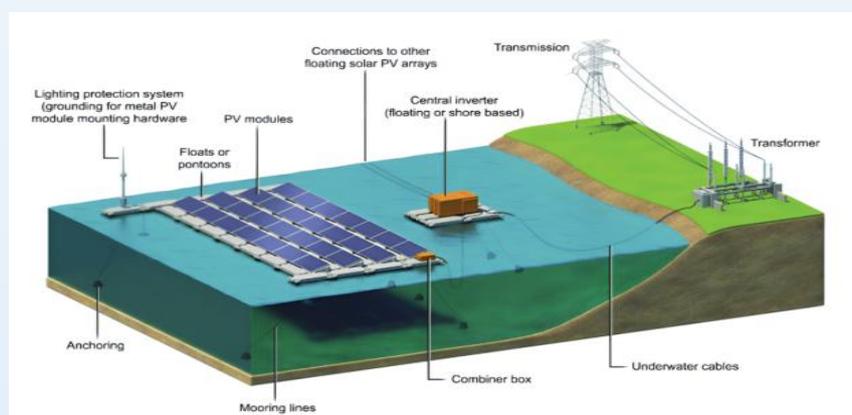


Figure 39 Schematic of FPV Plant.

Classification of FPV projects can be undertaken based on the location of installation i.e., onshore FPV projects and offshore FPV projects. Onshore FPV projects are relatively smaller in size and are installed on freshwater bodies, whereas offshore FPV projects generally do not have any size constraints and are installed on open waterbodies such as lagoons, oceans, etc. The components of onshore FPV are susceptible to erosion whereas in case of offshore FPV projects, the components are vulnerable due to salinity of water, tidal forces, etc. Onshore FPV projects have been adopted on a larger scale due to the absence of the challenges and vulnerabilities of offshore projects. In India, FPV installations are gaining a lot of speed due to untapped potential of artificial reservoirs.

4.4.1 Business Models

Currently the water bodies in the country are generally owned by the water supply department. Some of the water bodies are also owned by state governments, National Hydroelectric Power Corporation, municipal bodies, etc. These water body owners allow certain activities to be undertaken on the water bodies, which is an additional revenue stream for them. To carry out such activities, the implementing entity agrees with the water body owner regarding its usage. It is assumed that the water body owners have limited expertise in the project regarding power. Hence, the proposed business model considers participation from a project aggregator, who will ensure that the FPV project meets the technical standards. The schematic for the business model is illustrated in **Figure 40** below.

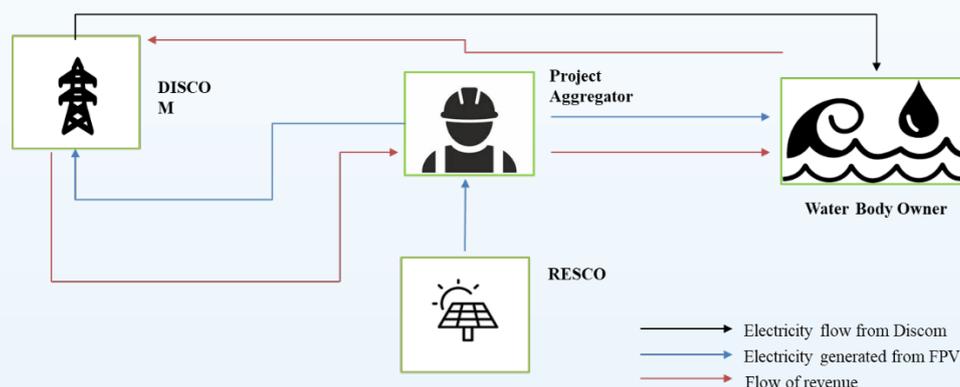


Figure 40 Business model - FPV.

The operational details for stakeholders involved in the installation of the FPV project is elaborated in the Table 7.

Table 7 Operational framework for FPV project

Stakeholders	Operations
Discom	<ul style="list-style-type: none"> • Procures power generated from the FPV project through PPA with the project aggregator • Supplies power to the water body owner
Project Aggregator	<ul style="list-style-type: none"> • Inviting the RESCO (developer) for the installation of the project • Signs a rent agreement with the water body owner • Ensure that the FPV project is functioning optimally
RESCO (Developer)	<ul style="list-style-type: none"> • Installation of the FPV project • Signs PPA with the project aggregator
Water body owner	<ul style="list-style-type: none"> • Signs agreement with aggregator

4.4.2 Policy and Regulatory Framework

An assessment of India’s policy and regulatory framework for Floating Solar Photovoltaic (FPV) projects highlights key gaps. Despite the vast potential, there is no dedicated national target for FPV, which could otherwise drive adoption and scale economies. There is also no centralized framework for identifying suitable water bodies in consultation with stakeholders. FPV development faces delays due to the need for multiple approvals from various departments. A single-window clearance system, similar to that for rooftop solar, could streamline processes and accelerate implementation. Additionally, standardizing technical specifications and certifications would enhance the quality, safety, and longevity of FPV installations.

4.5 Rail and Road Integrated PV

India has a significant railway network covering almost 99,235 km of track. The land in the vicinity of the railway tracks is generally owned by Indian Railways, who are involved in the solarization of the sector. Rail Energy Management Company (REMCL), a subsidiary of Indian Railways (IR) was created with this objective. Rail Integrated PV (RaIPV) is an innovative technology where solar modules are installed along the railway lines. RIPV has another benefit as it will utilize the existing infrastructure of IR, and feed the electricity generated from RIPV into the traction substation.

Similarly, Road Integrated PV (RoIPV) refers to the installation of solar modules along the roads. The electricity generated from (RoIPV) can be utilized in powering the streetlights and other infrastructure along the roads.

4.5.1 Categorization

Rail area in India can be mainly divided into noise barriers and unused area (refer **Figure 41**). Utilizing noise barriers for energy generation is undertaken in European countries. However, such an application is not common in India. In our country, utilizing the area in the vicinity of railways has been considered for the installation of solar modules.

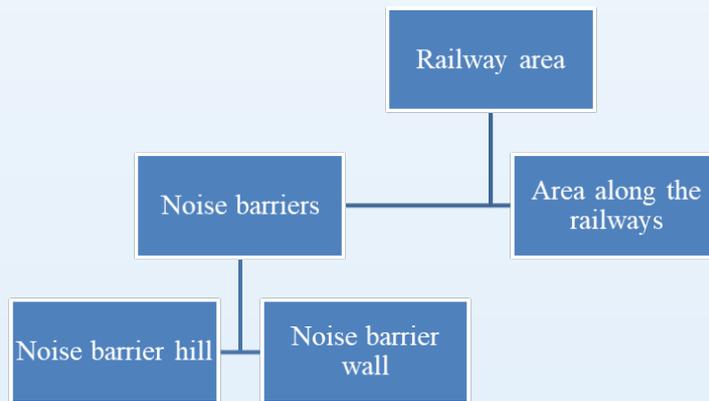


Figure 41 Categorization of RoIPV.

Categorization of RoIPV can be undertaken based on the area of the roads used for the installation of RoIPV projects (refer **Figure 42**). Either roadside area or road area can be utilized. Installation of RoIPV along the roadside is the globally practiced. Thus, the installation of RoIPV along the national highways in the country can be undertaken.

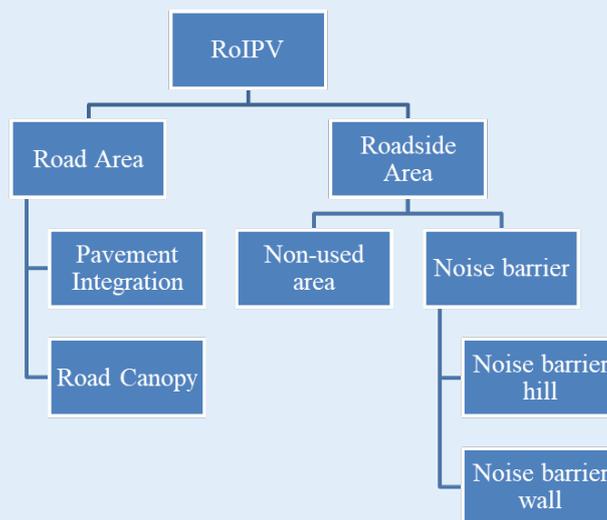


Figure 42 Categorization of RoIPV.

4.5.2 Business Models

REMCL is a joint venture between RITES and Indian Railways. It was introduced with a mandate to reduce electricity consumption from conventional sources, reduce the carbon footprint, and increase the renewable energy uptake. The proposed business model considers REMCL as a project aggregator, which undertakes the

installation of RaIPV projects by contacting the developer (refer **Figure 43** below). The electricity generated from the RaIPV project can either be consumed completely by the IR or partially, and the remaining can be sold to the respective distribution licensee. Similarly, for RoIPV projects, REMCL is replaced by an entity that will act as a project aggregator. At the same time, the role of Indian Railways will be undertaken by the National Highways Authority of India (NHAI).

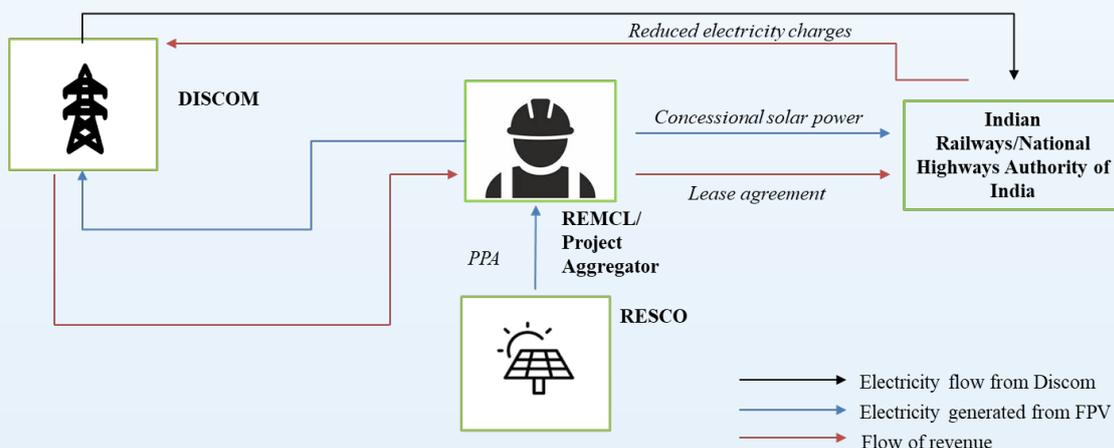


Figure 43 Business model for RaIPV/RoIPV.

