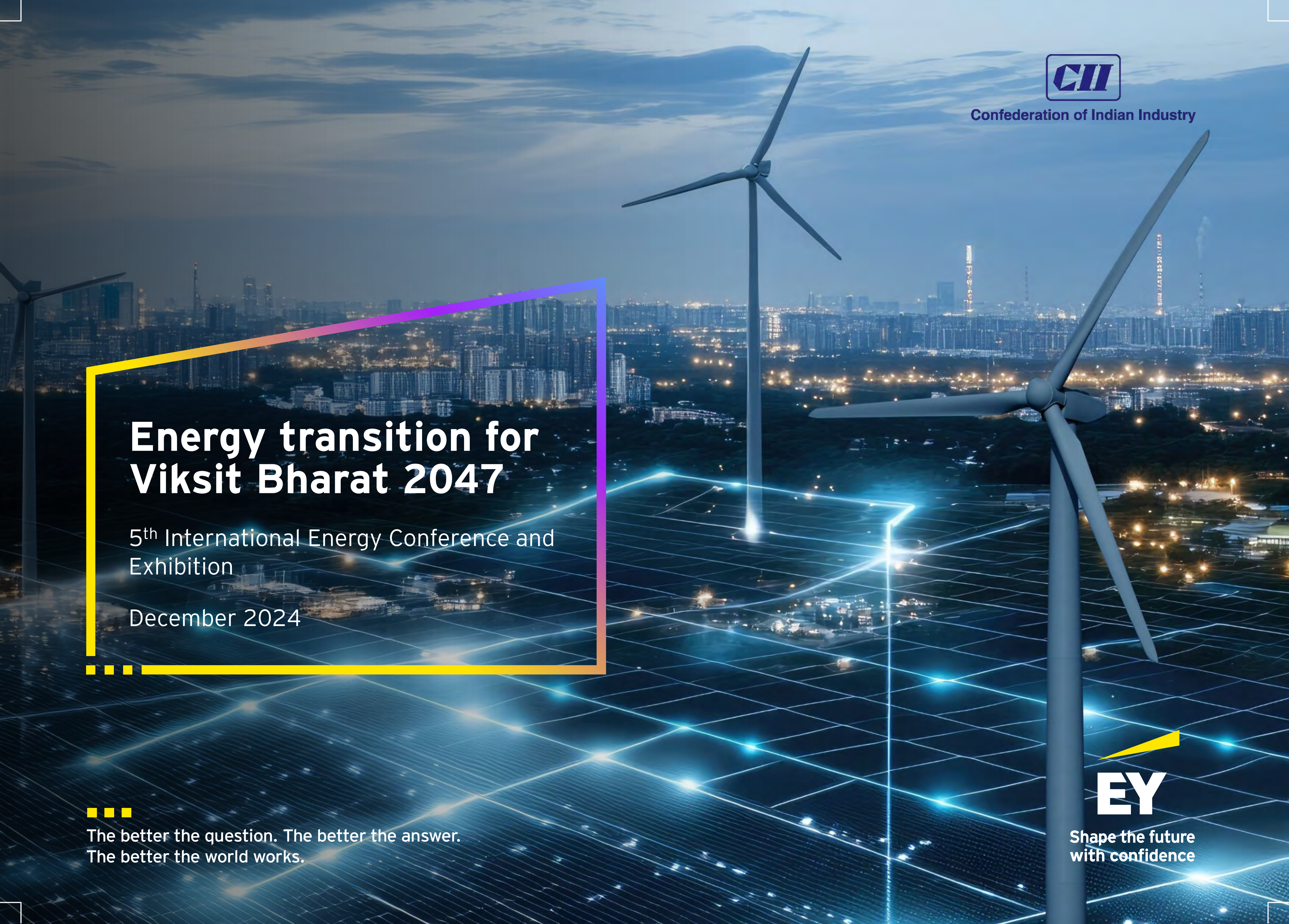

Confederation of Indian Industry

Energy transition for Viksit Bharat 2047

5th International Energy Conference and Exhibition

December 2024

The better the question. The better the answer.
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EY
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FOREWORD

CII

India's decarbonization journey is a story of resilience, innovation, and ambition. From achieving significant milestones such as surpassing 200 GW of renewable energy capacity to becoming the world's third-largest renewable energy producer, India's commitment to combating climate change is evident. Notable advancements include the early achievement of the 10% ethanol blending target in 2022 and aggressive plans to reach 20% by 2025. The Confederation of Indian Industry (CII) has been privileged to play a pivotal role in this journey, fostering collaboration between industries, policymakers, and global stakeholders. With the ambitious goal of net-zero emissions by 2070, India's pathway exemplifies a balanced approach to sustainability and economic growth.

This report, "Energy Transition for Viksit Bharat 2047," delves into key strategies and opportunities for India's energy transformation. Valuable insights from the Government and CII members contributed to the formulation of this report, making it an important recommendatory document in the energy sector.

The 5th CII International Energy Conference & Exhibition will also see the launch of "Energy Transition Investment Monitor 2.0", a platform that tracks over 1,000 decarbonization projects from concept to commissioning. This initiative highlights critical investments in renewable energy, green hydrogen, and energy storage, offering valuable insights into India's evolving energy policy landscape. We appreciate the support from our partner EY, for these two initiatives.

Chandrajit Banerjee

Director General
Confederation of Indian Industry

EY

India's pursuit of a sustainable future underscores its role as a global leader in climate action. With over 46% of its total installed energy capacity now coming from renewable sources and ambitious plans to triple nuclear power generation to 22.5 GW by 2032, India continues to redefine its energy landscape. The country's National Green Hydrogen Mission, backed by a US$2.4 billion investment, further solidifies its position as a pioneer in clean energy innovation. At EY, we are proud to contribute to this transformative journey, aligning our expertise with India's aspirations for a net-zero future by 2070.

The "Energy Transition for Viksit Bharat 2047" report outlines India's roadmap to energy sustainability. It features actionable insights on renewable energy innovation and highlights the "Energy Transition Investment Monitor 2.0," developed in collaboration with CII. This platform catalogs over 1,000 decarbonization projects, providing a comprehensive view of investment opportunities across the clean energy landscape.

We appreciate the valuable insights and cooperation from CII, Government and Industry stakeholders in shaping this report. EY remains committed to supporting stakeholders in realizing a sustainable, energy-secure, and inclusive future for "Viksit Bharat" by 2047.

Somesh Kumar

Partner & Leader – Power & Utilities - EY India

CONTENT

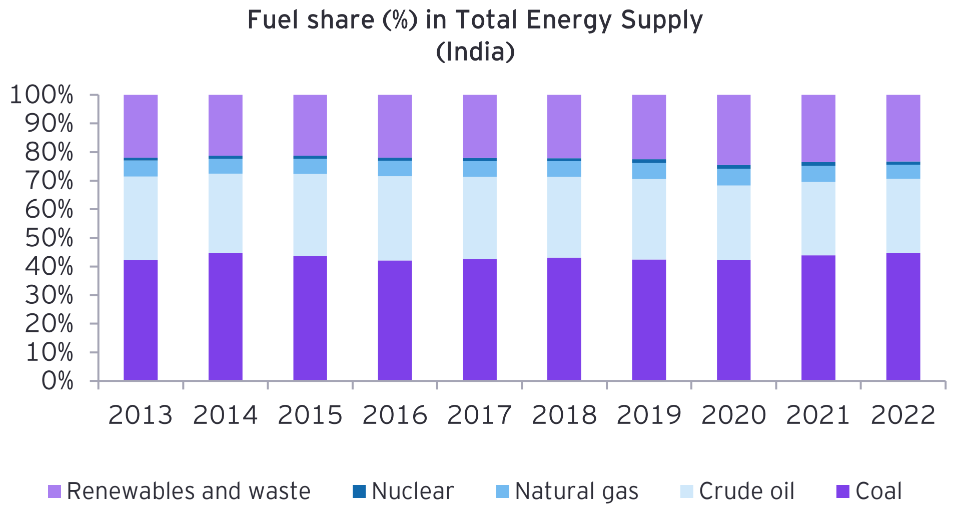
ACRONYMS

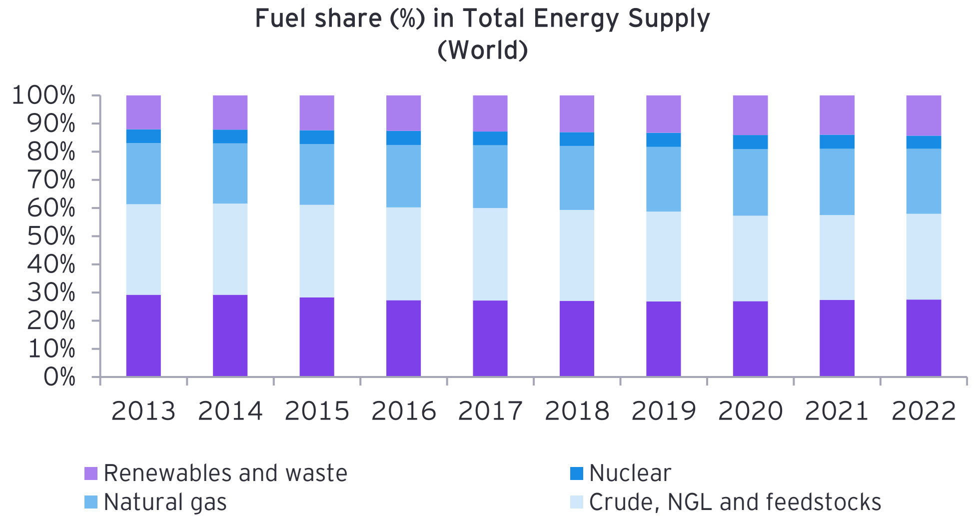
ADD	Anti-Dumping Duty
AERB	Atomic Energy Regulatory Board
ALMM	Approved List of Models and Manufacturers (solar PV in India)
ASC	Additional Surcharge
BARC	Bhabha Atomic Research Centre
BCD	Basic Customs Duty
BESS	Battery Energy Storage System
BWR	Boiling Water Reactor
CBG	Compressed Biogas
CEA	Central Electricity Authority
CEEW	Council on Energy, Environment, and Water
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CSEP	Centre for Social and Economic Progress
CSS	Cross Subsidy Surcharge
CTU	Central Transmission Utility
CTUIL	Central Transmission Utility of India Limited
CUF	Capacity Utilization Factor
CVD	Countervailing Duty
DAE	Department of Atomic Energy
DCR	Domestic Content Requirement
DFI	Development Financial Institution
DG	Diesel Generator or Director General
DRI	Directorate of Revenue Intelligence
ESS	Energy Storage System
ETIM	Energy Transition Investment Monitor
EU	European Union
EVA	Ethylene Vinyl Acetate (solar module material)
FBR	Fast Breeder Reactor
FDRE	Firm and Dispatchable Renewable Energy
FOM	Fermented Organic Manure
FY	Fiscal Year
GAIL	Gas Authority of India Limited
GDP	Gross Domestic Product
GH	Green Hydrogen
GHG	Greenhouse Gas
GNA	General Network Access
GOI	Government of India
GST	Goods and Services Tax
GW	Gigawatt
GWPA	Gigawatts Per Annum
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IEEE	Institute of Electrical and Electronics Engineers
IGL	Indraprastha Gas Limited
INR	Indian Rupee
IOCL	Indian Oil Corporation Limited
IREL	IREL (India) Limited
ISTS	Inter-State Transmission System
LIB	Lithium-Ion Battery
MBED	Market-Based Economic Dispatch
MECON	Metallurgical & Engineering Consultants (India) Limited
MMT	Million Metric Tons
MMTPA	Million Metric Tons Per Annum
MNRE	Ministry of New and Renewable Energy
MTPA	Metric Tons Per Annum
MW	Megawatt
NITI	National Institution for Transforming India (NITI Aayog)
NIWE	National Institute of Wind Energy
NLDC	National Load Dispatch Centre
NPP	Nuclear Power Plant
NTPC	National Thermal Power Corporation
PFC	Power Finance Corporation
PHWR	Pressurized Heavy Water Reactor
PIB	Press Information Bureau
PLI	Production Linked Incentive
PNG	Piped Natural Gas
PPA	Power Purchase Agreement
PSP	Pumped Storage Plant
PV	Photovoltaic
PWR	Pressurized Water Reactor
RBI	Reserve Bank of India
REC	Renewable Energy Certificate
RTC	Round-The-Clock
SAREP	South Asia Regional Energy Partnership
SATAT	Sustainable Alternative Towards Affordable Transportation
SEBI	Securities and Exchange Board of India
SGD	Sustainable Development Goals
SGST	State Goods and Services Tax
SIGHT	Possibly Solar Initiative for Green Hydrogen Transition
SMAM	Sub-Mission on Agricultural Mechanization
SMR	Small Modular Reactor
TFC	Total Final Consumption
TPA	Tons Per Annum
TPD	Tons Per Day
TTC	Total Transfer Capability
WETO	World Energy Transitions Outlook

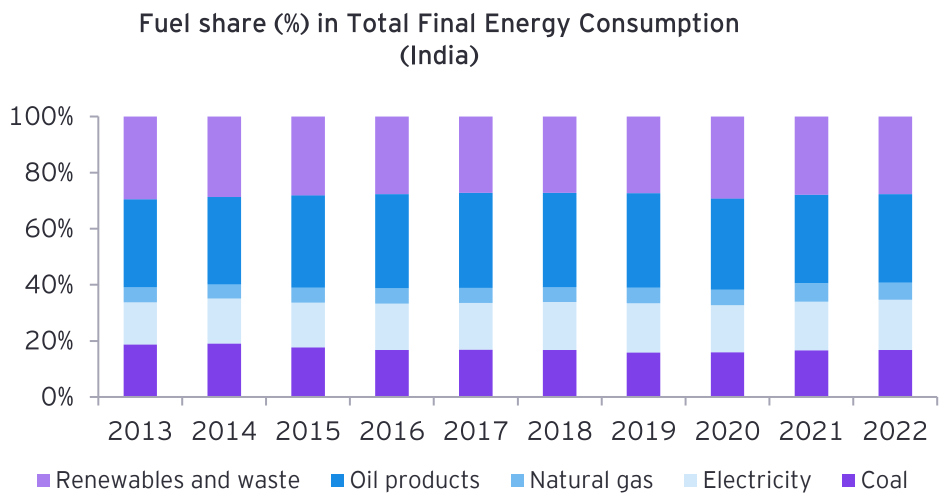
Executive summary

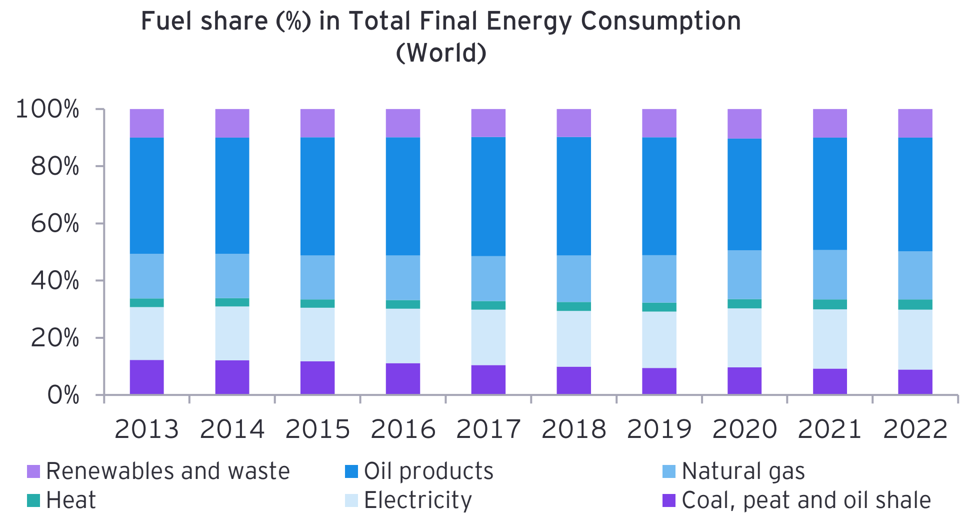
Chapter 01

India vs World: Fossil fuels remain the mainstay of energy supply mix; non-fossil energy share is rising and displacing crude oil in supply; electricity share is rising and displacing coal in final consumption









Source: EY analysis based on IEA World Energy Balance Highlights 2024; Oil product import exports and electricity import exports are excluded in the energy supply mix

Multiple transitions reshaping energy systems are progressing at speed: Together, these shifts signify a transformative opportunity in our experience of achieving Viksit Bharat by 2047

Electricity supply renewables, storage and nuclear transitions

Industrial feedstock supply green hydrogen transition

Bioenergy transitions for mobility and industry applications

Imperatives for energy transition powering Viksit Bharat by 2047

01 Fast paced deployment of low carbon energy technologies to meet rapidly growing energy demand

02 Efficiency and affordability of low carbon energy technologies for mass adoption

03 Development of indigenous advanced small modular reactor (SMR) technologies as scalable low carbon alternative for baseload coal power generation

04 Self-sufficiency of non-fossil technology supply chains to foster energy independence and security

05 Vertical integration fostering competitiveness of indigenous low carbon energy technology supply chains

06 Easing the pressure on natural resources for harnessing low carbon energy at scale

07 Skilling to foster livelihoods and jobs in the low carbon energy industry

08 Unlocking the full potential of bioenergy economy

Source: EY analysis; https://etim-india.com/

Policy actions should focus on improving the security, reliability, efficiency and affordability of low carbon energy systems deployed at scale

Utility scale RE - Transmission

- Increase the power import capability of each state to at least 60% of its peak demand
- Ensure the total transfer capability of states are greater than their GNA
- Synchronize transmission infrastructure commissioning with renewable energy project timelines
- Streamline processes for grid connectivity approvals

Utility scale RE - Land and resources

- Create graded land banks for RE projects and encourage utilization of existing landholdings
- Harmonize land use conversion approvals, charges, RoW compensation frameworks across states

Utility scale RE - Others

- Accelerate implementation of wind repowering policies
- Timely execution of Power Purchase Agreements (PPAs) for awarded projects
- Transmission connectivity and land should be allocated preferentially to wind power projects in high wind potential zones
- Streamlines the National Single Window System
- Establishment of a National Power Council for Coordinated Policy and Implementation

Civil nuclear energy

- Enable private entry through joint ventures and full ownership
- Permit private sector participation across the nuclear fuel cycle
- Focus DAE on areas of expertise (safety, research, security)
- Ensure AERB independence from DAE for unbiased safety oversight
- Support SMR development as replacements for coal plants
- Revise the Civil Liability for Nuclear Damage Act (CLNDA) Amend to align with international standards

Source: EY analysis

Every market should activate a range of accelerators to overcome the inertia of the status quo, keep up the momentum of change

Biofuels supply and adoption

- Incentivize adoption of biomass feedstock aggregation, storage and processing equipment
- Enhance the scope of biofuel blending mandates
- Introduce offtake mandates for bio-manure by fertiliser industry and promote adoption of Fermented Organic Manure (FOM)
- State driven policy incentives for attracting biofuel production investments

Green hydrogen and derivatives value chain

- Grid flexibility enhancement for integrating giga-watt scale renewable energy sources for green hydrogen production
- Recognizing green hydrogen under the harmonized infrastructure list
- Focus beyond electrolytic pathways for GH2 production that offer the best energy efficiency advantage
- GST rationalization of green hydrogen and its derivatives

RE financing – Off-taker (DISCOM) credibility

- Prioritize corporate governance in the Government's annual integrated rating and ranking exercise for DISCOMs
- Selection of Non-executive and Independent Directors with proven experience in scaling profitable energy transition services
- Stock exchange listing of state-owned electric utilities
- Review management structures to efficiently plan and implement energy transition investment strategies

Vertical integration of RE technology supply chains

- Public private partnerships led by energy PSUs for critical upstream component manufacturing
- Access to competitive low carbon energy services for renewable energy technology manufacturing industry
- Implement a mandatory 60% domestic content requirement and enhance cyber security measures for RLMM listed wind turbine generator models
- Expand access to export credit incentives for solar and wind component OEMs
- Production Linked Incentives (PLI) for domestic manufacturing of wind turbine generator components including forging, gearbox, castings, bearings, wind sensors and other small electronic components
- Develop dedicated renewable energy technology manufacturing zones with world-class infrastructure and reliable green energy open access

Source: EY analysis

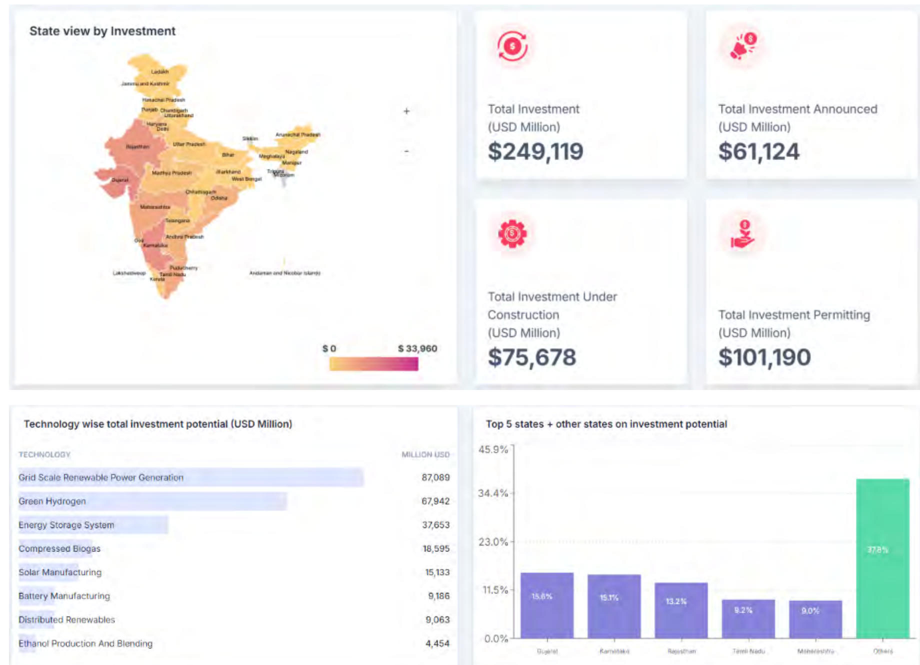
Energy transition investment monitor (ETIM)

https://etim-india.com

About the ETIM Dashboard

Ernst & Young LLP (EY) has collaborated with the Confederation of Indian Industry (CII) to create a platform that assists global investors in identifying and tracking energy transition investments throughout their development cycle. This encompasses various stages from concept to commissioning, including announcements, under bidding, permitting, and under construction phases.

The platform monitors nearly 1,000 energy transition investment opportunities that hold significant potential for economic growth, job creation, and contributing to India's long-term climate action goals and energy security objectives. The project-level information has been compiled through a combination of primary and secondary research tools, utilizing a wide array of public domain sources, and consultations with project developers, original equipment manufacturers (OEMs), and investors etc.



Enhancements in the Second Version of the ETIM Dashboard

The second version of the ETIM Dashboard includes new features aimed at improving user experience and functionality:

Simplified User Account Creation and Login:

Streamlined processes for users to create accounts and log in with ease.

"Verified by Developer" Mark:

Projects that have their data edited, validated, or added by the project developers themselves will receive a verification mark.

Project Management by Developers:

Developers now have the capability to add and edit project details directly on the platform.

Direct Communication with Developers:

Investors can contact project developers directly through a "Contact Developer" button, reducing transaction times.

Email Notifications:

Project developers will receive email notifications whenever their project data is added or edited.

Chapter 02

India's energy transition journey and imperatives for Viksit Bharat 2047

India: Coal remains the mainstay of primary energy supply; crude oil and natural gas contributions decline; renewables including hydro and nuclear together rise the share of non-fossil energy mix to > 5%

Crude Oil:

India saw a noticeable decline in the share of crude oil from 39.16% in 2012-13 to 31.48% in 2022-23. This suggests a gradual reduction in crude oil's importance in the energy mix.

Natural Gas:

The share of natural gas has decreased from 9.23% in 2012-13 to 6.61% in 2022-23. Natural gas's share is fluctuating but on a downward trend, indicating a reduced reliance on it in TPES.

Coal:

Coal's share has remained relatively stable, fluctuating slightly over the years but remaining the dominant source of energy, moving from 55.09% in 2012-13 to 58.98% in 2022-23. Coal continues to be the backbone of energy supply, though it peaked slightly higher during the years.

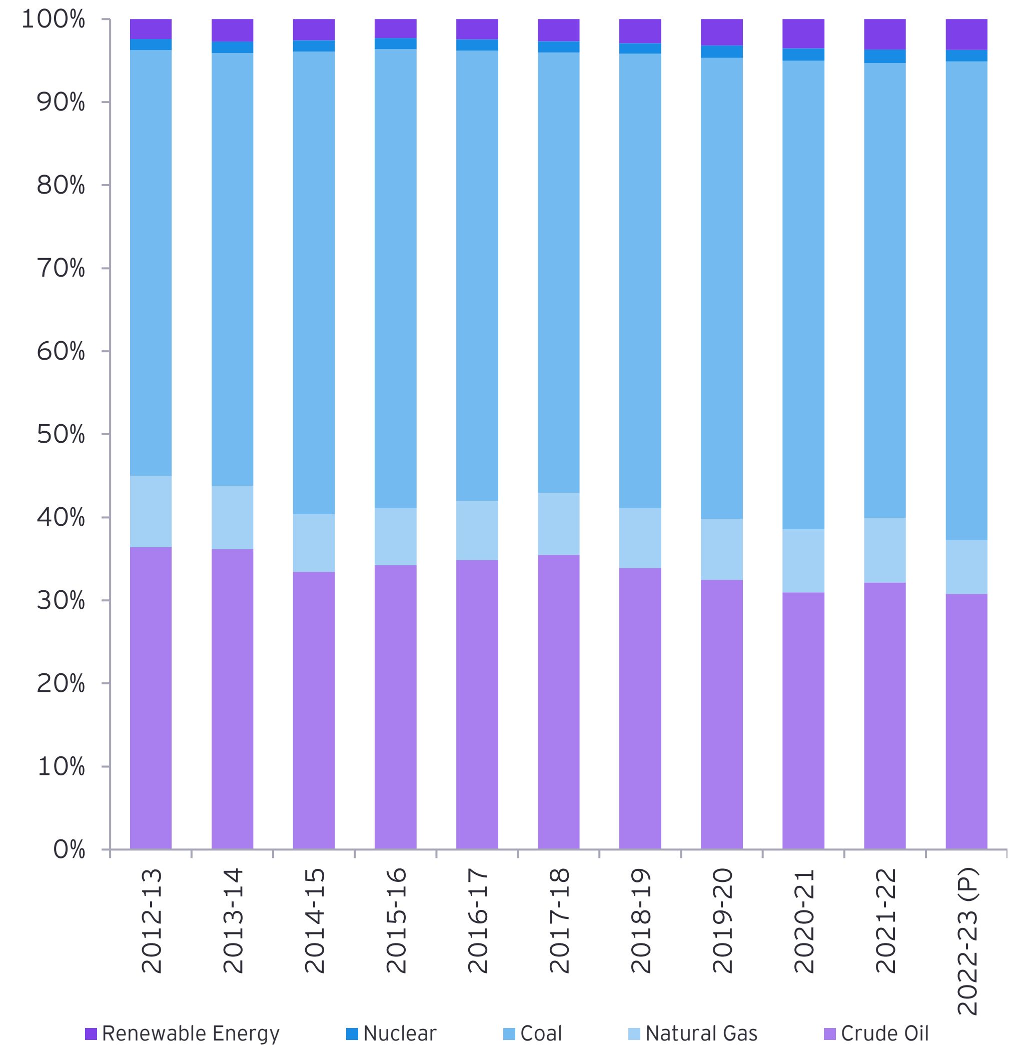
Nuclear:

The share of nuclear energy has remained constant, with a slight decrease over time, fluctuating around 1.3% to 1.65%.

Renewable Energy (RE):

The share of renewable energy has been increasing, from 2.56% in 2012-13 to 3.79% in 2022-23. Though the overall share is still small, the growth indicates a positive shift towards renewables.

Fuel share (%) in Total Primary Energy Supply (India)



Source: Energy Statistics India 2024, MOSPI, Government of India

India: Electricity is displacing coal in the total final energy consumption; oil products and natural gas demand remain stable

Oil Products:

India has witnessed a stable trend in oil product consumption, with fluctuations but a return to 41.18% in 2022-23 after decreasing in some years. This suggests oil continues to play a major role in final energy consumption.

Natural Gas:

The share of natural gas remains relatively low, fluctuating slightly from 6.04% in 2012-13 to 6.39% in 2022-23, suggesting minimal growth.

Coal:

Coal's share in TFC has declined, from 35.97% in 2012-13 to 30.55% in 2022-23. This suggests a gradual shift away from coal consumption in final energy use.