The operational framework for the stakeholders involved in the business model is elaborated in **Table 8**.

Table 8 Operational framework for RaIPV project

Stakeholders	Operations
Discom	<ul style="list-style-type: none"> • Procures power generated from the RaIPV/RoIPV project
REMCL	<ul style="list-style-type: none"> • Inviting the RESCO (developer) for the installation of RaIPV/RoIPV project • Sale of power to IR/NHAI • Sale of power to Discom • Ensures that the RaIPV/RoIPV project is functioning optimally
RESCO (Developer)	<ul style="list-style-type: none"> • Installation of the RaIPV/RoIPV project • Signs PPA with the project aggregator
Indian Railways/NHAI	<ul style="list-style-type: none"> • Signs agreement with project aggregator

4.5.3 Policy and Regulatory framework

Indian Railways, one of the world’s largest rail networks, accounts for about 2% of India’s total energy use. In line with SDG 7 and its goal of net zero carbon emissions by 2030, Indian Railways has ramped up renewable energy adoption. Traction energy reduction targets include 1.9% for passenger and 5.37% for goods trains (electric), and 3.38% and 1.36% respectively (diesel). Manufacturing energy reduction targets include 7.88% for locomotives, 7.47% for coach units, and 7.10% for wheel production. As per its 2022–23 Environmental and Sustainability Report, IR plans to install 1,000 MW of solar and 200 MW of wind, with 500 MW from rooftop solar. However, the absence of a dedicated RE policy for railways limits progress. A focused scheme could drive RaIPV adoption, while an updated Green Highways Policy could support broader infrastructure greening.

Conclusion and **RECOMMENDATIONS**



India's renewable energy transition is at a critical inflection point, marked by impressive capacity additions and an expanding portfolio of supportive policy instruments. With the assistance of major initiatives like "Make in India" and PLI schemes, India has taken the lead in expanding distributed renewable energy (DRE) projects and bolstering domestic manufacturing. Advances in energy accessibility and sustainable development are being driven by innovations like agrivoltaic systems, rooftop solar, and floating solar (FPV). Concurrently, India's push for a vertically integrated supply chain in solar, wind, and battery storage - complemented by strategic mineral partnerships and innovation from MSMEs and startups - signals a growing intent to establish itself as a global clean energy hub. However, to sustain this momentum, India must bridge critical gaps in upstream manufacturing, skills development, and R&D, while addressing cost competitiveness and quality standards.

On the infrastructure and regulatory front, accelerating utility-scale deployment hinges on resolving persistent challenges related to land acquisition, grid integration, and project financing. India's experience underscores the importance of anticipatory transmission planning, inclusive community engagement, and streamlined clearance mechanisms to enable timely and equitable project execution. The Green Energy Corridor, General Network Access (GNA) reforms, and cross-border connectivity ambitions like OSOWOG reflect the country's systemic approach to future-proofing its energy landscape. As India strives toward 500 GW of non-fossil capacity by 2030 and net-zero emissions by 2070, its multi-layered strategy offers critical insights for the global South. The Indian model demonstrates that a just, scalable, and resilient energy transition must balance technological innovation with institutional coordination, social equity, and international cooperation - an imperative for all nations navigating the complexities of climate-aligned growth.

5.1 Cross-cutting Themes

5.1.1 Institutional Gaps

India's renewable energy transition is progressing, but it lacks the kind of unified institutional architecture needed to drive this shift at scale. Unlike the conventional power sector, which benefits from clear technical leadership under bodies like the CEA, the renewable sector operates in a more fragmented space. This often results in overlaps, gaps, and delays in decision-making, particularly when coordination between central ministries, state governments, and utilities. Without a dedicated national entity to lead, guide, and align renewable energy planning and execution, many crucial issues remain stuck in administrative loops.

5.1.2 Financing and Risk Mitigation

Investors and developers face a challenging landscape. Grid curtailment during peak generation, delays offshore and floating solar approvals, and infrastructure bottlenecks create financial risks that dampen investor enthusiasm. Add to that India's continuing reliance on imported components like solar modules and advanced wind parts, and the financial uncertainty only deepens. While policy ambition is high, the pace of domestic manufacturing scale-up remains slow, raising concerns about long-term supply security and cost volatility for project developers.

5.1.3 Policy-Implementation Mismatch

India has announced some of the world's most ambitious renewable energy targets - but there's often a gap between these goals and on-ground execution. Offshore wind and floating solar, for example, have great potential but continue to face long delays due to the lack of operational frameworks and clear timelines. In

many cases, the policies exist on paper, but implementation is bogged down by bureaucratic complexity, unclear agency roles, and limited capacity at the state and local levels.

5.1.4 Need for Planning Reform

Planning for renewable energy infrastructure must go beyond generation capacity - it needs to consider where, when, and how these systems will be deployed. Currently, logistical and regional realities are often overlooked. For instance, the movement of large wind turbine components requires dedicated transport planning, which is rarely coordinated with project development. Similarly, floating solar projects need spatial and hydrographic planning that aligns with reservoir usage and grid access, which is not yet standard practice. Without integrated spatial and infrastructure planning, renewable growth risks running into avoidable roadblocks.

5.1.5 Regulatory Certainty and Market Signals

For India's clean energy sector to thrive, investors need consistent and transparent regulatory frameworks. Unfortunately, frequent changes in banking policies, curtailment practices, and unclear standards for emerging technologies like floating solar create uncertainty. In particular, the lack of enforcement on curtailment disincentives, and the limited development of real-time markets, means developers can't always depend on predictable revenue streams. This erodes trust and slows the pace of capital deployment.

5.2 Action Points for Stakeholders

Central Government Agencies:

- Establish a dedicated Renewable Energy Authority of India to steer technical guidance, inter-state coordination, and policy alignment.
- Expedite offshore wind development by introducing marine zoning, viability gap funding, and single-window clearance mechanisms.
- Broaden the PLI scheme to include the full renewable value chain and establish manufacturing clusters near ports and RE zones.

State Government Agencies:

- For better responsiveness and transparency, SLDCs and energy departments should establish specialized renewable energy cells.
- Draft floating solar development plans tailored to local water bodies and grid conditions.
- Integrate renewable infrastructure needs into regional transport and logistics planning.

System Operators and State Electricity Regulatory Commissions:

- Promote accessibility for the curtailment in generation from RE sources and levy penalties in case of unwarranted reduction in generation
- Promote the adoption of real-time electricity markets and invest in forecasting tools to enable better grid management.
- Define and adopt technical standards for offshore wind, floating solar, and emerging PV technologies.

Developers:

- Partner with research institutions to advance solar cell innovation and speed up commercial adoption.
- Invest in modular or localized manufacturing and assembly to simplify logistics.
- Explore public-private partnership models for complex projects like offshore wind and floating solar, with fair risk-sharing mechanisms.

5.3 Way Forward for Policy and Implementation

India stands at a critical juncture in its renewable energy journey. The foundations have been laid, but the next phase will require targeted reforms and greater alignment between policy intent and practical execution. First, a strong institutional anchor is needed - one that can cut through inter-agency delays and provide a single source of technical truth and policy coherence. Second, planning systems must evolve, incorporating spatial mapping, grid logistics, and supply chain needs from the outset. Third, India must place greater emphasis on innovation and standardization, especially in high-potential areas like offshore wind and floating solar. And finally, regulatory confidence must be strengthened by making market signals clearer, curtailment policies stricter, and project economics more stable.

If these gaps are addressed with urgency and coordination, India has the opportunity not only to achieve its 2030 and 2070 clean energy targets but to become a model for scalable, inclusive, and resilient energy transitions globally.

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- ⁸¹ [Investment Opportunities in Renewable Energy - Invest India](https://www.pib.gov.in/PressReleasePage.aspx?PRID=2140223)
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- ⁸⁴ [Climate-Bonds India Sustainable Debt SotM 2024 Jun-2025.pdf](https://www.pib.gov.in/PressReleasePage.aspx?PRID=2140223)
- ⁸⁵ [RBI Framework for acceptance of Green Deposits.pdf](https://www.pib.gov.in/PressReleasePage.aspx?PRID=2140223)
- ⁸⁶ [MNRE year wise achievement – As on March 31, 2025](https://www.pib.gov.in/PressReleasePage.aspx?PRID=2140223)
- ⁸⁷ [MNRE year wise achievement – As on March 31, 2017](https://www.pib.gov.in/PressReleasePage.aspx?PRID=2140223)

Abbreviations

ACC	Advanced Chemistry Cell
ADB	Asian Development Bank
AI	Artificial Intelligence
AIIB	Asian Infrastructure Investment Bank
AT&C	Aggregate Technical and Commercial
BIS	Bureau of Indian Standards
BoS	Balance of System
BCD	Basic Customs Duty
BESS	Battery Energy Storage System
CA	Compensatory Afforestation
CAGR	Compound Annual Growth Rate
CEA	Central Electricity Authority
CEWE-CEF	Clean Energy Window - Clean Energy Finance
CERC	Central Electricity Regulatory Commission
CPSU	Central Public Sector Undertaking
CSR	Corporate Social Responsibility
CTU	Central Transmission Utility
CTUIL	Central Transmission Utility of India Ltd
DISCOM	Distribution Company
DCR	Domestic Content Requirement
DPIIT	Department for Promotion of Industry and Internal Trade
EPC	Engineering, Procurement, and Construction
EIA	Environmental Impact Assessment
ESS	Energy Storage System
FC	Forest Clearance
FLDG	First Loss Default Guarantee
FRA	Forest Rights Act
FY	Financial Year
GCF	Green Climate Fund
GDP	Gross Domestic Product
GEC	Green Energy Corridor
GIS	Geographic Information System
GHG	Greenhouse Gas
GIB	Great Indian Bustard
GNA	General Network Access
GOI	Government of India
GW	Gigawatt
HJT	Heterojunction Technology
HVDC	High Voltage Direct Current
IAP2	International Association for Public Participation
IEA	International Energy Agency
IEX	Indian Energy Exchange