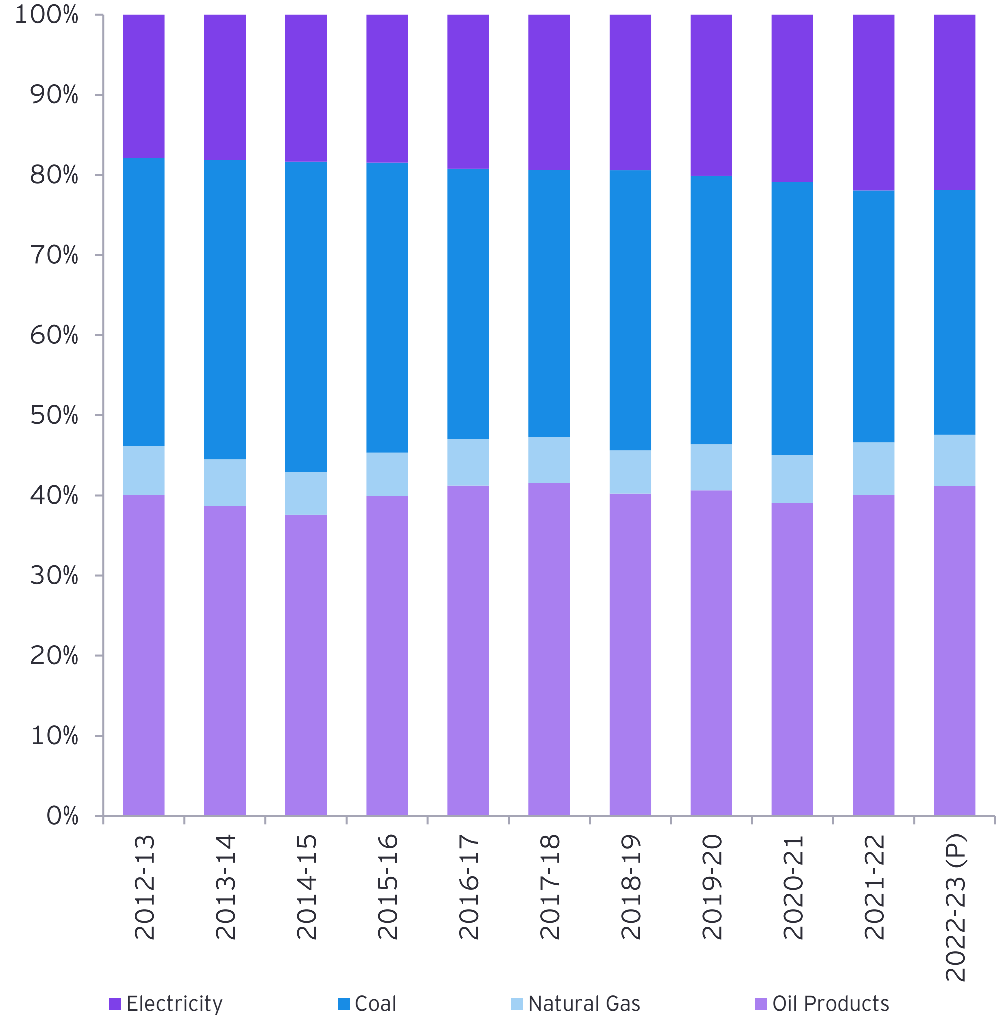
Electricity:

The share of electricity in final consumption has increased steadily, from 17.91% in 2012-13 to 21.88% in 2022-23. This is indicative of electrification trends in various sectors, including industry, transportation, and residential areas.

Divergent trends in energy supply and final consumption post transformation

- Crude oil share of supply is declining whereas oil products share of final consumption is stable
- Coal remains the mainstay of supply whereas its share is declining in final consumption

Fuel share (%) in Total Final Energy Consumption (India)



Source: Energy Statistics India 2024, MOSPI, Government of India

India: Renewables' share is rising in electricity production by displacing coal and natural gas; hydro and nuclear contributions remain stable

Thermal (Coal, Gas, Oil):

The share of thermal energy in electricity generation has been declining, from 81.42% in 2012-13 to 77.18% in 2022-23. This reflects a slow but steady move towards reducing thermal power's dominance in electricity generation.

Nuclear:

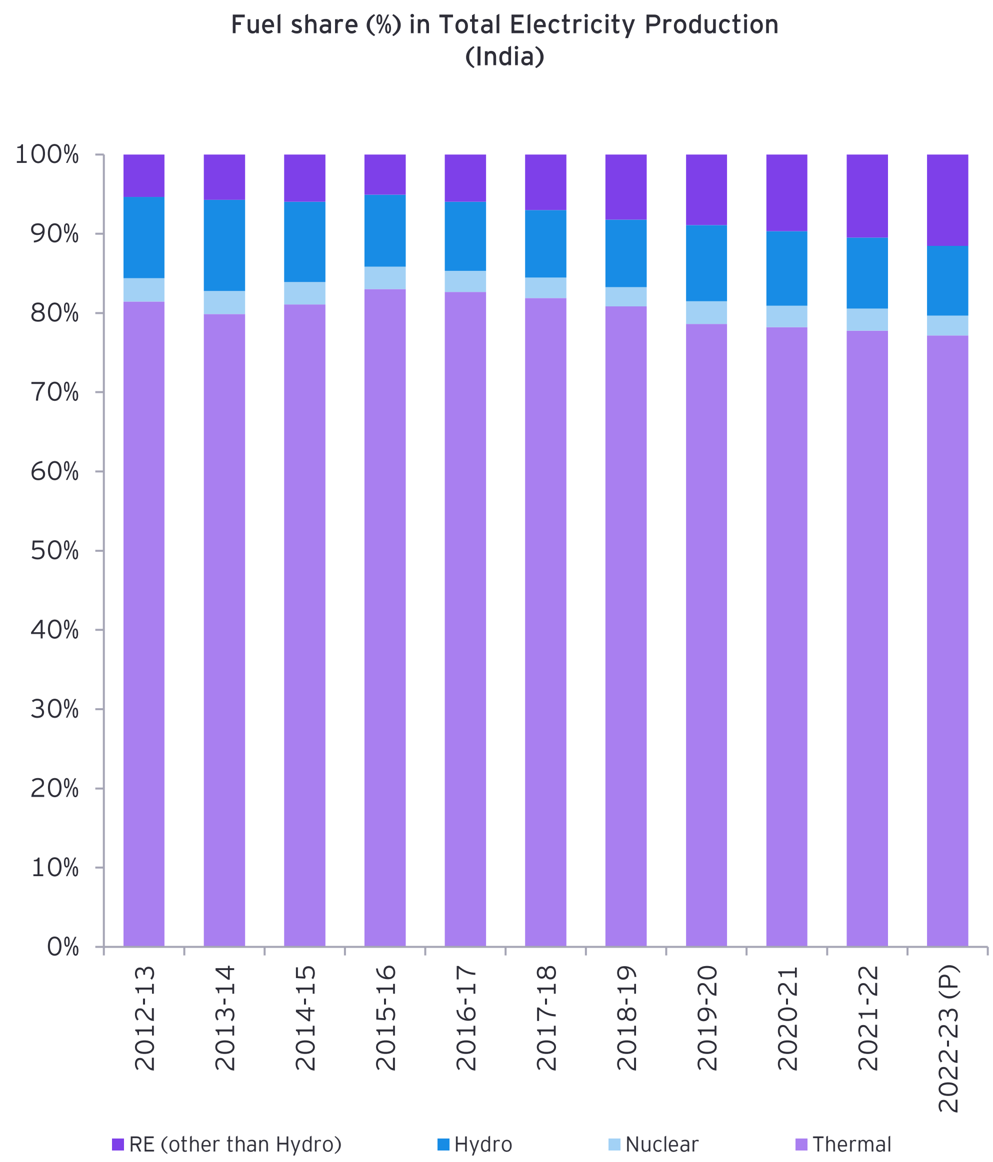
Nuclear power's share has remained relatively steady, around 2.8% to 2.96% in most years, dropping slightly to 2.49% in 2022-23.

Hydro:

The share of hydroelectric power has fluctuated but declined overall from 10.27% in 2012-13 to 8.81% in 2022-23. While hydro remains important, it has not grown as much as other renewable sources.

Renewable Energy (Other than Hydro):

India saw significant growth in renewable energy (other than hydro), increasing from 5.34% in 2012-13 to 11.52% in 2022-23. This reflects a substantial push towards solar, wind, and other forms of renewable electricity generation.



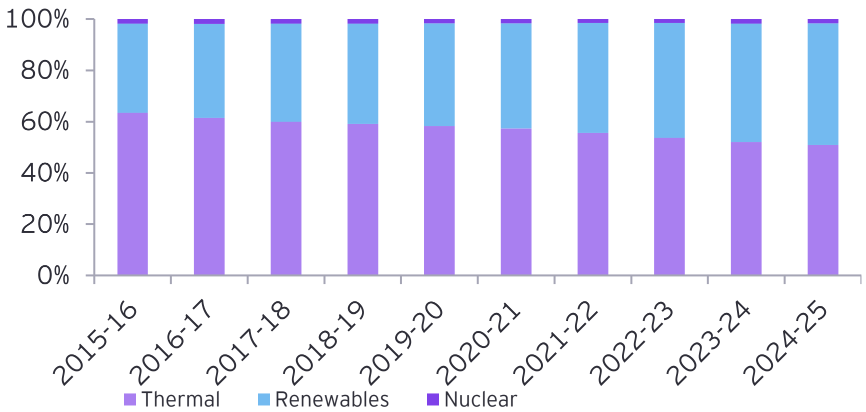
Source: Energy Statistics India 2024, MOSPI, Government of India

Multiple transitions reshaping energy systems are progressing at speed: Electricity supply – Renewables, storage and nuclear transitions

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

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

All India Installed Power Generation Capacity



Recent initiatives for enhancing the production of renewables are noteworthy. PM-Surya Ghar Yojana launched in Feb'2024 with a total outlay of INR75021 crore is expected to add 30 GW of solar capacity and reduce 720 million tonnes of CO2 equivalent, creating around 17 lakh direct jobs across the solar value chain. Also, given India's 7600 km long coastline, the Government has notified the national offshore wind energy policy and offshore wind energy lease rules in 2023. Several offshore zones have been identified for harnessing this potential and viability gap funding for initial capacity of one gigawatt has been announced.

The Government of India is pursuing a multi-pronged strategy for the development of energy storage for integrating variable renewable energy (VRE) sources. Government tenders and financial incentives such as Viability Gap Funding (VGF) are being adopted to encourage battery energy storage system (BESS) adoption. Faster approvals and infrastructure development including access to roads are being facilitated along with incentives for utilities and industries to source power from BESS and Pumped Storage Power (PSP) systems through inter-state transmission charge waivers.

The Ministry of Power has notified that sufficient storage capacity is available with obligated entities, i.e., a minimum percentage of electricity consumption within a Distribution licensee's area shall be procured from renewable energy through energy storage systems. The energy storage obligations of obligated entities is proposed to be gradually increased from 1% in FY 2023-24 to 4% by FY 2029-30, i.e., an annual increase of 0.5%. The Electricity (Rights of Consumers) Amendment Rules 2022 mandates that the consumers using DG sets shall endeavour to shift to cleaner technology such as renewable energy with battery storage and the like in five years or as per the timelines given by the State Electricity Commission for such a replacement.

India is set for a significant surge in the hydropower potential and is expected to rise from the current levels of 47 GW to 67 GW by 2031-32, an increase of over 50%. Hydroelectric power projects with an aggregate capacity of 15 GW are under construction. With the government's policy support this capacity can be achieved.

India is also aiming to triple the existing nuclear power generation capacity to 22.5 GW by 2031-32. In the recent budget presented by the Finance Minister of India, it was particularly emphasized that "nuclear energy is expected to form a significant part of the energy mix for Viksit Bharat." Towards that pursuit, our government will collaborate with the private sector for (1) setting up Bharat Small Reactors, (2) research and development of Bharat Small Modular Reactor, and (3) research and development of newer technologies for nuclear energy. The R&D funding announced in the interim budget will be made available for this sector. Government is pushing for development of indigenous small reactors with the participation of the private sector in nuclear power development.

Source: https://iced.niti.gov.in/energy/electricity/generation/capacity, https://pib.gov.in/PressNoteDetails.aspx?NoteId=153279&ModuleId=3&reg=3&lang=1, https://pib.gov.in/PressReleasePage.aspx?PRID=2035574

Multiple transitions reshaping energy systems

Industrial feedstock supply – Green hydrogen transition

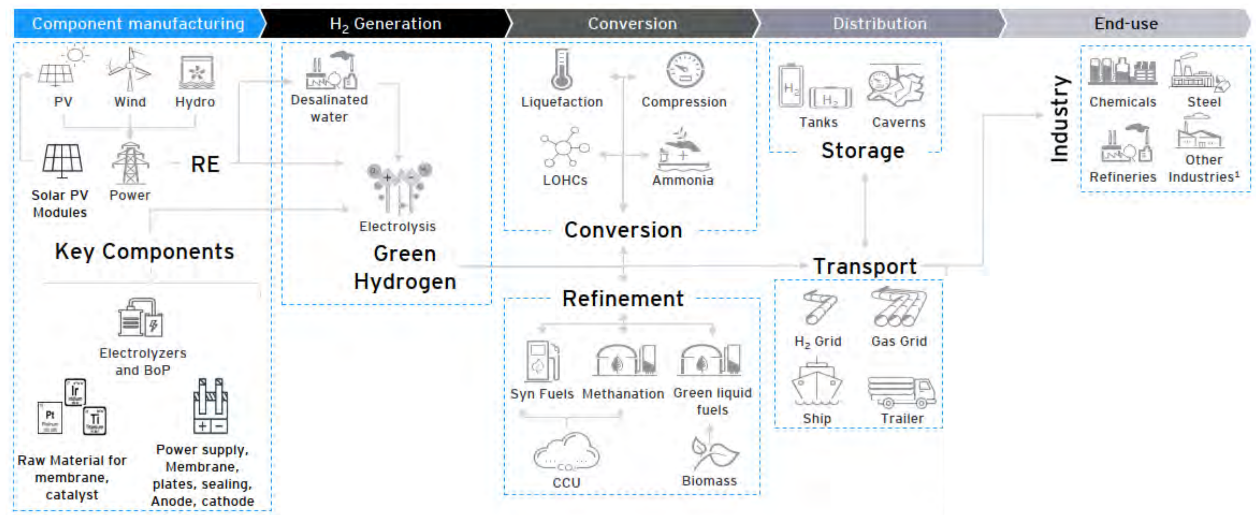
Industrial hydrogen used as feedstock in fertilisers, chemicals, refineries and other industries has immense potential to transition towards low carbon hydrogen production and value chain. The National green hydrogen mission was launched with a total outlay of INR19744 crore (US$2.4 billion) up to FY2029-30. INR4440 crore has been set aside for manufacturing electrolyzers while the remaining INR13050 crore will fund green hydrogen production between FY2025-26 to FY29-30. In addition, the government has announced allocations for pilot projects in the transport, steel and shipping sectors, aimed at replacing fossil fuels and fossil fuel-based feedstock with green hydrogen and its derivatives.

State governments have also formulated independent green hydrogen policies to accelerate and attract investments. The states that have announced policy incentives are Rajasthan, Uttar Pradesh, Maharashtra, West Bengal and Andhra Pradesh. Assam, Bihar, Punjab, Haryana and Gujarat are currently drafting their respective state green hydrogen policies. States such as Odisha provide capital subsidies to the tune of 30%, to attract incentives to their states. States are also providing financial incentives related to water supply, electrolyzer manufacturing, research and development expenditure and on usage of land. Additionally, tax incentives (in the form of GST refunds) and capital subsidies have also been provided by many states to encourage the deployment of green hydrogen. Other than these, benefits of exemptions on various types of electricity associated charges (electricity duty, cross subsidy surcharge, additional surcharge) have also been provided to the eligible developers under the different state specific policies.

Export-oriented investment pipeline

ACME (India) has proposed to supply green ammonia to Japan's IHI Corporation. The Green Hydrogen and Ammonia Project with a planned capacity of 1.2 MTPA is proposed to be developed by ACME in the state of Odisha. The IHI Corporation has signed an offtake term sheet with ACME for the supply of green ammonia from Odisha to Japan. Singapore's Sembcorp Industries has signed an agreement with power generation companies and conglomerates in Japan to export India-made green hydrogen to Japan. Under this arrangement, three companies will be exploring opportunities to produce green ammonia in India and export it to Japan. YARA Clean Ammonia (world's largest trader and distributer of ammonia) and Greenko ZeroC (green ammonia production arm of India-based AM Green) are reported to have recently signed a term sheet for supply of renewable ammonia from Phase 1 of Ammonia production facility in Kakinada in the state of Andhra Pradesh in India.

Green hydrogen production and value chain



Sources: IRENA, IEA, EY analysis.
Note: 1. Mainly food & beverage, semiconductors and glass.

Source: EY analysis based on information from IH2A, https://ih2a.com/resources/

Multiple transitions reshaping energy systems

Bioenergy transitions for mobility and industry applications

India's big focus on bioethanol helps it both reduce emissions and enhance energy security, besides linkages with the agricultural sector. The National Policy on Biofuels, notified by the Government of India in 2018, mandates oil marketing companies to blend 20% ethanol, sourced from agricultural inputs, into petrol by 2030. To ensure effective implementation, the government has also set a price at which ethanol would be procured by the oil marketing companies and has facilitated financial incentives towards setting up of ethanol manufacturing capacity in India.

India has achieved intermediate target of 10% blending of ethanol much ahead of target by November 2022. Therefore, the target of 20% ethanol blending was advanced from 2030 to 2025-26. In the future, it is likely that similar mandates are imposed on other fuels:

National Biofuels Coordination Committee (NBCC) under the aegis of Ministry of Petroleum and Natural Gas has proposed to blend compressed bio-gas (CBG) with compressed natural gas used for transportation and piped natural gas used for domestic purposes by entities licensed to supply city gas in India. As per the current plans, CBG blending obligations will be voluntary until FY2025 and become mandatory thereafter. In line with the experience of blending ethanol with petrol, the blending obligation will increase with time.

Ministry of Power issued revised guidelines for biomass policy and now mandates 5% biomass co-firing in Thermal Power Plants (TPPs) from FY 2024-25. This obligation shall increase to 7% from FY 2025-26. Similar proposals are under consideration for aviation fuel. A recent government release stated that 1% target of sustainable aviation fuel may be introduced for international flights in 2027.

Since its inception, the ethanol blending percentage has surged from 1.53% in 2014 to 15% in 2024. Encouraged by this progress, the government has set an ambitious target of reaching 20% blending by 2025 and is confidently progressing towards this goal. Over the past decade, this initiative has delivered significant benefits, including saving INR 99,014 crore in foreign exchange, reducing CO2 emissions by 519 lakh metric tons, and substituting 173 lakh metric tons of crude oil. Furthermore, the program has had a considerable economic impact, with Oil Marketing Companies disbursing INR1,45,930 crore to distillers and INR87,558 crore to farmers. The Global Biofuels Alliance (GBA), established during India's G20 presidency, serves as a collaborative platform for sharing knowledge, advancing technology, and developing policies to harness the US$500 billion opportunity in biofuels and accelerate global adoption through technology transfer. Government initiatives include specific blending targets for ethanol, CBG, and SAF; the Repurpose Used Cooking Oil (RUCO) initiative; Galvanizing Organic Bio-Agro Resources Dhan (GOBARdhan); and the Samarth Mission.

Source: EY analysis, https://www.niti.gov.in/sites/default/files/2021-06/EthanolBlendingInIndia_compressed.pdf

Biomass reforming for green hydrogen production

Biomass reforming presents a promising pathway for producing green hydrogen, leveraging organic materials as feedstock. Unlike electrolysis, which requires renewable electricity, biomass reforming offers a route that can utilize. agricultural residues, forestry waste, and other organic materials to generate hydrogen while maintaining a lower carbon footprint. There are several established and emerging technologies for biomass reforming:

Gasification: Biomass is converted into syngas (a mixture of CO and H_2) in the presence of a controlled amount of oxygen or steam.
Pyrolysis: Biomass is decomposed at high temperatures in the absence of oxygen, producing bio-oil, syngas, and biochar. Hydrogen can be extracted from the syngas component.
Dark Fermentation: Microorganisms produce hydrogen directly from biomass without light.

There are several advantages of Biomass reforming pathways:

Low Carbon Intensity: Biomass is considered carbon-neutral since the CO_2 released during reforming is offset by the CO_2 absorbed during biomass growth.
Resource Abundance: Agricultural residues, municipal solid waste, and forestry waste are widely available, providing a cost-effective and sustainable feedstock.
Decentralized Production: Biomass reforming can be deployed close to feedstock sources, reducing transportation costs and emissions.
Circular Economy: Utilizes waste streams, contributing to resource efficiency and waste reduction.

Value chain of Biomass-Based Green Hydrogen involves following:

Feedstock Supply and Collection:

- Sourcing of biomass from agriculture, forestry, or waste streams.
- Establishment of efficient supply chains and aggregation systems.

Pre-treatment and Processing:

- Drying, shredding, or pelletizing biomass to improve its conversion efficiency.
- Pre-treatment ensures consistent feedstock quality.

Conversion and Reforming:

- Deploying gasification, pyrolysis, or biochemical processes to produce hydrogen-rich gas streams

Imperatives for energy transition powering Viksit Bharat by 2047

India is a net importer of fossil fuel commodities and relies on imports to meet nearly ~40% of its energy needs. Consequently, volatility in prices of imported energy commodities renders the Indian economy vulnerable to external shocks. Energy transition provides a pathway for India to diversify energy mix, reduce reliance on imports and achieve greater energy independence by using domestically available low carbon energy resources. However, there are multiple imperatives to ensure a timely and seamless energy transition by 2047.

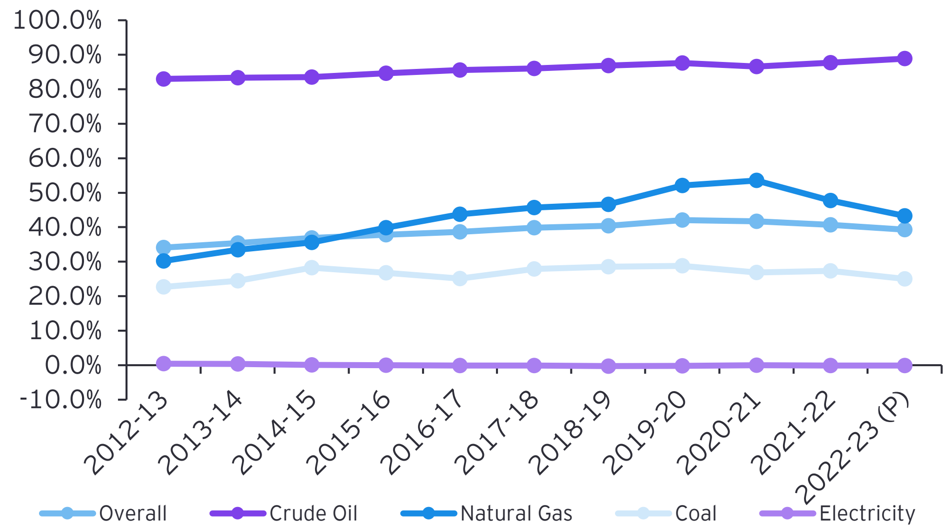
Fast paced deployment of low carbon energy technologies to meet rapidly growing energy demand

India's energy needs are expected to grow 2 to 2.5 times by 2047 to meet a growing economy's developmental priorities and aspirations. The country aims to increase the share of contribution of manufacturing from 17% to 25% of the total GDP, become third largest economy by 2030 and developed country (Viksit Bharat) by 2047. In a recent' Brainstorming Session on the Indian Power Sector Scenario 2047' organized by the Central Electricity Authority (CEA), the Union Minister for Power indicated that the electricity demand could reach 708 GW by 2047 and to meet this, installed power generation capacity may need to be quadrupled from existing levels to reach 2100 GW. Energy demand growth has consistently outpaced the non-fossil energy system (viz. solar PV, wind, energy storage, biofuels etc.) capacity addition required to serve the incremental demand for various reasons. Therefore, demand for fossil fuel energy services will remain to bridge this gap in the foreseeable future until capacity addition planning, procurement frameworks, project development (land acquisition, transmission build out, grid connectivity), construction and commissioning timelines for renewable energy deployments are streamlined, derisked and optimized at the required scale i.e.> 50 GW per annum.

Efficiency and affordability of low carbon energy technologies for mass adoption

Renewable energy sources such as solar and wind by nature are distributed (low spatial energy density) and exhibit intermittency / variability (diurnal and seasonal) in the production. Therefore, the efficiency of harnessing such energy with today's technologies (PV, turbines) and infrastructure can be characterized as sub-optimal when compared to fossil fuel-based energy systems. For example, land (spatial) footprint (MW installed/acre) for operating solar and wind power systems is four and two times that of coal based thermal power generation systems respectively. Further, a coal or natural gas based thermal power generation systems can operate at >80% capacity utilization factor (CUF) delivering firm and dispatchable electricity whereas renewable power generation sources such as solar PV and wind are intermittent with 20-35% CUF at best when they operate in hybrid mode. Harnessing and delivering intermittent low carbon energy sources to end-users will need vast networks of transmission infrastructure build out spanning across the country also operating at sub-optimal CUFs and expensive energy storage technologies for grid integration. Technology pathways that enable production of green hydrogen and its derivatives (e.g. water electrolysis @ <65%) operate at much lower efficiencies compared to fossil-fuel powered technologies (e.g. steam methane reformation @>80%).

Energy import dependency in % (India)



Source: Energy Statistics India 2024, MOSPI, Government of India

Imperatives for energy transition powering Viksit Bharat by 2047

Lithium-ion batteries for advancing electric mobility are much more efficient when we consider tank to wheel efficiency but when we consider well to wheel efficiency, critical minerals mining, refining, production of battery cells, modules, integration with renewable sources for charging operations come into play. Such embedded inefficiencies in low carbon energy technologies for land siting, transmission build out, grid connectivity and integration, feedstock supply, energy production, transformation, storage and end-use impede cost competitiveness and affordability for mass adoption. Access to reliable energy at a reasonable cost (affordable) and at a pace required to power ambitious economic development targets while on a low-carbon pathway is the sine qua non for energy transition. Moreover, balancing development needs with a low-carbon pathway is a tightrope, especially when financed predominantly through domestic resources which command higher cost of capital. The government of India has adopted commendable policies and initiatives to streamline and derisk project development and operations of renewable energy technologies, particularly, solar, wind, green hydrogen, energy storage, biofuels etc at scale.

Development of indigenous advanced small modular reactor (SMR) technologies as scalable low carbon alternative for baseload coal power generation

Nuclear energy is the most energy dense (spatial) low carbon alternative for baseload thermal power generation in the current scenario (see table). No other low carbon energy technology available today exhibits the competitive advantages (viz. spatial energy density, capacity utilization factor, firmness and dispatchability, levelized cost of electricity etc.) comparable or even better than fossil-fuel based power generation systems.

Mr. Anil Kakodkar, Former Chairman of the Atomic Energy Commission has said that a large enough role of nuclear energy is inevitable for realization of net-zero. Nuclear being the only clean energy baseload supply of significance is also important to keep tariff to electricity consumers under check which otherwise could become significantly larger with higher level of integration of variable renewable energy. Therefore, its rapid scale up to the required levels is a challenge that the country and its policy makers must brace up to.

However, scaling nuclear power generation is not without challenges. Mr. Amitabh Kant, Former CEO, NITI Aayog has said that the rise of SMRs in the post-Fukushima era has been on account of their small footprint requiring less than a tenth of a hectare, suiting space-limited areas and promoting sustainable nuclear power. They can be installed with no time and cost overruns. Compact, safe SMRs can enhance nuclear infrastructure, with modular designs for various use cases, including remote areas and industrial settings. SMR's ability to integrate with renewables can offer a resilient grid and manage intermittency. Costing around INR 4.0/kWh, they can also be valuable contributors to industrial processes, demonstrating versatility beyond traditional electricity generation. To accelerate the adoption and further manufacturing of SMRs and its components there are six critical areas where India needs to take expeditious action:

01
- Private Sector Participation

02
- Dedicated Nuclear Waste Agency and Policy

03
- Additional Insurance cover under the Civil Liability for Nuclear Damage (CLND) Act, 2010

04
- Accelerated Technology Transfer to India

05
- R&D and collaboration

06
- Inclusion in Green Taxonomy

Source: https://amitabhkant.co.in/upload/articles/11437336666ac741dee77b4.52091910_clear-on-small-nuclear.pdf, https://www.anilkakodkar.in/index.php/nuclear-energy/nuclear-energy-is-inevitable, https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1748885

Imperatives for energy transition powering Viksit Bharat by 2047

An investigation of the worldwide energy density for ten types of power generation facilities involving two non-renewable sources (i.e., nuclear power and natural gas) and eight renewable sources (i.e., hydropower, concentrated solar power (CSP), solar photovoltaic (PV) power, onshore wind power, geothermal power, offshore wind power, tidal power, and wave power). In total, the study covers 870 electric power plants worldwide, where not only the energy density but also the resulting land or sea area requirements to power the world are estimated.