IEC	International Electrotechnical Commission
IIFCL	India Infrastructure Finance Company Limited
INR	Indian Rupee
InvIT	Infrastructure Investment Trust
IREDA	Indian Renewable Energy Development Agency
ISA	International Solar Alliance
ISTS	Inter-State Transmission System
ITI	Industrial Training Institute
JETP	Just Energy Transition Partnership
KABIL	Khanij Bidesh India Ltd
kWh	kilowatt-hour
LT-LEDS	Long-Term Low Emissions Development Strategy
MMT	Million Metric Tonnes
MNRE	Ministry of New and Renewable Energy
MoEFCC	Ministry of Environment, Forest and Climate Change
MoP	Ministry of Power
MoU	Memorandum of Understanding
MVA	Mega Volt Ampere
MW	Megawatt
NABARD	National Bank for Agriculture and Rural Development
NBWL	National Board for Wildlife
NDC	Nationally Determined Contribution
NEP	National Electricity Plan
NEP-Tx	National Electricity Plan - Transmission
NGO	Non-Governmental Organisation
NIT	National Institute of Technology
NMC	Nickel Manganese Cobalt (Battery Chemistry)
NREL	National Renewable Energy Laboratory
NTPC	National Thermal Power Corporation
OEM	Original Equipment Manufacturer
OPEX	Operational Expenditure
OSOWOG	One Sun One World One Grid
PAT	Perform, Achieve and Trade
PCG	Partial Credit Guarantee
PFC	Power Finance Corporation
PGCIL	Power Grid Corporation of India Ltd
PiB	Press Information Bureau
PLI	Production Linked Incentive
PM JANMAN	PM Janjati Adivasi Nyaya Maha Abhiyan
PM-KUSUM	Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyan
PMU	Phasor Measurement Unit
PoC	Point of Connection
POSOCO	Power System Operation Corporation
PPA	Power Purchase Agreement
PSP	Pumped Storage Plant

R&D	Research and Development
RDSS	Reforms-based and Results-linked Distribution Sector Scheme
REC	Rural Electrification Corporation / Renewable Energy Certificate (contextual)
REMC	Renewable Energy Management Centre
RE	Renewable Energy
RRECL	Rajasthan Renewable Energy Corporation Limited
RoW	Right of Way
SCGJ	Skill Council for Green Jobs
SCADA	Supervisory Control and Data Acquisition
SERC	State Electricity Regulatory Commission
SECI	Solar Energy Corporation of India
SIDBI	Small Industries Development Bank of India
SIGHT	Strategic Interventions for Green Hydrogen Transition
SLDC	State Load Dispatch Centre
SNA	State Nodal Agency
STU	State Transmission Utility
STATCOM	Static Synchronous Compensator
TBCB	Tariff-Based Competitive Bidding
TOPCon	Tunnel Oxide Passivated Contact
UL	Underwriters Laboratories
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USD	United States Dollar
VGf	Viability Gap Funding
VS-PSP	Variable-Speed Pumped Storage Plant
WACC	Weighted Average Cost of Capital

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Distinguished
SPEAKERS





Shri Santosh Kumar Sarangi

Secretary, MNRE

Shri Santosh Kumar Sarangi is a 1994 batch IAS officer of Odisha cadre. He holds Degree in Master of Arts (Political Science) from the University of Delhi and Master in Public Policy from the Duke University, USA.

In Odisha, apart from being District Magistrate in three districts, he has served in various sectors like Education, Tourism, Mining and Tribal Affairs, Science and Technology. Between 2013 to 2019, he served as Joint Secretary in the Ministry of Commerce & Industry, Government of India and handled responsibilities as Chairman, APEDA & Chairman, Tea Board. He has also worked as Additional Secretary to the Government of India in the Department of School Education and Literacy under the Ministry of Education along with the charge of Chairperson, NCTE, New Delhi. He has worked as Director General of Foreign Trade and held additional charge of GTPO Division, IBEF and IIP in the Department of Commerce, Ministry of Commerce & Industry, Govt. of India.

At present Shri Sarangi Kumar Sarangi is working as Secretary, Ministry of New and Renewable Energy, Government of India.



Shri Ghanshyam Prasad

Chairperson, CEA

Shri Ghanshyam Prasad is presently holding the post of Chairperson and Ex-Officio Secretary to the Government of India, Central Electricity Authority, Ministry of Power from 15th July 2022. He is also the Member, ex-officio, of the Central Electricity Regulatory Commission. He belongs to the Central Power Engineering Services batch of 1989.

Prior to this he was holding the post of Joint Secretary in the Ministry of Power from 1st June 2020. He has served in the Ministry of Power for around 9 years in various capacities, i.e. Director (OM, Transmission) and Chief Engineer (OM, Transmission, Reforms & Restructuring and Regulatory Compliance Monitoring).

He did his graduation in B.Tech (Electrical Engineering) for IIT/BHU, Benares Hindu University. He holds a M.Tech in Energy and Environment Management from IIT, Delhi and also a MBA(Finance) from IGNOU, Delhi.

He has served 30 years in power sector and three years in the Bokaro Steel Plant, SAIL. During 30 years in power sector, he has worked and contributed in the areas of generation including the renewable energy, transmission, distribution, power market development/trading of power, Reforms & restructuring in power sector, energy efficiency, regulatory commission experience, disaster management in power sector, data analytics and information management system. A number of measures were taken to reduce the cost of power, ease of doing business, simplification of the procedures for approvals, bringing competition in power sector etc.

He has also served in Haryana Electricity Regulatory Commission for around six years and brought out new regulations.

He also has corporate experience and was Government Nominee Director of Power Grid Corporation of India Limited (PGCIL), a Maharatna Company; Power System Operation Corporation Limited (POSOCO); and Jammu and Kashmir State Power development Corporation Limited (J&KPDCL). Presently he is the Director on the Board of Nuclear Power Corporation of India Limited in an ex-officio capacity.



Shri R. V. Shahi

President, IEF and Former Secretary (Power)

Mr. R V Shahi was Secretary, Ministry of Power, Government of India, from 2002-07 which is the longest term served by any incumbent. In this position, he was responsible for policy initiatives and implementation for India's entire Power Sector (2,00,000 MW capacity) and over significant restructuring with the institution of the Electricity Act 2003, National Electricity Policy 2005 and National Tariff Policy 2006. Other major initiatives include 50,000 MW Hydro Power Initiative 2003, Accelerated Power Development and Reform Programme 2003, Setting up Bureau of Energy Efficiency 2003, Rural Electrification Policy 2005, Ultra Mega Power Policy 2006 and Merchant Power Policy 2006. Mr. Shahi is currently the Chairman of Energy Infratech Pvt. Ltd. and was formerly the Chairman and Managing Director (1994-2002) of professionally managed BSES Ltd (later taken over by Reliance Energy in 2004). He transformed BSES from a small distribution utility to a multi-unit fully integrated power utility having generation, transmission and distribution. At National Thermal Power Corporation (NTPC) from 1978-94, he was the General Manager in charge of Dadri Power Project; Executive Director in charge of Southern Region of NTPC, and Member on the Board of Directors of NTPC in-charge of Operations, R&D and Commercial functions. He has authored several books on the power sector, is a Fellow of the World Academy of Productivity Sciences, Institution of Engineers (India), International Institute of Electrical Engineers, and Indian National Academy of Engineering. He has been on the Boards of Xavier Management Institute Bhubaneswar, IIM Lucknow, and Management Development Institute in Gurugram. Mr. Shahi is a graduate in mechanical engineering from the National Institute of Technology, Jamshedpur, post-graduate in Industrial Engineering, post graduate in Business Management (MBA), and a diploma in Advanced Industrial Management (Delft, Holland). Mr. Shahi is currently, as Consultant, Senior Energy Advisor with the World Bank for South Asia Regional Integration.



Shri Gurdeep Singh

CMD, NTPC

Gurdeep Singh is the Chairman & Managing Director of NTPC Limited since 2016. Prior to joining NTPC, he was Managing Director of Gujarat State Electricity Company Limited.

He has an illustrious career spanning over three decades in the power sector. He started his career in 1987 as an Engineer Trainee with NTPC and has worked his way through various ranks in public and private sector including MNCs.

He graduated in mechanical engineering from NIT Kurukshetra and has undergone Management Education Program from IIM Ahmedabad. He has also received management and leadership inputs from renowned global institutions like Saïd Business School-Oxford (UK), Harvard-Kennedy School (USA), Darden School of Management - Virginia (USA), Singapore Civil Services College (Singapore) and ISB Hyderabad (India).

He is a member of IEA's High Level advisory group on Coal in the Global Net Zero transition and also a member of the Clean Energy Ministerial H2I advisory group. He served as Co-chair for the taskforce on Energy & Resource efficiency, B20 Italy 2021.

He has launched a series of initiatives to sustain NTPC's growth and bring about cultural changes necessary to maintain NTPC's position as a leading global energy company. He has positioned NTPC at the forefront of energy transition and has started many initiatives like aggressive renewable addition, green Hydrogen, acquisitions, Biomass, Waste-to-Wealth, CCU, global presence etc. to transform NTPC from merely a "Coal based Power Generating Company" to a "Sustainable Integrated Energy Company".

His strong focus on increasing competitive edge helped NTPC winning various tenders and emerged as a strong player in renewables. His thrust on minimizing environmental footprint, maximizing sustainability efforts and a focused approach of 'Low-Cost Low Emission' aligns with India's ambitious target of cleaner and affordable power for all and helped in conceptualisation of coal swapping, freight rationalisation, priority in scheduling of cheaper stations and flexibility in scheduling schemes.

He is also the Chairman and Managing Director of both NTPC Green Energy Limited and North Eastern Electric Power Corporation Limited (NEEPCO) and Chairman of Ayana Renewable Power Private Limited.



Shri Hemant Jain

Member (Grid Operation & Distribution), CEA

Shri Hemant Jain, an officer of the 1990 batch of Central Power Engineering Services (CPES) Group 'A' Cadre, is holding the post of Member (Grid Operation & Distribution), Central Electricity Authority and Ex-Officio Additional Secretary to the Government of India since 1st February, 2024.

Born on 24th July, 1968, Shri Hemant Jain graduated in Electrical Engineering from Madan Mohan Malviya Engineering College, Gorakhpur (UP) (now, Madan Mohan Malviya University of Technology, Gorakhpur). Subsequently, he completed his M.Tech. from Indian Institute of Technology (IIT), Delhi, prior to joining Central Electricity Authority (CEA) in CPES cadre as Assistant Director in February, 1991.