	Mean specific power (p_g)		Annual energy density (ε_g)		C_g	
Source	*mdn* (W/m^2)	*avg* ± *dev* (W/m^2)	*mdn* (TWh/km^2)	*avg* ± *dev* (TWh/km^2)	*avg* (%)	*n*
Nuclear	587.17	764.69 ± 549.69	5.147	6.703 ± 4.819	81.0	159
Natural gas	350.37	374.14 ± 247.38	3.071	3.280 ± 2.168	52.7	26
Hydro	4.26	33.73 ± 157.28	0.037	0.296 ± 1.379	41.9	451
Solar (CSP)	14.45	20.33 ± 12.74	0.127	0.178 ± 0.112	24.8	27
Solar (PV)	9.13	9.91 ± 3.28	0.080	0.087 ± 0.029	14.2	17
Wave	9.73	7.94 ± 2.77	0.085	0.070 ± 0.024	35.1	11
Geothermal	5.56	4.88 ± 3.39	0.049	0.043 ± 0.030	65.2	8
Solar (rooftop)	4.17	4.58 ± 2.25	0.037	0.040 ± 0.020	13.1	39
Wind (offshore)	3.84	3.89 ± 1.61	0.034	0.034 ± 0.014	44.3	11
Tidal	2.29	2.84 ± 2.49	0.020	0.025 ± 0.022	24.1	12
Wind (onshore)	1.49	2.12 ± 2.06	0.013	0.019 ± 0.018	34.0	148
Biomass[3]	0.08	0.13 ± 0.02	0.001	0.001 ± 0.000	n.a.	63

Aggregated result of the mean and annual power and energy densities of the 10 different energy
resources examined. The mean, median and standard deviation are given, as well as the average capacity factor and the number of samples (n) per population.
Source: Spatial energy density of large-scale electricity generation from power sources worldwide | Scientific Reports (nature.com)

Self-sufficiency of non-fossil technology supply chains to foster energy independence and security

The CEEW argues that building indigenous supply chains for non-fossil technologies is critical to enhance energy independence, foster value-addition in manufacturing, and create positive externalities on growth and innovation. Indigenising supply chains thus supports distinct yet interconnected avenues of strategic value to the Indian economy – resilience and security; domestic value capture; export opportunities; and structural transformation all of which are embedded in the 'Aatma Nirbhar' Bharat vision by 2047. Self-sufficiency reduces reliance on imports, enhances energy security through domestic production. Most importantly it enables domestic value capture and export opportunities improving balance of payments, fosters price stability, drives economic growth and creates additional jobs. Government of India has adopted policies promoting production linked incentives for value added low carbon technologies such as solar PV, Li-ion batteries, electrolysers etc. while also mandating the adoption of indigenous listed products (Solar PV cells and modules, wind turbines) for access to various fiscal and non-fiscal incentives available for development of projects and provision of energy services.

Vertical integration fostering competitiveness of indigenous low carbon energy technology supply chains

Project developers delivering various energy services from deployment of low carbon technologies face intense competition from domestic and international players through reverse auctions, tenders to secure projects, off-take agreements, export contracts, sales of products and services etc. In this scenario, cost competitiveness and quality assurance of indigenous technology supply chains is critical, especially when the government policies are binding for the industry to adopt locally manufactured products. Otherwise, the cost of low carbon energy services for end-users tends to be higher than affordable levels ultimately delaying the pace of energy transition. Vertical integration of supply chains from raw material production to end-use product is fundamental to achieve this. For example, in the solar PV module industry, local supply chains must be integrated from polysilicon – ingot – wafer – cell – module with robust R&D ecosystem for continuous technology advancement keeping pace with global market developments. Similarly, Li-ion batteries, wind turbines, electrolyser supply chains should aim to vertically integrate from critical minerals, active raw materials to end-products for domestic value addition, profitability, resilience, and cost competitiveness.

Source: https://amitabhkant.co.in/upload/articles/11437336666ac741dee77b4.52091910_clear-on-small-nuclear.pdf, https://www.anilkakodkar.in/index.php/nuclear-energy/nuclear-energy-is-inevitable, https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1748885

Easing the pressure on natural resources for harnessing low carbon energy at scale

The CEEW estimates that India will need a solar capacity of over ~5,600 GW and a wind capacity of ~1,800 GW to achieve net-zero emissions by 2070. Furthermore, the green hydrogen demand in India in sectors such as fertiliser, refinery, steel, and transportation could reach ~30 million tonnes per annum (MTPA) by 2050 if cost competitiveness is achieved without fiscal support. However, large-scale RE and green hydrogen development entails challenges related to land and water access. The availability of land is a major challenge for India, which has the lowest land availability per capita amongst the G20 countries. The transition cost would be amplified with the expected increase in the need for land for renewable energy projects.

While RE deployment depends on land availability, green hydrogen relies on water resources. These constraints hinder the full realization of RE generation and green hydrogen production potential. Solar power, a major renewable source, requires extensive land resources. The current distribution of land use, as well as potential changes therein will determine whether sufficient land is available for widespread RE deployment. Additionally, the location of the available land is crucial, as end users prefer to deploy RE sources locally rather than transmitting power over long distances. Moreover, green hydrogen production requires access to water resources, known as uncommitted water, beyond what is already committed to the agricultural, industrial, domestic, and other sectors. The cost of land and availability of water directly influence the levelized cost of power and hydrogen. Therefore, to meet the ambitions of Viksit Bharat 2047 and net-zero targets, India needs to evaluate the overall potential for RE and green hydrogen and understand the challenges associated with realising this potential.

Skilling to foster livelihoods and jobs in the low carbon energy industry

The renewable energy industry, including solar, wind, bioenergy, and energy storage, requires specialized technical and operational skills different from those needed for fossil fuel-based sectors. Technologies like solar photovoltaic (PV) installation, wind turbine maintenance, energy storage management, and green hydrogen production are new and rapidly evolving, creating a demand for a trained workforce capable of operating these systems. The International Renewable Energy Agency (IRENA) estimates that the global transition to renewable energy could generate **42 million jobs by 2050**. In India alone, meeting renewable energy targets could create **1 million new jobs by 2030** across construction, operation, and maintenance roles. Renewable projects also create indirect jobs in the supply chain (e.g., manufacturing of solar panels and wind turbines) and auxiliary services, such as project management and financing. As fossil fuel-based industries decline due to growing demand for affordable low carbon energy services driven by policies, there is an urgent need to retrain workers from traditional energy sectors to prevent job losses and ensure just transition. Fossil fuel workers already possess transferable skills that can be adapted to the renewable sector. For example, electricians, mechanical engineers, and plant operators can transition to solar, wind, or energy efficiency roles with targeted training programs. Renewable energy projects, particularly solar and wind farms, are often situated in remote and rural areas, offering local employment opportunities. Skilling local populations ensures that the benefits of these projects are distributed equitably. For example, India's rooftop solar programs are fostering jobs in installation and maintenance for urban and rural communities, contributing to decentralized energy access and employment. In the context of emerging markets, skilling also plays a role in promoting innovation and local manufacturing, thus reducing reliance on imported technologies. A skilled workforce is essential to unlock the full potential of the low-carbon energy industry. Effective skilling will not only foster livelihoods but also facilitate a smooth transition for displaced fossil fuel workers (if any), ensure equity, and enhance productivity in renewable sectors. Governments, industry stakeholders, and educational institutions must collaborate to build this workforce, ensuring long-term competitiveness and sustainability.

Imperatives for energy transition powering Viksit Bharat by 2047

Unlocking the full potential of bioenergy economy

Biofuels involve the direct conversion of biomass into liquid fuels, which can be blended with existing automotive fuels. Ethanol and biodiesel are the two main transport biofuels. These fuels can be produced from a variety of biomass. First generation (1G) biofuels are usually made from edible feedstock like sugarcane, beets, food grains etc. 2G fuels are produced from lignocellulosic biomass obtained from energy crops or waste biomass, such as agricultural and forest residue.

The government of India's strategy encompasses several vital areas, including ethanol and biodiesel blending, Compressed Biogas (CBG), Sustainable Aviation Fuels, biomass utilization (such as pellets and briquettes), Biohydrogen, and waste-to-energy solutions.

Turquoise hydrogen could also be produced using biochar grown from various bioenergy plantations, such as bamboo, rice stacks, cotton plant residue, and many other agricultural crop residues. Biochar demand generation from sectors such as steel making and agriculture itself could propel and incentivize supply. This would in turn incentivize farmers, supporting their incomes, industries established in rural areas, and the whole green ecosystem transitions in India.

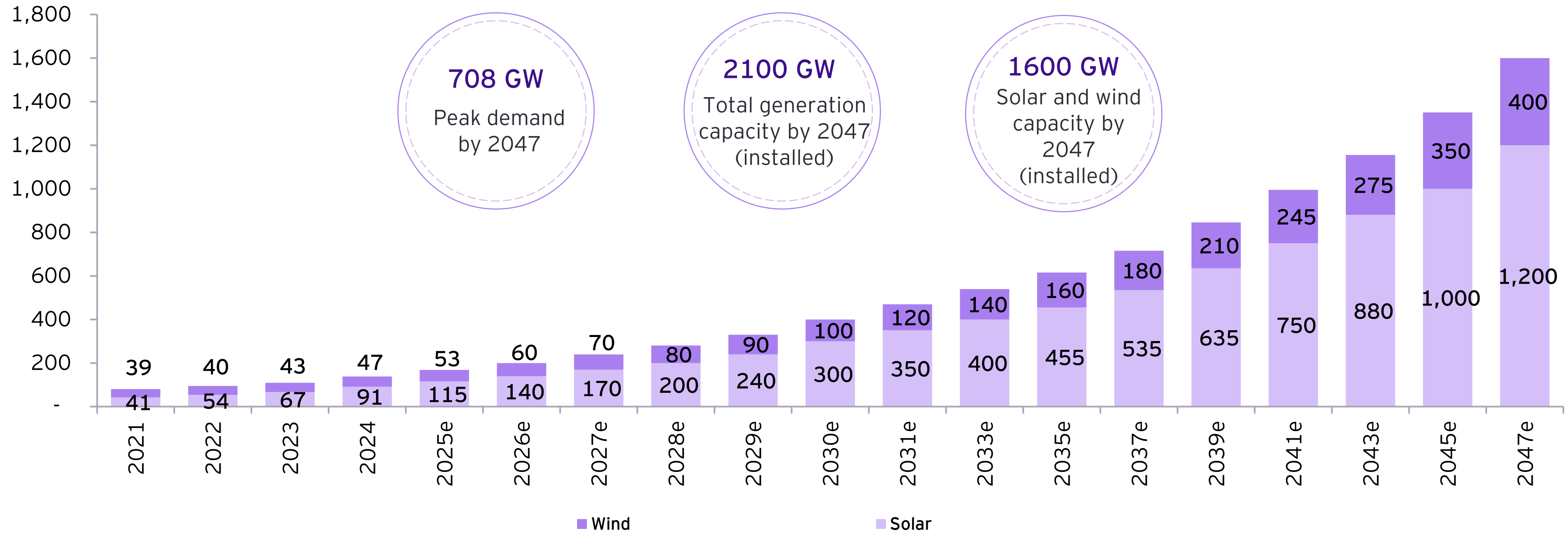
Utility scale renewable energy development and grid integration

Chapter 03

India solar and wind capacity addition run-rate (expected) by 2047

Annual capacity additions need to scale ~2x by 2030 and progressively to ~10x by 2047

All India solar and wind power generation capacity (expected) (GW)

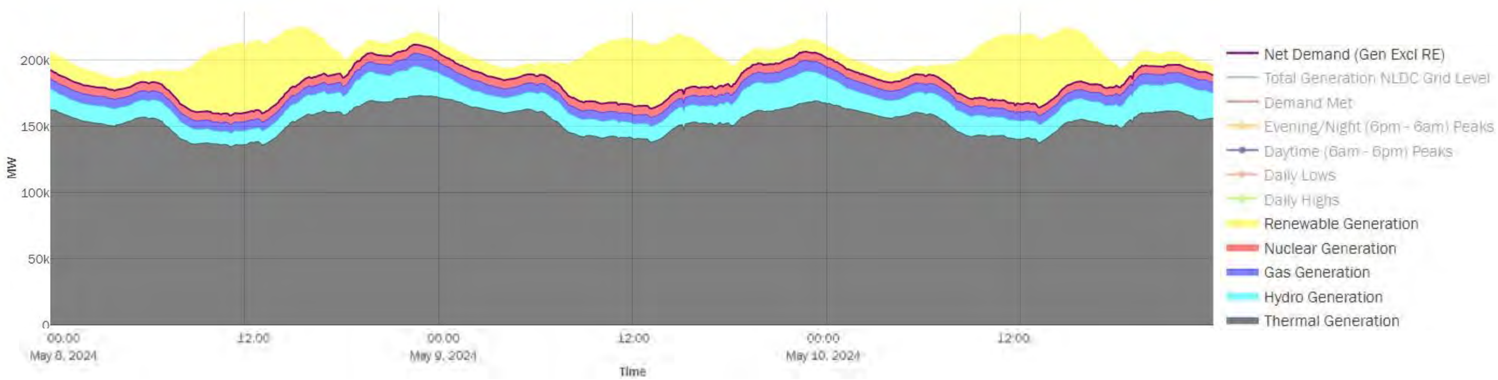


Total run-rate, GW per annum	14 - 28 GWPA	30 - 70 GWPA	70 - 250 GWPA
Wind run-rate, GW per annum	1 - 4 GWPA	5 - 10 GWPA	20 - 50 GWPA
Solar run-rate, GW per annum	13 - 24 GWPA	25 - 60 GWPA	50 - 200 GWPA

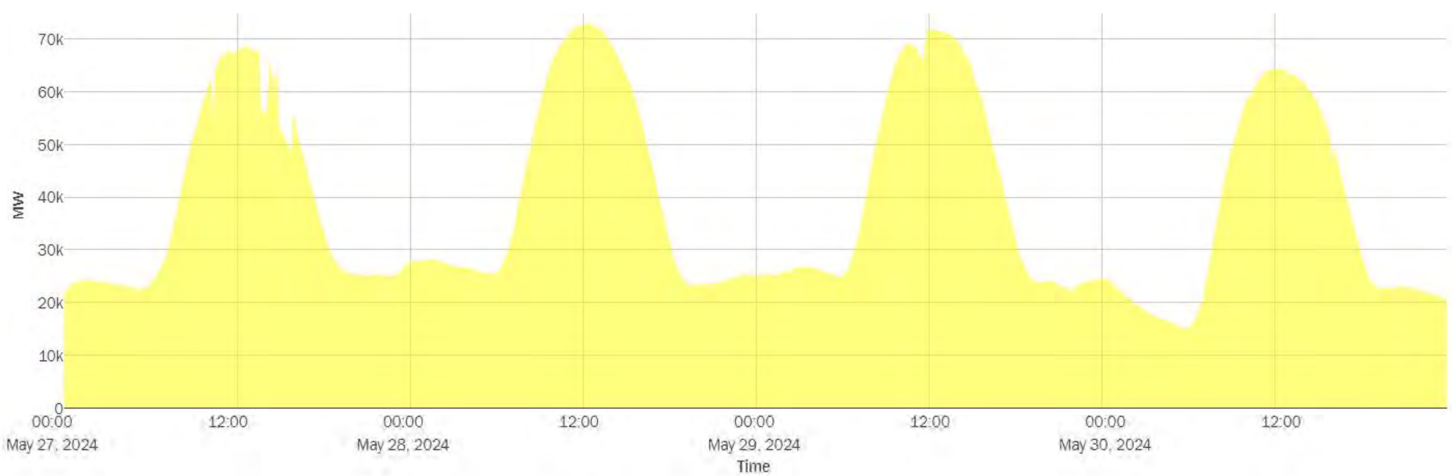
Source: MNRE, MoP, CEA, EY analysis; https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2064702

Flexibility from energy storage systems is fundamental to manage intermittency of renewables: The current net load curve assumes a characteristic "duck" shape, with a decrease during the day and increase in the evening

All India Electricity Generation Profile in May 2024



All India Renewable Power Generation Profile in May 2024

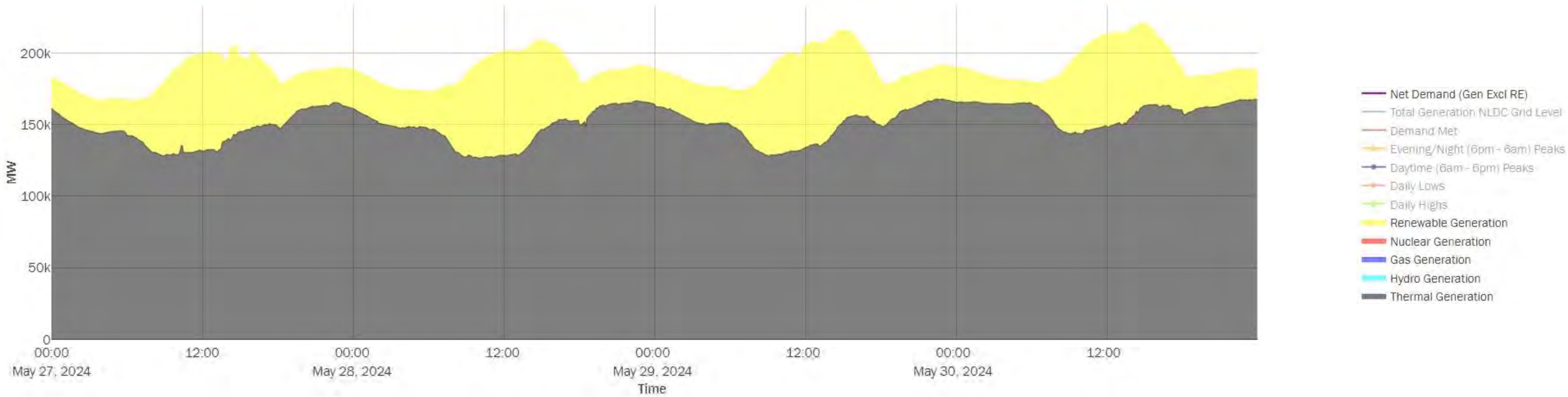


Source: EY analysis, CSEP Electricity & Carbon Tracker

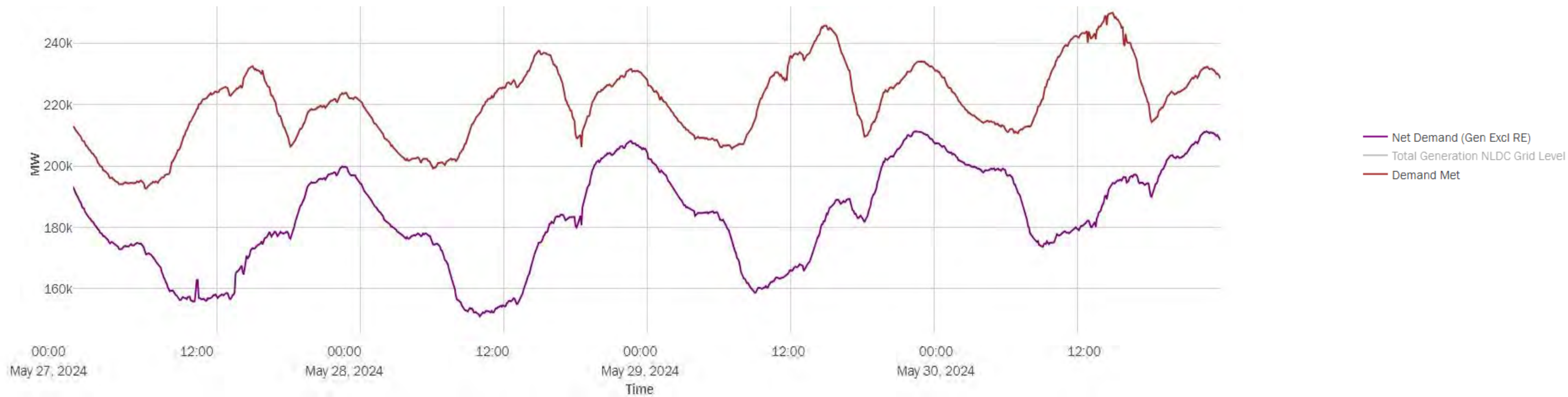
The Indian power grid is becoming increasingly characterized as a low-inertia system due to its high and growing share of renewable energy sources, particularly solar and wind. Inertia in a power grid comes from conventional synchronous generators, such as those in coal, natural gas, and hydroelectric plants, whose spinning rotors provide stability by resisting sudden changes in frequency. However, renewable sources like solar PV and wind turbines are typically connected to the grid via inverters, which do not inherently contribute to inertia. India's renewable energy push has led to a rapid increase in renewable penetration, which means the grid has less of the rotational inertia typically provided by fossil-fuel-based plants. As a result, the Indian grid is more susceptible to frequency fluctuations and requires innovative solutions to maintain stability. With lower inertia, the grid becomes more sensitive to load-generation imbalance, making it challenging to quickly recover from disruptions without advanced stability-supporting technologies, such as synthetic inertia, grid-forming inverters, and energy storage systems.

Ramping of coal power generation and hydro remains the principal flexibility resource available for managing renewable energy intermittency in the short to medium term until energy storage systems are adopted at scale

Flexible ramping of coal power generation to integrate variable RE in May 2024



Characteristic duck curve depicting net demand (demand met minus RE) in May 2024



Source: EY analysis, CSEP Electricity & Carbon Tracker

Flexible ramping of coal power generation at lower minimum loads adjusting output rapidly for load generation balancing during RE fluctuations is critical to maintain grid stability and reduce RE curtailment

Flexible ramping of coal power generation helps meet RE targets without compromising grid stability and extensive storage investments.

Key performance metrics as defined by CEA

Minimum Load: A target of 40% minimum load is established to reduce base load levels effectively.

Ramp Rates: Coal plants need faster ramp rates to respond to sudden changes in RE output, with a benchmark of 1-2%/minute.

Two-Shift Operation: For flexible grid management, coal plants must adopt two-shift operation, turning on and off based on demand.

The transition to flexible ramping of coal power generation faces significant challenges:

Technological Constraints: Older, subcritical plants, which dominate India's thermal fleet, lack advanced automation and control systems required for frequent load changes, making flexible operation costly and complex.

Coal Quality: India's variable and often poor-quality coal complicates low-load operations, causing issues like furnace instability and requiring secondary fuel (oil) for stable combustion.

Increased Wear and Maintenance: Low-load operations increase wear on components, especially in boilers and turbines, and raise maintenance costs. For example, frequent start-ups and shutdowns lead to thermal fatigue and creep in high-temperature components.

Environmental Impact: Emission control systems, such as Electrostatic Precipitators (ESPs) and Flue Gas Desulfurization (FGD), may underperform at low loads, raising challenges in maintaining SOx and particulate limits.

Several pilot tests conducted across different plants demonstrated the following:

Low Load Instability: Plants faced challenges in achieving stable operation at 40% load, with fluctuations in steam temperatures and combustion instability, highlighting the need for enhanced control systems.

Equipment Stress: Tests revealed high stress on equipment like drum boilers, requiring targeted modifications and improved operational practices for durability under flexible conditions

Source: CEA task force report on flexibilization of thermal power plants, 2017

Technical measures to achieve 40% and 25% minimum load:

- Optimization of automation and controls
- Reliable flame detection for burners
- Advanced Frequency control
- Online combustion management system
- Stable 2 mill operation
- Condition monitoring system
- Optimization and automation of start up sequence
- Online combustion management system
- Online Coal Analysis
- Re-commissioning of the steam coil air pre-heaters
- Replacement of start-up temperature measurements

The CEA task force on flexibilization of coal power plants estimates up to US$ 2.7 million for achieving 40% minimum load for each unit.

The market for standalone energy storage services in India is expected to go beyond 270 GWh by 2030

The ability to yield healthy returns from energy storage investments requires mastering a highly regionalized, fast-changing and complicated market. An attractive market is one that offers:

01

Revenue stacking potential: Unlike other renewables assets, energy storage system (ESS) operators generally need to "stack" revenues to make investment worthwhile. Regions that allow ESS to participate across multiple markets (i.e., ancillary, energy arbitrage and capacity) offer the best opportunity to do this.

02

Energy price volatility: Higher volatility, usually in places with high penetration of solar and wind generation and lower degrees of interconnection increases energy arbitrage opportunities for ESS (i.e., the ability to store power when it's free or cheap and then sell back to the grid when prices are higher).

03

Intelligent grid infrastructure and operations: Markets with a modern, digitized grid enable batteries to compete with other technologies in the race for dispatch. ESS can respond far more quickly than most competing technologies, but optimizers need to be able to use sophisticated technology, including artificial intelligence (AI), to interface with system operators.

Three key markets for energy storage

01

Ancillary: Ancillary services reward ESS operators for supporting grid stability and include frequency response, voltage control, peak shaving and backup support.

02

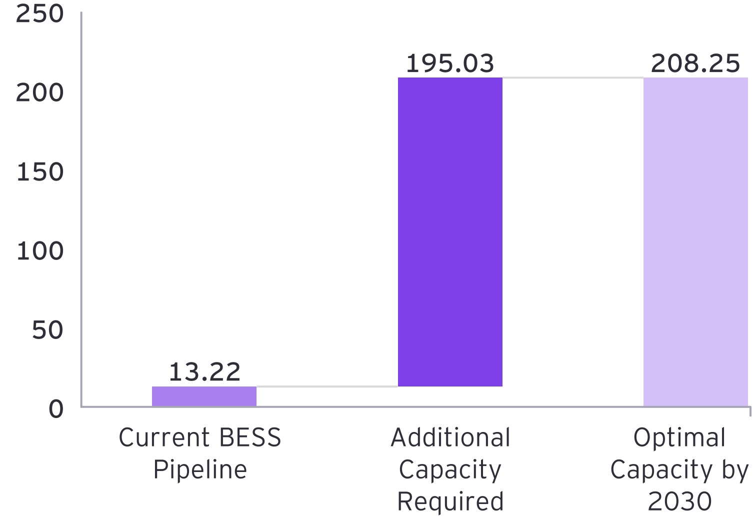
Energy arbitrage: ESS operators can earn revenues by helping balance the grid, by buying and storing energy at times of low demand, and releasing it at times of high demand, when it is most needed (usually morning and afternoon peaks). Revenues can also be earned by participating in short term trading in power exchanges through options including day-ahead, intraday etc.

03

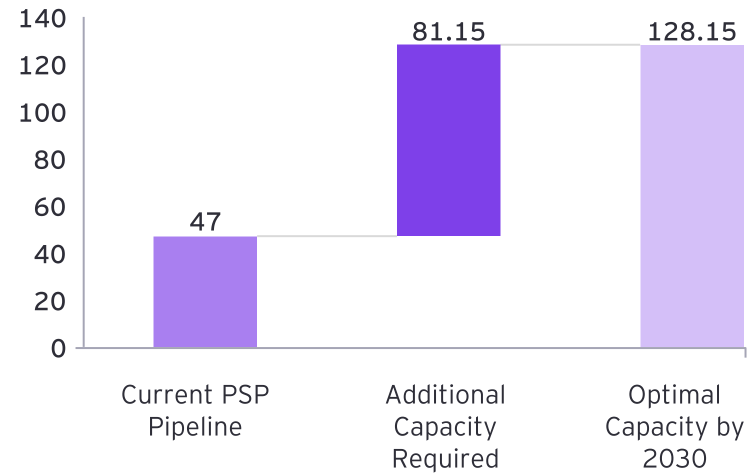
Capacity: Capacity markets, which allow ESS operators to win contracts to provide capacity in the future, offer secure and steady, if relatively modest, returns, but they do not exist in all markets.

The Indian market of renewable energy auctions has witnessed multiple innovations in the above context. There are several contracting structures adopted in the auctions today such as standalone capacity contracts, peak power supply, round the clock renewable energy supply, firm and dispatchable renewable energy supply etc. all of which largely address the energy arbitrage and capacity markets.