With a work experience of over 33 years in various facets of power sector, Shri Hemant Jain is presently heading the Grid Operation & Distribution Wing of CEA, which comprises of five Divisions and five Regional Power Committees (RPCs), each headed by a Chief Engineer level Officer.

After his initial stint as Assistant Director in Grid Management Division of CEA, Shri Jain was amongst the few officers deputed by Ministry of Power to the newly created Central Electricity Regulatory Commission (CERC) in 1999. In CERC, he had handled the work related to formulation of Indian Electricity Grid Code (IEGC), Regulation of Inter-state transmission of electricity including licensing and tariff setting, preparation and notification of related Regulations.

With the regulatory experience of over five (5) years in CERC, he was deputed in Office of Chairperson, CEA, for handling all the technical, administrative, regulatory, legal and vigilance matters referred to Chairperson, CEA, for final decision. In 2006, Shri Jain was sent on deputation to Delhi Electricity Regulatory Commission (DERC) as Joint Director (Engg.) for almost three (3) years where he handled the work of approval of Capital expenditure Schemes of Distribution and Transmission Licensees, setting of Generation, Transmission and Retail Consumer Tariff, approval of Power Purchase Agreements (PPAs) and all technical matters related to operation of Delhi power system.

Back in CEA, Shri Jain worked in the Integrated Resource Planning (I.R.P) Division, CEA, and also handled the additional charge in Office of Chairperson, CEA, from October,2008, to February,2016, for administrative coordination of the activities of various Divisions and Wings of CEA apart from handling of all the technical, regulatory, legal and vigilance matters. Subsequently, he had gained experience in the Renewable Energy Source (R.E.S.) Development Division, Regulatory Affairs (R.A.) Division, Grid Management (G.M.) Division and Renewable Project Monitoring (R.P.M.) in CEA, before moving to his present assignment on 1st February,2024.



Shri V S Verma

Former Member CERC & CEA

Director General, Bureau of Energy Efficiency India

Shri V.S. Verma has merited a degree in Bachelor of Science from Agra University followed by BE Mechanical (Hons) and ME Mechanical (Hons) in Applied Thermal Sciences from IIT Roorkee. He has also been trained under UNDP, with CEGB, UK and Gilbert Commonwealth of USA.

He started his career in the Central Power Engineering Service (CPES 1971 batch) in Central Electricity Authority (CEA) and was appointed as Member (Planning) in the year 2002. He held the charge of Director General of Bureau of Energy Efficiency (BEE) for Three years and Member (Hydro) in CEA for an year.

In his long standing career of over 52years in the power sector Shri Verma acquired wide and valuable experience in the field of Planning, thermal and Hydro power plant engineering, project monitoring, construction, supervision, operation monitoring, human resource development, grid operations, conservation and efficiency, low carbon growth strategy and other environmental issues.

Shri Verma has been associated extensively in the policy formulation by the Government and specially after the enactment of Electricity Act 2003. Shri Verma had, while in CEA. He was responsible for the 17th electric power survey as a Chairman of the Committee and the 11th plan Planning document as the Member Secretary of the working group appointed by the then Planning Commission. Planning for the power sector was the main responsibility of Shri Verma as Member Planning CEA.

Shri Verma as Member Secretary of the Eastern Regional Electricity Board (New ERPC) was responsible for the coordinated grid operation in the eastern region in the year 1997-98 and dealt with Optimization of Generation and transmission capacities, inter-state and inter-regional exchange of energy, generation scheduling and accounting etc.

He was responsible for operation of the Hotline Training Centre at Bangalore in bangalore.

As Director General of the Bureau of Energy Efficiency the various initiatives were taken under his leadership to promote energy conservation, standards and labelling programme, energy efficiency in the various sectors of industry in the Country and for promoting CDM mechanism in the power and industrial sector in the Country. Shri Verma headed various Committees set up by the Government including Renewable Resources of Energy, Low Carbon Growth in

power sector, adoption of Supercritical Technology in India, the next higher size of thermal generator to be adopted after 200/210 MW, IGCC, Co-generation etc. Shri Verma headed various working Groups on National Action Plan for Climate Change, Task Force of formulation of the action plan for development of energy sector in the North Eastern Region, Expert Committee to study the geo-thermal based power generating potential in the Puga geo-thermal fields of Ladakh, J&K, Working Group of research and development of energy sector for 11th plan. Shri Verma played a lead role in 50,000 MW of hydro power initiative announced by the Hon'ble Prime Minister in 2004. Credit of publication of CO2 Baseline data in the Indian power sector first time in the world goes to him. The setting up of Excellence Enhancement Centre in the Power Sector is his brain wave.

As the Member of the Central Electricity Regulatory Commission (CERC) Shri Verma was involved in his role for fixation of bulk tariff of electricity, making various Regulations including those of Renewable Energy, Renewable Energy Certificate Mechanism, Development of the power markets, grid discipline and interstate flow of power and resolving disputes on various matters pertaining to inter-state flow of power, setting up of operational frequency band standard.

Shri Verma has travelled extensively overseas making professional/official visits to USA, Canada, Europe, UK, Poland, Belgium, Germany, USSR, Vietnam, Kenya, Guyana and Nigeria, zimbabwe, Sri Lanka and Bangladesh. To his credit he has more than 50 technical papers published and presented in the national and international forums.

Shri Verma has also been on Governing Council/Board of Directors of various institutions like CPRI, NPTI, CWet, DVC etc. Shri Verma received Life Time Achievement Award from CBIP and from Rajiv Gandhi Technical University, Bhopal, Leading Energy Personality Award 2014 from Council of Power Utilities, Distinguished Alumni Award of IIT Roorkee. He has been a professor Adjunct for IIT Kanpur, distinguished professor at CPRI, Bangalore, professor adjunct at IIT Kanpur. Shri Verma has been the member of the task force advising Govt of Rajasthan to bring down the distribution losses appointed by the Govt of Rajasthan for five years. Shri Verma Co authored a book namely 'Solar Energy made simple for a sustainable future', Published by Springer Nature Singapore.



Dr. (Mrs) Malti Goel

Hon. Convener, Renewable Energy Group, IEF

Dr. Malti Goel, Convener, Renewable Energy Group, India Energy Forum is a leading expert in climate change and sustainability science, with over 55 years of experience in scientific research and policy planning. As a former adviser to the Department of Science and Technology (DST) and Emeritus Scientist in Council of Scientific and Industrial Research (CSIR), she has effectively led thrust area programmes in Physical & Atmospheric Sciences, playing a pivotal role in advancing scientific knowledge and innovation. As Member-Secretary of the Inter-Ministerial Science and Technology Advisory Committee (IS-STAC) at DST she successfully spearheaded collaborative Joint Technology projects, forging strong partnerships among industry, academia, and government. Dr. Malti Goel holds a doctorate in Physics and a D.I.I.T. (Solid State Physics) from the Indian Institute of Technology (IIT), Delhi, and a Master's degree in Physics from the Birla Institute of Technology and Science (BITS), Pilani, where she received a Gold Medal. A prolific academic, Dr. Malti Goel has published around 300 research papers in international journals and conferences. She has authored or co-edited sixteen scientific books on energy and environmental topics. Her work significantly influences the science-technology-policy-society interface, showcasing her dedication to these critical issues.



Shri Pradip K Das

CMD, IREDA

Shri Pradip Kumar Das is the Chairman & Managing Director of the Indian Renewable Energy Development Agency Limited (IREDA). He is a Fellow Member of the Institute of Cost Accountants of India and an Associate Member of the Institute of Company Secretaries of India. He also holds a PGDBM from the Xavier Institute of Management.

Under his dynamic leadership, IREDA underwent a complete strategic and operational turnaround culminating in its highly successful IPO in 2023 and upgradation to Navratna status in 2024.

IREDA's IPO witnessed a remarkable 38x over-subscription closing at ~88% premium over issue price on its debut day. The share has been a top-performer gaining ~480% in value over issue price in less than 7 months since IPO.

Over a span of 4 years, Mr. Das led IREDA's transformation into India's largest pure-play green financing NBFC achieving market leading loan book growth & profitability along with best-in-class asset quality and corporate governance.

In recognition of its exemplary performance, IREDA has received Infrastructure Finance Corporation status from RBI, AAA(Stable) credit rating from leading agencies, as well as 'CMD of the Year' award under Miniratna Category at the 13th CPSE excellence awards.

Before joining IREDA, Mr. Das held the position of Director (Finance) at India Tourism Development Corporation Limited (ITDC) spearheading the disinvestment/divestment of more than 10 hotel properties in line with the Government of India priorities.

With a career spanning 37 years, he has extensive experience in various financial roles, including finance, banking, reporting, compliance, audit, resource mobilization, treasury, loan and recovery, and disinvestment/divestment, in both public and private sectors. Mr. Das has also worked with organizations such as Rural Electrification Corporation Limited (REC), Bharat Heavy Electricals Limited (BHEL), Nuclear Power Corporation Limited (NPCL), Bharat Heavy Plate and Vessels Limited (BHPV), Kusum Products Limited., and others.

His distinguished status as a member of high-level committees formed by the Government of India Bodies and Industry associations reflects his involvement in strategic decision-making.



Shri Samir Chandra Saxena

Chairman & Managing Director, Grid India

Shri Samir Chandra Saxena (DIN:10712444) is the Chairman and Managing Director of our Company. He is a Fellow of the Institution of Engineers (India), Senior Member IEEE and Distinguished Member CIGRE. He obtained his Bachelor's Degree in Electrical Engineering from Aligarh Muslim University and MBA from Indian Institute of Technology, Delhi and has also completed a Certificate Course in "Regulation of Power Sector" from the Florence School of Regulation, Italy. Prior

to assuming the charge of CMD, he was the Director (Market Operation) of the Company. Shri Saxena has about 30

years of experience in diverse areas comprising of Power Market Operations, Power System Operations, Power Exchange Operations, Electricity Market Design, Regulatory Affairs, Integration of Renewables, REC markets design & operations, and SCADA-IT system and has also served as the head of National Load Despatch Centre (NLDC). Shri Saxena has been actively associated with the development of the regulatory framework for integration of Renewables, implementation & development of Ancillary Services, Fast Response Ancillary Services and Market Based Ancillary Services. He was responsible for the implementation of the Real Time Market (RTM) and Integrated Day Ahead Market (including Green Day Ahead Market). He has been associated with the implementation of Security Constrained Economic Despatch (SCED) at inter-state level in India. He also led a pilot study for intra-state SCED implementation with multiple states. He has led the team for implementation of the National Open Access Registry (NOAR), a one stop portal for administration of the Short Term Electricity Market in India. In 2023, as head of the National Load Despatch Centre, he has led the implementation of Market Based Ancillary Services and the implementation of IEGC 2023. He has also been associated with the capacity building of Power System Operators and the System Operator Certification Programs. He represents India in the CIGRE Study Committee C5 on Electricity Markets and Regulation and has many publications related to his work areas in various national and international journals & conferences. He joined our Board in July, 2024.