BESS Outlook in India (GWhr)



PSP Outlook in India (GWhr)



Source: EY analysis based on CEA optimal energy mix report for 2030

India energy storage auction landscape: ~35 GWh of storage capacity awarded and under execution; ~30 GWh under open tendering stage; Operationalizing these investments will determine the readiness for further capacity additions

Total no. of Tenders: 46

Total Capacity: 72 GWh

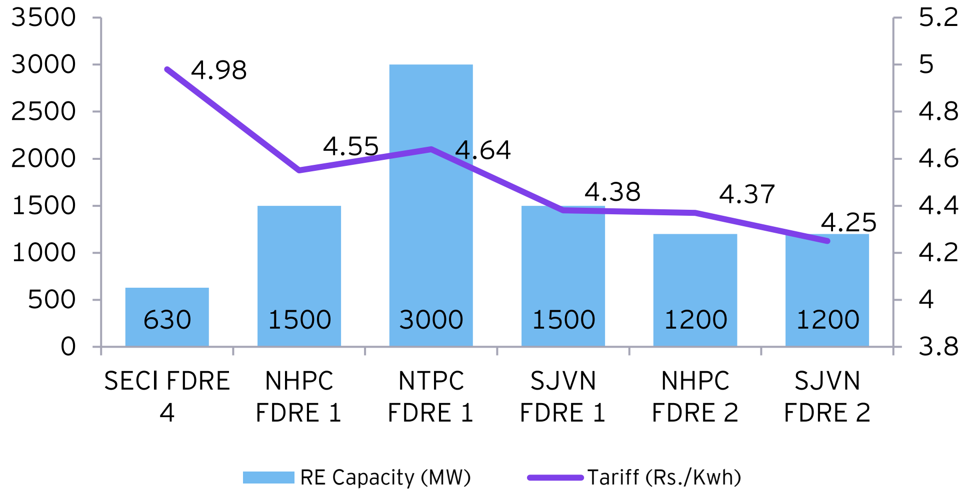
Energy Storage Linked Tender Categories

	Standalone		RE+ESS				Solar + BESS
	BESS	PSP	Peak Power	RTC	FDRE Peak Guarantee	FDRE Load Following	
Number of Tenders	14	14	5	5	8	1	12
Total Capacity	7.34 GWh	49 GWh	1.9 GWh	2.2 GW (RE)	12.9 GW (RE)	0.6 GW (RE)	8.2 GWh
Under stages of execution	4.1 GWh	27 GWh	1.9 GWh	2.2 GW (RE)	9.3 GW (RE)	0.6 GW (RE)	1.5 GWh
Under Tendering	3.2 GWh	20 GWh	-	-	3.6 GW (RE)	-	6.5 GWh

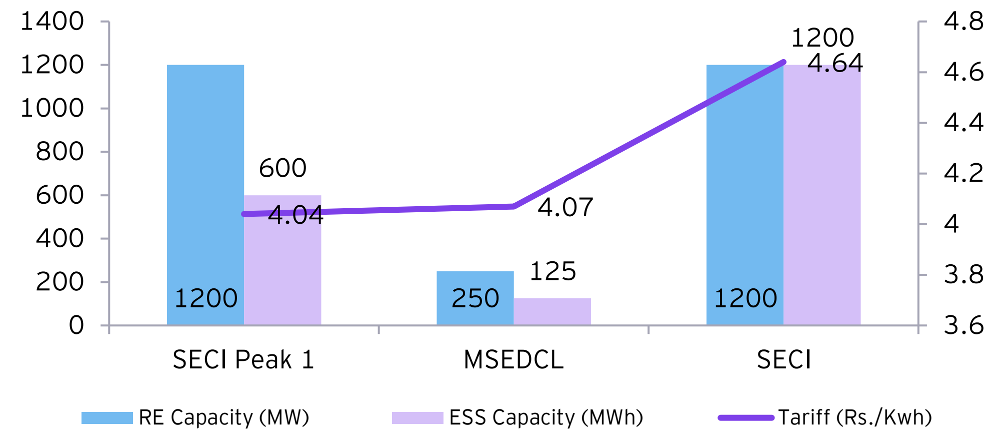
Source: EY analysis based on information compiled by Debmalya Sen - World Economic Forum, https://www.linkedin.com/posts/debmalya-sen_india-ess-market-update-diwali-special-activity-7257001410569916417-i5kw?utm_source=share&utm_medium=member_android

Price discovery for auctions focusing on peak power supply (~4 hours morning and evening) from hybrid systems combining wind, solar and energy storage indicate higher degree of competitiveness for DISCOMs

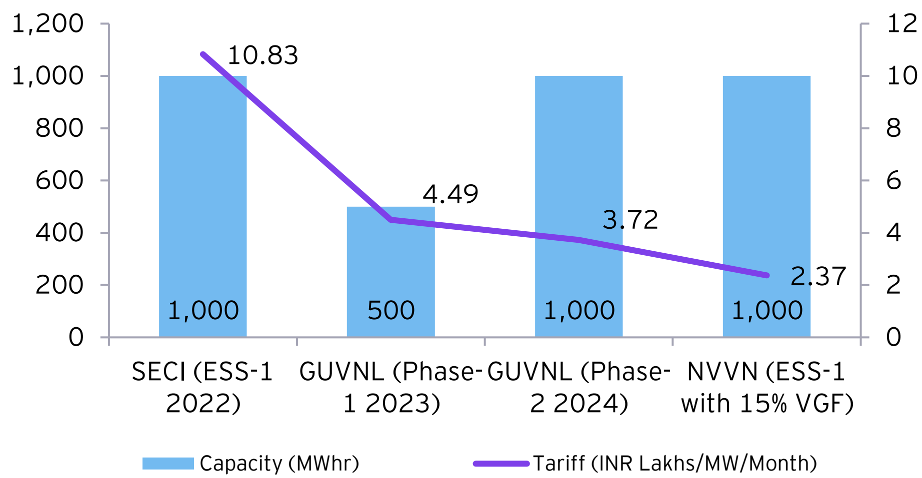
Price discovery of recent FDRE auctions



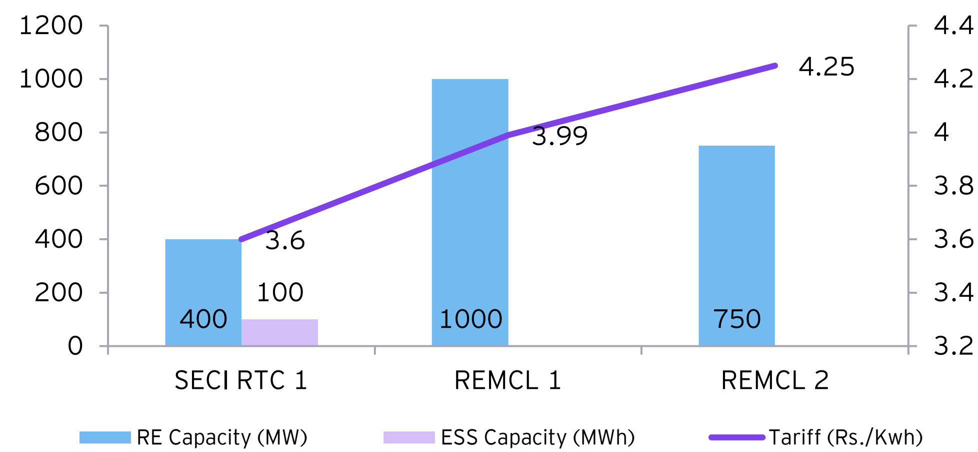
Price discovery of recent Peak power supply auctions



Price discovery of BESS (standalone) auctions



Price discovery of RTC power supply auctions



Source: EY analysis based on information compiled by Debmalya Sen - World Economic Forum, https://www.linkedin.com/posts/debmalya-sen_india-ess-market-update-diwali-special-activity-7257001410569916417-i5kw?utm_source=share&utm_medium=member_android

Synchronize inter-state and intra state transmission infrastructure planning & commissioning with renewable energy project timelines

Transmission adequacy plays a critical role in maintaining the stability of the grid, reducing bottlenecks and ensuring that energy from diverse sources, including renewables, can reach all parts of the country. The challenges and opportunities associated with the Indian power grid, marked by its diverse intra-state systems and massive geographical spread, are key to integrating renewable energy, enhancing market operations and improving overall grid resilience. Transmission planning in India is a multi-tiered process involving stakeholders at both national and state levels. The National Electricity Plan provides a strategic framework for generation and transmission, incorporating both short-term and long-term perspectives to align state-level planning with national energy needs. The Central Electricity Authority's transmission planning criteria facilitate coordination between central and state entities.

Policy and regulatory interventions play a pivotal role in this transition. Entities like the Central Transmission Utility of India Limited (CTUIL) and state transmission utilities (STUs) are essential for effective transmission planning and execution. Reforms in power purchase agreements and bulk electricity markets have spurred innovation in transmission access, siting, grid operations, technology, and cost allocation. Mechanisms such as Point of Connection charges and General Network Access (GNA) are becoming integral to India's transmission infrastructure, ensuring that pricing and access align with market needs while maintaining reliability.

Development of interstate and intra-state transmission networks

Robust interstate and intra-state transmission networks are crucial for transferring electricity between regions and states efficiently. A well-connected network balances supply and demand across the country, enabling the transfer of electricity from regions with surplus generation to those with deficits. This is particularly important in a diverse country like India, where electricity demand and generation capacity vary significantly across regions and seasons.

Adequate transmission connectivity is necessary to manage the variability of renewables within a state, allowing for the import of balancing power from neighbouring states or regions to maintain grid security and reliability. Energy storage also functions as a transmission asset by shifting electricity in time, thereby reducing congestion and curtailment of renewable energy sources.

Challenges and strategies

India's renewable energy sector has grown rapidly in recent years, with the country setting ambitious targets to achieve 500 GW of installed renewable energy capacity by 2030 and 1600 GW by 2047. However, the renewable-rich states, particularly those with huge wind and solar power capacity, will need to further enhance their intra-state transmission networks to facilitate energy export to other regions.

Key challenges include the need for significant and timely financial investments to upgrade existing infrastructure and build new transmission lines. Ensuring the resilience of the transmission network to natural disasters and other disruptions is also critical. This requires investments in climate-resistant infrastructure and the implementation of advanced technologies like smart grids and real-time monitoring systems.

Suboptimal bidding zone configurations, lack of mechanisms for sharing re-despatching costs, lack of visibility on critical network elements beyond the primary limiting factors are other bottlenecks that need urgent reforms. There is also an urgent need for calculating the Locational Marginal Price to capture the congestion in the inter-state and intra-state networks.

One of the key strategies recommended by experts to enhance transmission adequacy is to increase the power import capability of each state to at least 50-60% of its peak demand. This approach ensures that states with limited generation capacity can meet their electricity needs by importing power from other regions or neighbouring states. Achieving this target requires significant investment in both interstate and intra-state transmission networks, as well as improved coordination between CTUIL and STUs.

As India's renewable energy capacity grows, it is critical to address the imbalance between increasing generation potential and limited interconnection capabilities. One of the critical economic justifications for expanding transmission infrastructure is the potential to reduce congestion costs. In India's dynamic energy market, wholesale electricity prices exhibit significant geographic variations. Transmission infrastructure that reduces price disparities can provide substantial economic value by enabling lower-cost

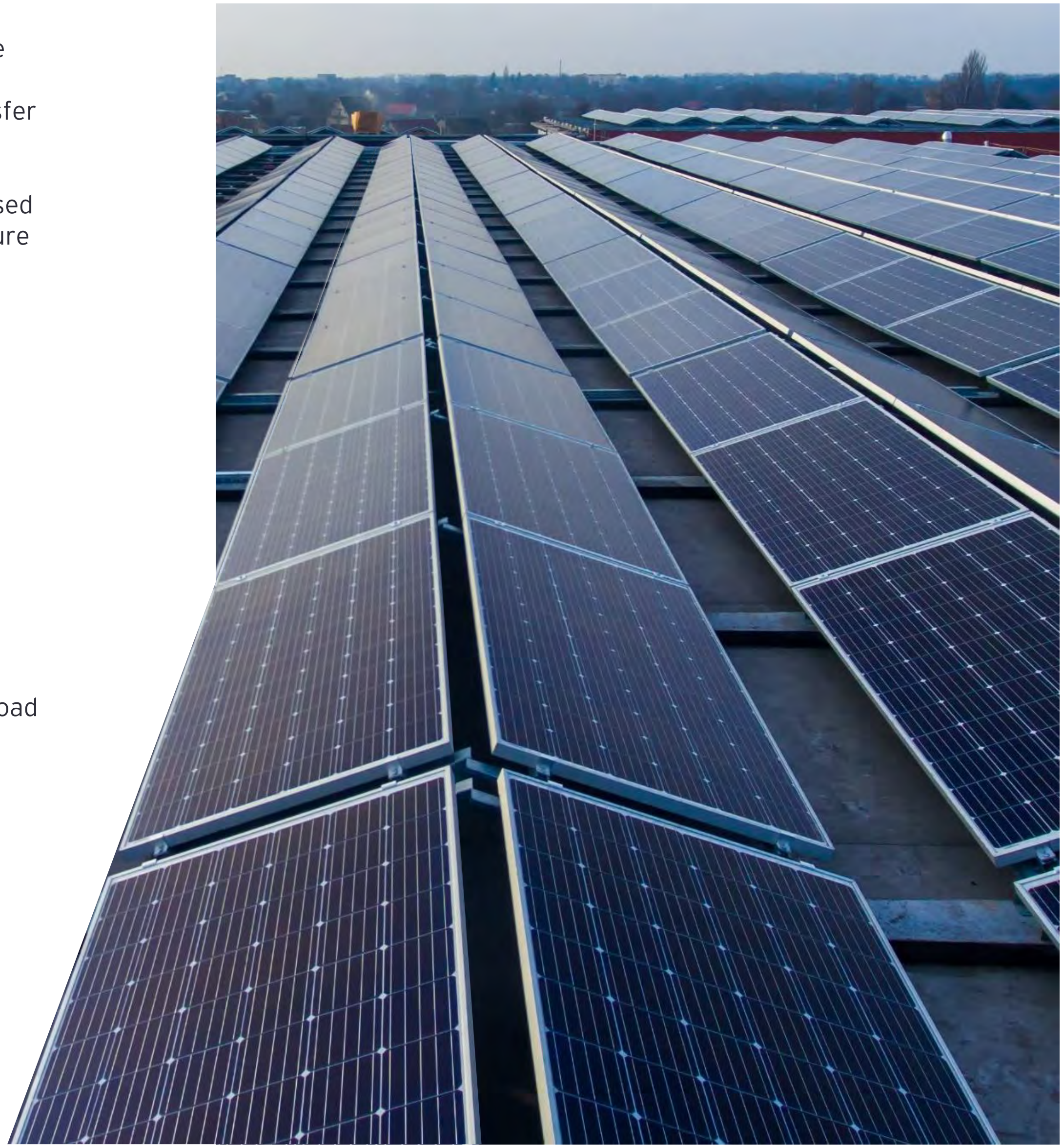
Source: S.K. Soonee, Former and Founder CEO, POSOCO; Dr Deb Chattopadhyay, Senior Energy Specialist, The World Bank; Debasis De, Former Executive Director, NLDC Grid-India; and K.V.N. Pawan Kumar, Deputy General Manager, and Abishek R.S., Manager, Grid-India, https://powerline.net.in/2024/10/05/transmission-adequacy-in-india-building-a-resilient-and-sustainable-grid-2/

The total transfer capability (TTC) for a state should be higher than their GNA requirement to transfer the power for which access has been obtained without affecting security

generators to meet the country's energy demands. Timely expansion/upgradation is essential, otherwise network congestion would rise again. However, rigorous techno-economic analysis of each line is a must, before any investment decision is taken. It is also evident that the total transfer capability (TTC) for a state should be higher than their GNA requirement to transfer the power for which access has been obtained without affecting security. Hence, this ratio should be always greater than 100% and can be used as one of the indicators for evaluating access performance and planning future expansion/upgradation.