Dr V K Garg

Former Chairman, Joint Electricity Regulatory Commission for Goa & UTs Former CMD, PFC

Dr Garg is Former Chairman of the Joint Electricity Regulatory Commission for Goa and UTs and Former CMD of Power Finance Corpn Ltd. He has an MA, an MBA, and a Ph.D in Business Administration. He has attended Courses at Bradford University UK, Texas University at Dallas, USA, and Cambridge University, UK

Dr Garg started his career in the Indian Economic Services (1973 Batch). He served in the Ministry of Industry and Ministry of Finance for 17 years. Dr Garg has also been a Director (Finance) with the Power Grid Corpn Ltd.

Achievements:

He steered PFC, the market cap of PFC increased from Rs 11,000 crores to Rs 29,000 crores under his leadership. PFC was conferred with a 'Navratna' status by the Government of India in 2007.

Two of India's biggest Thermal Power Projects of 4000 MW each UMPP at Sasan and Mundra were facilitated to finalise developers through the International Competitive Bidding process. 43,000 MW of Thermal Power capacity was catalyzed as a financial institution.

In 39 months, PFC added new business (sanctions) of Rs.1.41 Lakhs crores i.e. more than double the business that was procured in the preceding 19 years since its inception.

Disbursement which generates income was Rs 46,000 crores, which was equivalent to the past 19 years cumulative achievement.

Achieved one of the highest per capita productivity in the Indian financial sector, i.e. a post-tax net profit of Rs 4.3 crores per employee, per annum in 2006-7.



Dr S K Chatterjee

Chief (Regulatory) – CERC

Presently Chief (Regulatory Affairs) with Central Electricity Regulatory Commission (CERC), Dr. Chatterjee has long experience of dealing with power sector reforms, especially, Regulatory Reforms since its inception in 1998.

He is a Fulbright Scholar and has been a post-doctoral research fellow at Harvard Kennedy School, USA. He holds a Ph.D. in Management, MBA in Finance and Masters in Economics.

He has - co-authored “The Electricity Sector in India: Policy and Regulation” (Oxford University Press, 2012); authored “S.K. Chatterjee’s Commentary on the Electricity Laws of India” (Delhi Law House, 2006); published papers on renewable (World Bank 2013; NREL 2016; Energy Policy 2021; The Science 2022; The Electricity Journal 2023); completed research as Principal Investigator (Topic: “Meeting the Renewable Revolution: A Roadmap for Electricity Market Design in India”) at International Growth Centre, London School of Economics, UK (2017); co-authored “Renewable Energy in India: Economics and Market Dynamics” (Sage Publishing, India, 2021).

Public policy has been his passion in professional and academic life. He has demonstrated a leadership role in conceiving, designing, and implementing policy and regulation, especially on renewable and electricity market design in India. He has played a pioneering role in introducing the Electricity Act, 2003; Renewable Energy Certificate mechanism; Security Constrained Economic Dispatch; Real Time Market; market based Ancillary Services.

He has been / is a part of several Committees constituted by Ministry of Power, CERC, Forum of Regulators, and South Asia Forum for Infrastructure Regulation. He is a regular guest faculty in several institutions in India/abroad. Dr. Chatterjee has been nominated as the first President of Indian Association of Energy Economics.



Shri Sivakumar V Vepakomma

Director (Power System), SECI

Shri Sivakumar V Vepakomma joined as Director (Power System) of Solar Energy Corporation of India Limited on 30th August, 2024.

He has 34 years of experience in the power sector in areas like Project Construction, Commissioning, O&M, Commercial and Regulatory as well as Energy and Efficiency Management. His contributions in renewable energy (RE) sector are equally notable in developing of Solar, Wind, Hybrid, and Storage solutions.

Before joining Solar Energy Corporation of India (SECI), Shri Sivakumar served at NTPC Green Energy Limited, a wholly owned subsidiary of NTPC Ltd as Chief General Manager. In this role, he was responsible for engineering, contracts, commercial and regulatory, business development, and carbon trading functions. Additionally, he was the maiden CEO of the joint venture company of NTPC Green Energy Ltd and IOC Ltd.

Among his many achievements, Shri Sivakumar was instrumental in bringing up 40 MW Ayodhya City Solar Project from concept to commissioning in record time. Over a decade ago, his initiative in conceptualizing and commissioning the

first floating solar demo project of 100 kW at NTPC, Kayamkulam, paved the way for large-scale floating solar projects in the country.

Academically, Shri Sivakumar is an engineering graduate and holds an MSc. in Energy Systems and Environment from the University of Strathclyde, Glasgow, UK (British Chevening Scholar). He has also completed a Post Graduate Certification Program in Project Management from the Indian Institute of Management, Indore. Further, he is a certified Energy Auditor awarded by Bureau of Energy Efficiency.



Shri Sarit Maheshwari

CEO, NTPC Renewable Energy Ltd

Mr. Sarit Maheshwari is the Chief Executive Officer of NTPC Renewable Energy Limited (NREL), a wholly owned subsidiary of NGEL and CEO of NTPC Green Energy Limited (NGEL). With over 35 years of rich experience in the power sector, he is widely regarded as a dynamic and forward-thinking leader committed to driving clean energy transition of India.

Mr. Maheshwari holds a Bachelor's degree in Mechanical Engineering from Aligarh Muslim University, a Master's degree in Power Generation Technology from IIT Delhi, and also holds an MBA from Indira Gandhi National Open University. Before taking over as CEO of NGEL, he held key leadership roles within the NTPC Group, including CEO of NTPC Renewable Energy Limited and CEO of NTPC Rajasthan Green Energy Limited (a JV between NGEL and Rajasthan Rajya Vidyut Utpadan Nigam Limited).

He also served as Head of Project at NTPC Korba, one of the company's major thermal power stations. Mr. Maheshwari is at the forefront of Energy Transition goals, leading strategic initiatives in the clean energy landscape of the organization. His work underscores a holistic and sustainable approach to energy development, with a strong emphasis on reducing carbon intensity and embracing innovative, clean technologies.



Shri Pawan Kumar Agrawal

MD & CEO - Waaree Energies Limited

Mr. Pawan (Rank holder CA, ICWA, MBA (FMS), CFA (USA)) has about two and half decades of experience, primarily in renewable energy space. Before joining Waaree Group as MD&CEO of Renewable IPP Business in April 2024, Pawan served as CFO of Azure Power for over 5 years, and as Global Head of Renewable Energy of YES Bank for over 11 years. He has also worked with CRISIL, Indian Oil, and E&Y.

Mr. Pawan has been deeply involved in several policy initiatives and served as member of USA-India Clean Energy Task Force, Clean Energy Finance Forum (CEFF), Carbon Pricing Leadership Coalition (CPLC) High Level Assembly meeting in Washington DC. He made presentations to International Solar Alliance's Steering Committee on Mobilizing 1 Trillion Financing. He has been member of several Business Delegations with Minister

Piyush Goyal including Indo-Japan Energy Dialogue in Tokyo, Indo-USA Energy Dialogue in New York, and Indo-Sweden Energy Dialogue in Stockholm.

Mr. Pawan was instrumental in several low cost innovative financing such as Co-Financing and Guarantee Lines from EIB and ADB, raising of funds under India's First Green Infrastructure Bonds in 2015, and showcasing ESG strengths to global clean energy capital providers.

Mr. Pawan is married to Tipti (who is also a CA), has 2 kids (Divit Mittal 12 years and Kushagra Mittal 10 years), and lives in Vasant Kunj, New Delhi.



Shri Vivek Srivastava

CEO- India Business, Suzlon Energy Limited

Vivek is a Global business professional with versatile experience of three decades in Mobility, Energy & Energy Transition having donned multiple leadership hats in Strategy, Business Development, Marketing, Sales, Operations, Program Management etc., with several "First in India" initiatives while working with Industry leaders in Petroleum, Mobility, Manufacturing & New Energy.

In his current role as CEO- India Business, he is steering Suzlon's accelerated growth agenda and enabling customers and partners in their journey to "Net Zero". As Group CEO of Waaree, he was instrumental in the transformative journey of India's foremost Solar manufacturing & services company to leadership in New Energy with global footprint and committed leadership in ESG and sustainability. Previously, he led the foray of India's largest private sector company into Petroleum Retailing that revolutionised the fuel retailing Industry, focussed on international markets before rapidly growing Mobility business through strategic network expansion & slew of offerings.

Vivek is a well-known Speaker, member of several committees and considers the confluence of running and shaping a business with the societal good and India's energy security as an endearing challenge. He is passionate about sustainability and driving it as an integral part of the organisational DNA rather than a compliance.



Shri Ashish Khanna

CEO, Adani Green Energy Limited (AGEL)

Mr. Ashish Khanna, a renewable energy industry veteran, is a campaigner for 'green growth' and is committed to accelerating India's clean energy transition. In April 2025, he took charge as CEO of Adani Green Energy Limited. He joined the Adani Group as the CEO of International Energy Business, where he led the Group's expansion efforts across regions outside of India.

Prior to joining Adani Group, he was President – Generation in Tata Power. He was at the forefront of leading the renewables business of Tata Power as CEO of Tata Power Renewable Energy Limited (TRPEL), wherein he was conferred with responsibility for the firm's clean energy business. Formerly, he was also the CEO

and Managing Director of Tata Power Solar Systems. With his optimistic vision for clean energy, he made the portfolio grow multifold. His 36 years of career span ranges from Oil & Gas, Petrochemicals, Thermal/Power & Renewables.

He is also the Chairman of ASSOCHAM – the National Council for New and Renewable Energy. Mr. Khanna was also named as one of the Meaningful Business 100 Leaders for 2021 by Meaningful Business, a global platform that acknowledges exemplary leaders who excel at amalgamating profit with purpose. Prior to joining Tata Power, he worked with some of the leading organizations like Bechtel and Engineers India Limited. He is also a distinguished member of renowned business councils and collaboratives like the CII, FICCI and ICC.

Ashish has done Executive Program for IIM (Ahmedabad), holds a Master's Degree in Management & Systems for IIT (Delhi) and Bachelor of Engineering from Delhi College of Engineering.



Shri Yugal Kumar Sehgal

Director, Greenko Energy Ltd

As an experienced power transmission professional, Mr Y. K. Sehgal has demonstrated expertise in planning, developing, and operating national transmission systems. With a strong track record in strategic planning, grid management, and the implementation of green energy corridors, Mr Sehgal has played a pivotal role in shaping the Indian power sector. His contributions extend to formulating regulations, standards, and open access procedures while actively engaging in international energy cooperation initiatives.

Experience:

Mr Sehgal has held senior positions at the Central Transmission Utility of India (CTU), including the role of COO. During his tenure, he spearheaded the planning of the National Grid and Green Energy Corridors, contributing significantly to the efficient operation and high availability of the transmission network. His expertise has been invaluable in providing vital inputs for charging new transmission networks and granting long-term access to the Inter-State Transmission System (ISTS). Moreover, Mr Sehgal has actively participated in developing tariff regulations and grid standards, promoting a more equitable and efficient power market. His commitment to international energy cooperation has led him to spearhead initiatives for cross-border power trade with neighboring countries, fostering regional energy integration.

Publications:

Mr Sehgal has authored and co-authored several publications on power transmission advancements and grid management practices, sharing his valuable insights and contributing to the knowledge base of the field.



Shri Satyajit Ganguly

MD and CEO, Power Exchange India Limited (PXIL)

Satyajit Ganguly has joined as MD and CEO in PXIL in June 2023 after completion of his tenure of three years as MD in NETC (North Eastern Transmission Company Ltd- JV among POWERGRID, OTPC and six NER State Governments) and five years as MD in OTPC (ONGC Tripura Power Company Ltd (JV among ONGC, IL&FS, IDFC and GOT). He led PXIL to achieve business goals in terms of growth in business volume and market share by planning, implementing and providing strategic direction whereas he managed India's largest clean Combined Cycle Gas Power Plant of 726 MW (2x 363.3 MW) at OTPC, Tripura along with 650 KM evacuation network in North-eastern Region at NETC successfully.

He is a first-class Honours Graduate in Electrical Engineering with a Post – Graduate Diploma in Business Management. He is also a graduate in Law. He has also received management and leadership inputs from renowned global institutions like IIM Bangalore, ISB Hyderabad, MDI Gurgaon.

He has more than thirty-nine years of experience in Power Generation, Transmission, Regulatory, Power Market, Trading, Energy Transition, Renewables, Strategy and Business Development in Power Sector across Central Government, Public Sector and Private Sector of India.

After a brief stint in National Thermal Power Corporation (NTPC), Satyajit successfully cleared Indian Engineering Services Exam and began his career as Assistant Director in Central Electricity Authority in the year 1988. He handled Grid Management, Supervisory Control and Data Acquisition (SCADA) system, Operational Studies in Western Region of India. He joined Power Grid Corporation of India Limited in 1996 and was involved in Implementation of Availability Based Tariff (ABT), coordination of Short-Term Open Access (STOA), Operational studies and implementation of Energy Management System (EMS) in Western Region. He joined Power Exchange India Limited in 2008 and was instrumental in its business operation and regulatory compliance. He also worked as Senior Vice President – Business Development and Strategy in LANCO Power Limited and Vedanta Power Limited till 2014 and was responsible for strategy formulation, Policy and Regulatory Advocacy and Business Development including power sale.

He is a Chartered Engineer, Fellow of Institution Of Engineers (India) and has been felicitated as “Eminent Engineering Personality of the year” by The Institution Of Engineers (India) in 2018. He is also recipient of International Icon Award 2019 by Institute of Economic Studies during “Indo-Thai Economic Co-operation” seminar at Bangkok. He has also been awarded ‘Leading CEO of the Year for 2019 ‘ by Greentech Foundation.

He has published number of technical papers in O&M in Power Generation, Transmission, Grid Operation, Contingency Analysis, Smart Grid, Operation of Power Exchanges and Congestion Management in national and international Conferences. He has recently successfully completed 18-week certificate course in Leadership with Gen AI in July 2025 from ISB Hyderabad.



Shri Mukesh Dadhich

Head- Sustainability and Clean Technology, Business development and NTI
BSES Yamuna Power Limited

Mukesh Dadhich is having professional experience of more than 29 years mainly in Power Distribution Sector. He is an Electrical Engineer from ECK Kota with an added qualification of PGDBM (Energy Management) from MDI, Gurugram. Presently Mukesh is heading Sustainability and Clean Technology and Business development functions at BSES Yamuna Power limited which is a premier power distribution utility serving over 1.8 million consumers in central and eastern parts of Delhi.

He has been driving various initiatives in the areas of Renewable Energy, Energy Storage, E-mobility, Demand Management, Research based projects, Energy Efficiency, ESG and has been frequently involved with Govt agencies and think tanks on policy front. He also Systems Operations function at BYPL and was instrumental in introducing energy storage technologies for management of peak demand. He has in depth experience in utilities domain and has been instrumental in bringing in innovative technologies and programs related to RE Integration, grid flexibility, managed charging solutions, auto demand response, renewable energy generation forecasting, urban microgrids and is keenly working on bringing in decarbonizing framework for power distribution utilities. Under his leadership BYPL is contributing greatly to development of EV charging infrastructure in the license area and beyond.



Dr Alok Mishra

Director India Offers and Country Director Westinghouse India

Dr. Alok Mishra holds a B.Tech in Chemical Engineering, Masters in Energy Systems Engineering and a PhD from IIT Bombay. He also holds an MBA with specialization in finance from University of Mumbai. He was a UNENE (University Network of Excellence in Nuclear Engineering) post-doctoral fellow at the Institute for Risk Research, University of Waterloo, Canada and was a recipient of IAEA fellowship for advanced training at Argonne National Laboratory Chicago, USA.

Alok has over 30 years of experience in the nuclear industry globally. He started his career as a trainee scientific officer with the Department of Atomic Energy in 1989. For the last 15 years he is working with Westinghouse. Alok is responsible for licensing and development of the techno commercial offer in supporting the Westinghouse AP1000 project in India, SMR-AP300, e-Vince Advance Micro Reactor, Long Duration Energy Storage System (LDES) and the development of India supply chain. Before joining Westinghouse, he was working in USA as a principal consultant for consulting firms for the new build nuclear power plants safety analyses and licensing. He also worked as a consultant to the Canadian Nuclear Safety Commission for their Aging PRA studies and the OPG for its technology evaluations for the LWRs. During his early years at NPCIL, he was involved in KAPS-2 and NAPS-2 commissioning, he had played a key role in resolution of safety issues in Indian NPPs (PHWRs/BWRs) raised by AERB and was a member secretary for the task force for root cause and direct cause analysis of safety related unusual occurrences in the Indian NPPs. He played a pivotal role in Kudankulam-1&2 licensing and was associated with Kurchatov and OKB Gidropress Institute at Moscow. Alok was also

involved as a member of the taskforce in NPCIL for preparation of Technical Assignment for EPRs in India. Alok has keen interest in large-scale multi objective optimization for risk and reliability using genetic algorithms. He has undergone advance training in joint venture management and mergers & acquisitions at IIM Bangalore. He has several publications in International referred journals/conference proceedings and has received several awards and recognitions. Alok was a National Talent Search Scholar.



Shri Amit Kumar Parihar

Director, Clean Power Program
Shakti Sustainable Energy Foundation

Energy and environment professional with around 14+ years of experience in leading and managing the implementation of projects in India and South Asia on Climate Change mitigation, energy transition, supply chain sustainability, air pollution, energy access, skilling, and livelihoods supported by corporate brands in textiles, automotive industries, prominent bilateral organizations, and renowned foundations to advance work on International/national commitments and Sustainable Development Goals.

I have demonstrated experience in program conceptualization, strategy development, program management, technical implementation, research and policy advocacy, stakeholder consultations, partnership, and donor engagement, training, and capacity building. For the past few years, my work has been focused on the development of innovative approaches and business models to advance climate change mitigation efforts at a large scale in South Asia Region.

My Master's and doctoral study in the area of energy and environment has strengthened my skills in research and advocacy, sustainability assessment, data management, critical analysis, and developing research tools and methodologies.



Dr. Rahul Walawalkar

President & MD, Customised Energy Solutions

Dr. Rahul Walawalkar is President & MD of Customized Energy Solutions (India). He leads the Emerging Technologies domain for Customized Energy Solutions globally, which under his leadership has emerged as a thought leader in the areas of energy storage, renewables, demand response, electric vehicles, and green hydrogen technologies. A strong votary of accelerating scale up of clean energy, energy storage and e-mobility, Rahul founded the India Energy Storage Alliance

in 2012 and continues to serve as its President. He served as a board member for Energy Storage Association, USA during 2009-15 and as the Chair for Global Energy Storage Alliance during 2018-20. Rahul has served on many committees over past 2 decades for shaping regulations and policies around the globe for agencies such as US DOE, Federal Electricity Regulatory Commission (USA), IRENA, World Bank, Ministry of New and Renewable Energy (India), Ministry

of Power (India), NITI Aayog (India), Central Electricity Authority and Central Electricity Regulatory Commission (India) etc,. Under Rahul's leadership, Customized Energy Solutions has received numerous awards including IPPAI Power Innovation Award for the creation of the India Energy Storage Alliance in 2016-17, Brad Roberts Award for outstanding industry contribution by Energy Storage Association (USA) in 2016, USAID's PACEsetter Fund Award for MICRO initiative in 2016 & 2019 and CII Innovative Energy Services Award for Tata Power Demand Response program in 2012. Rahul holds a Ph.D. in Engineering and Public Policy from Carnegie Mellon University, a Master's degree in Energy Management from NYIT, United States, and a B.E. from Walchand College of Engineering, India.



Mr. Sanjay Ganjoo

Director General, Indian Federation of Green Energy
Chairman, Bhavsar Foundation (Formerly Bhaskar Foundation)

Mr Ganjoo is Director General of Indian Federation of Green Energy (IFGE) an Industry Organisation for Green Energy Companies. IFGE is an Industry body for Green Energy Companies. IFGE has been working extensively on subjects like Bio Fuel, Waste to Energy, Electric Mobility etc and has organized many national and international conferences on these subjects.

He worked in Federation of Indian Chambers of Commerce & Industry (FICCI) the apex business organization of India for 13 years. He worked at various levels and at the time of leaving he was Director Trade Fairs. He worked on various business sectors and promoted business, investment and trade. The sectors include Chemicals, Pharmaceuticals, Construction, Aviation, Power, Telecom, Health, Defense, Mining etc. While working in FICCI he traveled to more than 25 countries across globe and interacted with many Government and Private Institutions. He was associated with many prestigious events of the country from conceptualization to implementation including Pravasi Bharti Diwas, Vibrant Gujarat, Aero India, India Chem, India Aviation, India Electricity, India Aviation, Arogya etc. He also represented India at many important Global events.

He joined Bhaskar Foundation (Dainik Bhaskar Initiative) as CEO in year 2008 and was responsible for carrying out CSR activities of Dainik Bhaskar Group the largest and most admired Media Brand. The Group has diversified business interests in sectors including Power, Textiles, Agro Processing, Real Estate, Mining etc.

In year 2016 he was appointed as Chairman and Trustee of Bhaskar Foundation. The Foundation works in various sectors of social development including skill development, water conservation, rural development, healthcare, education and sanitation. Various projects on above focus areas are being implemented in states including MP, Chhattisgarh, Rajasthan, Haryana, Punjab and Gujarat. Skill Development has been a major focus area of Bhaskar Foundation. In last decade the foundation trained more than One lakh unemployed youth mostly from rural areas and deprived sections of society and provided them with placement linkages

He was the Vice President of People of Indian Origin Chamber of Commerce & Industry (PIOCCI) an organization which supports initiatives for PIO/NRI community.

He was member of the Governing Body of IIM Jammu and Council for Advancement & Peoples Action and Rural Technology, Govt of India.

Mr Sanjay Ganjoo has studied upto MSc in Statistics from Kashmir University. He has spoken at many national and international conferences and has been participating through debates and panel discussions on electronic media.



Shri Ajit Pandit

Founder Director and CEO
Idam Infrastructure Advisory Pvt. Ltd

Mr. Ajit Pandit, is the **Founding Director and CEO of Idam Infrastructure Advisory Pvt. Ltd.** He has over 30 years of experience in policy, regulatory and project development matters concerning electricity industry, electricity market design, developing business models and financial structuring of utilities, designing frameworks for RE proliferation, RE grid integration in India and abroad. He has worked extensively with international organizations as Team Leader for several TA projects of World Bank, USAID, DFID, GIZ, ADB, REEEP on issues associated with power sector reforms, wholesale market design and clean energy development initiatives across Indian states.

In addition to his work in India, Ajit has extensive international experience, including formulation of FIT regulations for Bangladesh (BERC), solar regulatory framework for Bhutan (ERA), cost of supply study for Eswatini (EEC), formulation of a net-metering framework for Maldives, and preparation of an action plan for the World Bank's South-South Knowledge Exchange Programme between India and Kenya. He has also worked for assignments in Nepal and Sri Lanka, and has been to the US, UK, Germany, and Australia for professional visits.

He is involved in several pioneering key policy & regulatory initiatives in RE domain across RE technologies & applications. Some of the pioneering initiatives include MSKVY 2.0 - PMU tool, digitalization initiatives in RE such as USRTP tool, FIT framework, RPO compliance monitoring framework & tool, REC mechanism – conceptual and registry implementation framework, Solar policy guidelines under JNNSM (Ph-I and Ph-II), National Wind Mission, Wind Repowering framework. Ajit was a Member of FOR Technical Committee to formulate framework for Grid Integration of Renewables.

Ajit has expertise in Energy Modelling tools for Capacity Expansion, Production Cost Optimization, Reliability Assessment and Resource Adequacy Assessment. He has been involved in guiding Flexibility Resource Initiative (FRI) studies for four Indian States with LBNL, Resource Adequacy Planning studies for several states in India and continues to support FOR-WG on formulation of Resource Adequacy framework for Indian states.

Ajit is a graduate in Electrical Engineering and Master of Management Studies. His articles are published in several reputed journals, and he has been invited as a distinguished speaker at several international conferences.



Shri Balawant Joshi

Managing Director
Idam Infrastructure Advisory Pvt Ltd

Balawant Joshi is a founder, promoter and Managing Director of Idam Infrastructure Advisory Private Limited. He is also director on the boards of Enfragy Solutions and Aurus Lending Solutions Pvt Ltd. Balawant had started Origin Renewables Pvt Ltd, an innovative platform for solar rooftop services which he exited in 2020 by selling it to private equity. Balawant is a Founder Member and Secretary of Indian Renewable Energy Federation. He is a member of Institute of Electrical and Electronic Engineers (IEEE) and Life Member of Computer Society of India. Recently, he has been appointed as Member of Advisory Board of Power Exchange India Limited.

With more than 30 years of experience in the power sector, he is a well-known expert on policy/regulatory matters concerning electricity, renewable and energy efficiency. His experience spans from operation of power systems to financial modeling and valuation, from Utility to consulting, from technology to regulatory.

He has been extensively involved in restructuring/ reforms of utilities and has dealt with various issues ranging from financial restructuring, regulatory, financial due diligence, assessment and development IT processes, etc. He has been associated with design, development and implementation of several regulatory initiatives such as MYT, FITs for several technologies, RPOs, power trading, licensing, etc.

In clear energy sector, he has several 'firsts' to his credit such as Feed-In Tariff (FIT) determination for wind, solar and biomass. He was involved in implementation of the first Renewable Purchase Obligations at the state level. He was involved in design and implementation of 'Renewable Energy Certificates' as well as 'Energy Saving Certificates' mechanisms. He has supported several states in developing RE/ solar related policies. Recently, he was involved in development of Wind Repowering Policy, Prime Minister Solar Rooftop Scheme for Government of India.

He has worked extensively with public/ private sector as well as multilateral agencies such as World Bank, GIZ, ADB, USAID and international NGOs / Associations on issues associated with power sector reforms and clean energy development across Indian states. Apart from India, he has worked on engagements in several countries such as EU, Maldives, Eswatini, Kenya, Sri Lanka, Bangladesh, Thailand, Micronesia, Nepal, etc.

Balawant has been closely associated with various industry bodies. In the past, he was member of Power Committee, Renewable Energy Committee and Climate Change Business Council of CII. Currently, he is a member of Energy Transition Task Force of CII Southern Region. He is a member of Wind Repowering Committee of MNRE. He is also member of Advisory Board of IPPAI.

Balawant is an electrical engineer with post-graduation in both finance and software technology.



Shri Alexander Hogeveen Rutter

Research Manager, Third Derivate

Alexander Hogeveen Rutter is the Manager, Electricity Sector for Third Derivative, leading on solar, wind and hydro as well as emerging topics such as LDES, White Hydrogen and Advanced Geothermal.

He previously worked for multilaterals including the International Solar Alliance and International Finance Corporation, as well as for Boston Consulting Group, with a focus on electricity markets, energy storage and green hydrogen.

Previously he worked for the control center and planning departments at Manitoba Hydroelectric, an integrated utility in Canada.

He holds an MBA from the Indian School of Business and a Bachelor in Electrical Engineering from the University of Waterloo.



Shri Bhairaw Kumar Mandal

CEO at Enerture Technologies Pvt Ltd

Bhairaw Kumar Mandal is an accomplished professional with extensive experience in the power sector. As the Founder and Managing Director of Enerture Technologies Private Ltd since May 2012, Bhairaw has led initiatives in management consultancy within the renewable energy domain. Prior experience includes serving as a Senior Consultant at EY from July 2015 to April 2017, focusing on transaction advisory services for power sector companies, and as an Assistant Manager at CESC Ltd.

where responsibilities encompassed business process re-engineering and strategic business planning. Bhairaw's career began as a Project Engineer at Tata Consulting Engineers Ltd., where significant contributions included the design and commissioning of over 3000MW in thermal power projects. Educational qualifications include advanced studies at London Business School, a PGDM from Great Lakes Institute of Management, and a B.Tech in Electrical Engineering from NIT Jamshedpur.



Shri Pankaj Kumar

Co-Founder & Director - Quant Solar

With over a decade of experience, Shri Pankaj Kumar as Co-Founder & Director at Quant Solar reflects a deep commitment to advancing cleantech through innovative Floating Solar Technology. Our team's dedication has led to the installation of India's first Megawatt Scale Floating Solar Plant and is propelling us towards executing several Megawatt scale floating solar projects across India.

Leveraging skills in shipbuilding and marine engineering, I have cultivated a comprehensive approach incorporating R&D, design, engineering, and manufacturing to deliver world-class solutions. At Quant Solar, our mission is to transform the renewable energy landscape, ensuring sustainable and efficient energy solutions for the future.



Shri S M Mahajan

SG, IEF

He is a Mechanical Engineer from Delhi University (70 Batch), M.Tech in Management & Systems from IIT, Delhi. He served in BHEL for 39 years in various capacities, functions and units before superannuating as Executive Director. Handled Manufacturing Technology Up-gradation, Investment Planning, Modernization of manufacturing facilities in BHEL units, Material management & operation management, manufacturing of nuclear power equipment in BHEL units.

Post BHEL, he has been engaged with the manufacturing industry guiding them in business development and manufacturing capabilities- in fabrication industry for Power, infrastructure and Aviation sectors. Has served as an Industry Expert with two banks for evaluation of Bank Investments and due diligence.

He was Associated with Ministry of Electronics and IT as Expert in evaluation and recommendation of R&D proposals in area of Electronic System Development for different sectors. Guided several projects for successfully completion.

Also, associated with many professional Associations. Currently President of Asian Welding Federation and Former President of Indian Welding Society.

He is a Consultant with an Aviation Sector Manufacturing Company and a Dubai based company in Renewable Energy: Convenor, Nuclear Energy Group of India Energy Forum.



Shri Sutripto De

General Manager (NREB), BHEL

Sutripto De is General Manager in Bharat Heavy Electricals Limited. He has nearly 35 years of rich experience in various industrial and renewable energy assignments in BHEL. He has a Degree in BE (Electrical) from Delhi College of Engineering and an MBA from IIT Delhi. He has spearheaded Management Research projects on adoption of innovative process in Operations and maintenance of Solar projects and affordable Green Hydrogen solutions. His current researches are on

integration of Renewable Energy with Captive Power in refinery and petrochemical complex. He has won Prestigious CBIP, IFGE and REI awards for excellent contribution to Renewable Energy for BHEL.

He is presently heading the Solar and Hydrogen groups in New and Renewable Energy Business in BHEL.

ABOUT ORGANISER

India Energy Forum

India Energy Forum is a unique, independent, non-profit research organization and represents energy sector as a whole. It was set up in February 2001 and formally inaugurated in January 2002. The mission of IEF is to help evolve a National Energy Policy aimed at development of a sustainable and competitive energy sector in India. It is, probably, the only organization which championed the cause of TOTAL ENERGY – all forms of energy ranging from Coal, Power – Thermal & Hydro, Oil & Gas, Nuclear and Renewable from the beginning of its function. This feature of its functioning gave a distinctive advantage of taking an integrated look on the energy scene. In fact, IEF did frame an Energy Policy document which became an input to the Planning Commission's Integrated Energy Policy brought out in August 2006. Its membership includes all the key players of the energy sector both from private and public and over 140 highly respected energy experts.

The Forum has an MOU with International Solar Alliance to promote the development solar power projects not only in India but throughout the world.

Every year it organizes its flagship events viz, India Power Forum, Oil and Gas Conference, Renewable Energy Summit, Coal Summit/Roundtable Conference on Coal and Nuclear Energy Conclave besides webinars which are organized almost every month.

It publishes a monthly e-journal TOTAL ENERGY which provides authentic information on the whole energy sector at one source. It also brings out DAILY ENERGY NEWS REPORT.

Board of Management 2025 & 2026

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Members

Dr Anil Kakodkar Former Chairman, AEC	Shri Alok Perti Former Secretary (Coal)	Shri U Tripathi Former DG, International Solar Alliance Former Secretary, MNRE
Shri. S K Srivastava Former Secretary (Coal)	Shri Alok Kumar Former Secretary (Power)	Shri P S Bhattacharyya Former CMD, CIL
Shri R S Dhillon Former CMD, PFC	Shri Subhash Kumar Former CMD, ONGC	Shri M N Jha Former CMD, SECL/CPMDI
Shri Anil Sardana MD & CEO, Adani Energy Solutions	Shri Sanjay Banga President – T&D, TATA Power	Shri B Bhambhani Former SG, IEF Former ED, BHEL
Shri K K Govil Former Director, PFC	Shri V.P. Singh Former ED, BHEL	Shri A K Tooley Former Director, WCL
Shri V.K. Sehgal Former CMD, SECL		Shri Ashok Mehta Former CMD, WCL

KNOWLEDGE PARTNER

Idam Infrastructure Advisory Pvt Ltd (Idam Infra or Idam) is a leading advisory firm dedicated to enabling India's clean energy transition. Established in 2007 and headquartered in Mumbai, Idam Infra is an ISO 9001:2015 certified organisation that works closely with policymakers, electricity regulatory commissions, project developers, financial institutions, and multilateral agencies to address critical challenges in the power sector.

Its expertise spans renewable energy integration, energy efficiency, power market reforms, and digital solutions for utilities, combining policy insights, financial structuring, and technology solutions across the energy value chain. Idam has supported landmark initiatives with MNRE, MoP, CERC, PFC, REC, the World Bank, and ADB, contributing to policy frameworks, regulatory design, and capacity-building programs.

Through its wholly owned subsidiary, Enfragy Solutions India Pvt. Ltd., Idam Infra also delivers IT, geospatial analytics, and energy efficiency services, enhancing operational capabilities for utilities and market operators. By bridging policy, markets, and technology, Idam Infra continues to drive scalable and sustainable clean energy solutions for India's energy transition.

More details: www.idaminfra.com

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50 YEARS OF POWERING INFINITE POSSIBILITIES FOR INDIA



For 50 years, NTPC has been a key force behind India's rise. From a modest beginning, it has emerged as a powerhouse of innovation, helping India realise its dreams. NTPC powers industries, uplifts communities and touches people's lives in myriad ways. As a trusted energy leader, NTPC is now championing India's journey towards clean, sustainable power for all and a Viksit Bharat by 2047.



Powering Progress for a Resilient Future

A target of 130 GW by 2032 on the back of a strong portfolio across conventional, RE sources and nuclear plans



A Trusted Source of Energy

Lighting every fourth bulb in the country, and ensuring reliable, affordable supply of power



Empowering Lives Beyond Energy

Serving communities, protecting environment, and securing biodiversity for inclusive growth



Innovating for a Greener Tomorrow

A leader in floating solar, green hydrogen, e-mobility, carbon capture, biofuels and energy storage solutions



Sustainability at its Core

Driven by a 'People, Planet, Prosperity' approach, NTPC is steadily marching towards a Net Zero future

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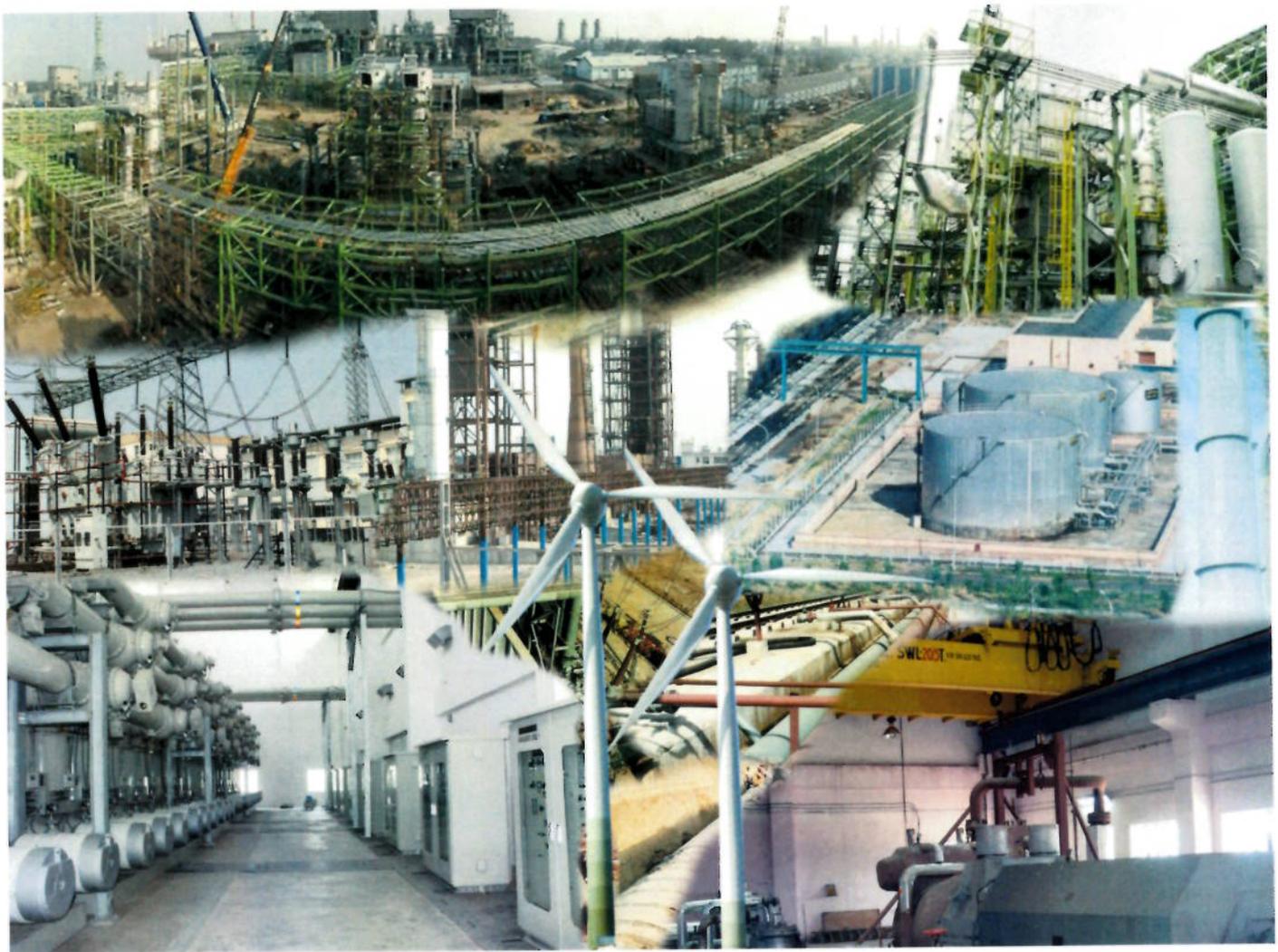
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A powerful presence in power...

Where Progress is Performance...

■ TECHNO, a synonym of Performance has been in the forefront of National Power Development Programme in the Generation, Transmission and Distribution Sector since 1980 participating in setting up over 50 per cent of India's Power Generation Capacity along with their associated Systems.

■ In Generation sector, Techno has executed small capacity Captive Power Plants as well as BoP for Ultra Mega Thermal Power Plants both for Electrical & Mechanical Auxiliary Systems.

■ TECHNO also executed prestigious coal based fluidized heater project for Mitsubishi Chemicals.

■ Techno has already developed and own 79 Nos. Wind Power Generator with aggregate capacity of 129.9 MW in Tamil Nadu and Karnataka.

■ In Transmission, Techno is well acknowledged Country Leader having already executed 7 Nos. 765 KV and more than 55 Nos. of 400 KV Substations, both of AIS and GIS Types on EPC basis.

■ TECHNO is also a transmission licensee and has set up and own a 102KM, 400KV Transmission Link with 2 Nos. 24 Bay 400KV/220KV/132KV Substations of 2400MVA capacity in Haryana and 1 No. 400/220 KV GIS S/S of 1000MVA Capacity in Punjab in PPP Model.

■ In Distribution Sector, Techno has again emerged as one of the best Performer in execution of very large APDRP / RGGVY / IPDS / DDUGJY Projects under Schemes of Government of India across the Country.

Awards

Techno's Performance has been recognized by the Government of India and other Giants in Power Sector. To mention a few, National Award for meritorious performance in the Power Sector from the Ministry of Power, 2014.

Best Performance of Award for Substation Construction - 2013 from Power Grid Corporation of India Limited.

Top 100 Companies of India – Business Standard, 2013.



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(An ISO 9001 - 2008 Company)

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