Transmission adequacy (access) performance indicators:

- Price differentials in the wholesale market vis-à-vis cost of congestion
- Ratio of total transfer capability (TTC) of interconnections to GNA, peak load and installed renewable generation capacity
- Ratio of GNA to demand and generation projections



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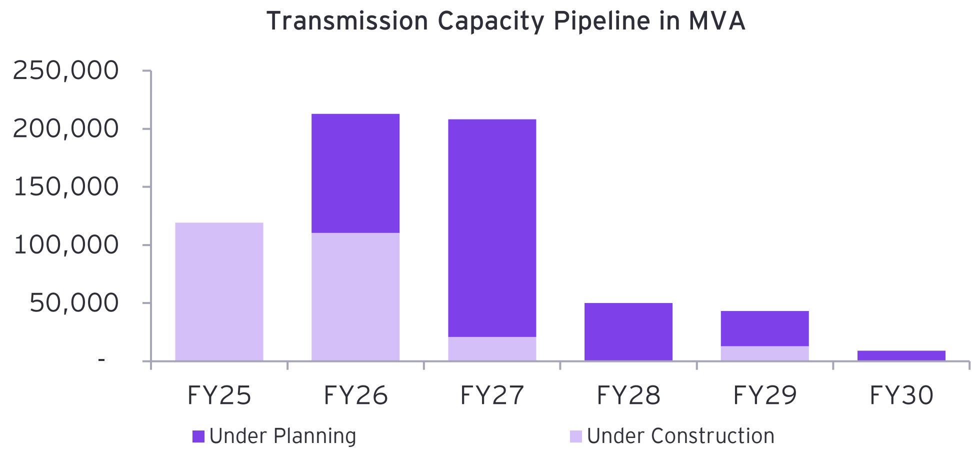
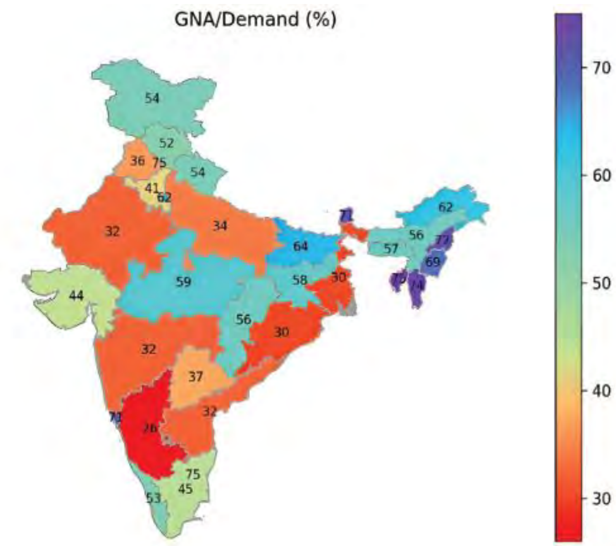
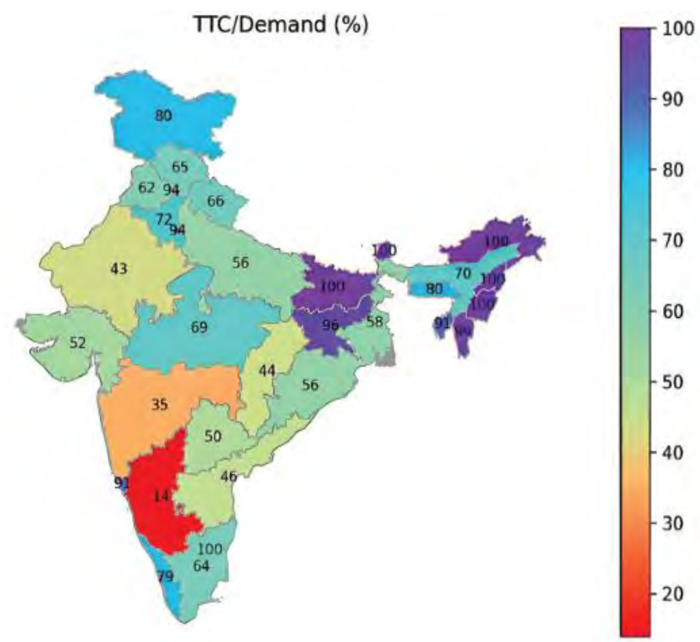
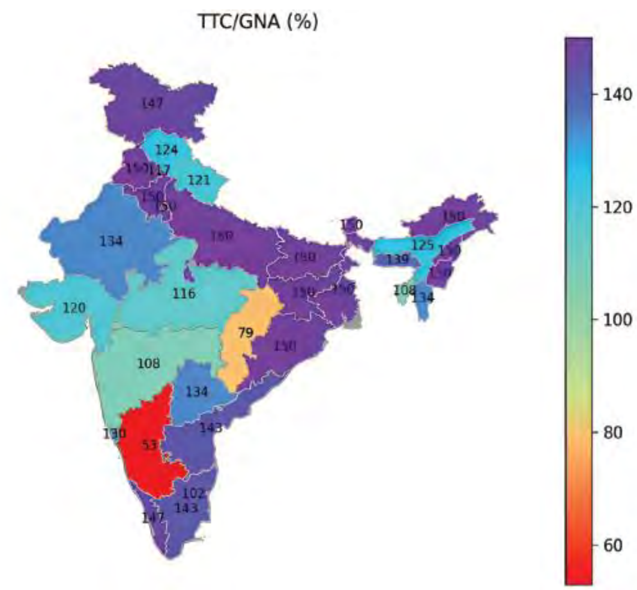
Transmission adequacy (access) performance and planning indicators for large scale RE integration









Source: S.K. Soonee, Former and Founder CEO, POSOCO; Dr Deb Chattopadhyay, Senior Energy Specialist, The World Bank; Debasis De, Former Executive Director, NLDC Grid-India; and K.V.N. Pawan Kumar, Deputy General Manager, and Abishek R.S., Manager, Grid-India, https://powerline.net.in/2024/10/05/transmission-adequacy-in-india-building-a-resilient-and-sustainable-grid-2/

Government of India has implemented a range of measures and initiatives aimed at promoting and accelerating renewable energy capacity across the nation

National Green Hydrogen Mission

PM Surya Ghar: Muft Bijli Yojana

PLI scheme for high efficiency solar PV modules

Offshore Wind Energy Lease Rules, 2023, notified to regulate the grant of leases for offshore wind energy development

Announced Renewable Purchase Obligation trajectory until 2029-30, including separate RPO for Decentralized Renewable Energy

Notification of a trajectory for renewable energy power bids of 50 GW per annum by Renewable Energy Implementation Agencies (REIAs) from FY 2023-24 to FY 2027-28

PM KUSUM

Waiver of Inter-State Transmission System charges for solar and wind power projects commissioned by June 30, 2025; green hydrogen projects until December 2030; and offshore wind projects until December 2032

Foreign Direct Investment permitted up to 100% under the automatic route to attract investments

A Project Development Cell has been established to attract and facilitate investments in the renewable sector

Standard Bidding Guidelines issued for tariff-based competitive bidding for procurement of power from grid-connected solar, wind, and wind-solar projects

Issued Electricity (Rights of Consumers) Rules, 2020, for net-metering up to 500 kilowatts or the electrical sanctioned load, whichever is lower

Green energy corridors

The "National Repowering and Life Extension Policy for Wind Power Projects, 2023" has been released

Ultra Mega Renewable Energy Parks are being set up to provide land and transmission for large-scale renewable energy projects

Launched the Green Term Ahead Market (GTAM) to facilitate the sale of renewable energy power through exchanges

Procedure for Uniform Renewable Energy Tariff (URET) has been established

"Strategy for Establishment of Offshore Wind Energy Projects" outlines a bidding trajectory of 37 GW by 2030

A transmission plan has been prepared to augment transmission infrastructure until 2030

The Electricity (Late Payment Surcharge and Related Matters) Rules have been notified

Green Energy Open Access Rules 2022 have been issued to promote renewable energy

Source: EY analysis; MoP, MNRE, CERC

Policy Recommendations

Increase the power import capability of each state to at least 60% of its peak demand

This approach ensures that states with limited generation capacity can meet their electricity needs by importing power from other regions or neighbouring states. Achieving this target requires significant investment in both interstate and intra-state transmission networks, as well as improved coordination between CTUIL and STUs.

Ensure the total transfer capability of states are greater than their GNA

The ratio of a state's TTC to its GNA requirement should be greater than 100% to ensure that power can be transferred without affecting security. This ratio can also be used to evaluate access performance and plan future expansion.

Synchronize transmission infrastructure commissioning with renewable energy project timelines

Reactive transmission planning and substation construction delays are causing commissioning delays. Completion time for transmission is >2.5 years vs ~1.5 year for renewable energy projects. Aligning transmission upgrades with RE project timelines is essential. A coordinated effort between central and state utilities to synchronize infrastructure with RE projects can help. Additionally, investing in transmission specifically in renewable energy-rich regions, along with smart grid technologies, will enhance resilience and accommodate fluctuating supply.

Create graded land banks for RE projects and encourage utilization of existing landholdings

Harmonized land policies and provisions across renewable rich states are essential for the large-scale development of RE, whereas policies in some states lack provisions for land use conversion and land banks, creating an information gap in these states. While provisions for deemed land use conversion are available in most states, the conversion still requires statutory approvals and fee payments. Most states have fully or partially exempted project developers from having to make stamp duty payments for purchasing land. However, of the 12 states analyzed, only Jharkhand, Karnataka, Odisha, and Uttar Pradesh have provisions for land banks in their policies. While wastelands are an attractive option for project developers, the RE policies of most states do not include provisions for them.

States and union territories should establish land banks based on on-ground validation. The land banks can be graded based on the quality of RE, water availability, and connectivity to the power grid and right-of-way (RoW) transport infrastructure such as roads, rail, and pipelines. Several institutions such as the Indian Railways, public sector undertakings, port trusts, defence establishments, special economic zones, state industrial departments, private industries, educational institutes, and private trusts hold significant land in the country. States and union territories should create graded land banks for RE projects to accelerate India's energy transition.

CEEW estimates that ~ 66000 GW of solar power potential exists in crop-lands. Not all of these will be suitable for agrovoltaics, but even utilizing a fraction of the crop-land for generating RE will substantially contribute to national targets. Agrovoltaics should be explored in crop-lands, particularly in horticultural areas, to increase generation capacity and farmer income.

Streamline processes for grid connectivity approvals

Connectivity approvals often face bottlenecks due to overlapping regulatory requirements, which can increase the financial burden on developers. As of 2023, connectivity delays have impacted nearly 20% of RE projects, underscoring the need for streamlined processes.

Harmonize land use conversion approvals, charges, RoW compensation frameworks across states

Establishing a standardized framework for land use conversion provisions in state RE policies, Right of Way (RoW) compensation frameworks will further

Source: EY analysis; MoP, MNRE, CERC

Policy Recommendations

streamline land acquisition and lower costs. This approach will accelerate the development of RE projects, reduce land-related uncertainties, and help India meet its renewable energy targets for 2030 and 2047. Implementing a single-window clearance system could significantly reduce the time needed for approvals, providing developers with a streamlined process for all necessary permits. Automating approval procedures and granting fast-track status for projects that meet established criteria would also help address this issue. These reforms could boost efficiency and ensure timely grid connection, allowing RE projects to move forward without added delay.

Accelerate implementation of wind repowering policies

The National Institute of Wind Energy (NIWE) has estimated the repowering potential of the country to be 25.4 GW, considering wind turbines below the capacity of 2 MW. Wind turbine generator technology has evolved, with individual rated capacities increasing from sub-MW scale to multi-MW scale. The National Repowering and Life extension policy for wind power projects allows replacing older turbines with efficient ones before their end of design life. Tamil Nadu is the first state to notify a state level policy for wind repowering. Tamil Nadu Green Energy Corporation was appointed as the state nodal agency (SNA) for the implementation of the policy.

Timely execution of Power Purchase Agreements (PPAs) for awarded projects

In India, a significant 35 GW of renewable energy projects are delayed due to the lack of Power Purchase Agreements (PPAs) between Renewable Energy Implementing Agencies (REIAs) and developers. This delay hinders progress towards the nation's renewable energy goals and affects compliance with Renewable Purchase Obligations (RPOs). To address the issue of delayed PPAs, a “deemed approval” mechanism, where PPAs are automatically considered approved after a specified period, could also be implemented. Additionally, DISCOMs could be encouraged to adopt measures like escrow accounts or partial guarantees, which would help mitigate credit risks and incentivize timely PPA signings and boosting investor confidence.

Transmission connectivity and land should be allocated preferentially to wind power generation projects in high wind energy potential zones

CTU S/S in high Wind Potential Area are getting blocked/booked for the Solar Projects. To harness the high wind potential, Govt. should reserve the S/S Connectivity and Land for Wind Projects.

Streamline the National Single Window System (NSWS) for facilitating all approvals and clearances to construct and operate renewable energy power plants

India has developed the National Single Window System (NSWS), a digital platform designed to streamline the process for businesses and investors seeking approvals and clearances. Launched in September 2021, the NSWS aims to serve as a one-stop shop, integrating approvals across various central departments and state governments. There is a need for renewable energy industry to provide feedback to enhance the system's effectiveness.

Establishment of a National Power Council for Coordinated Policy and Implementation

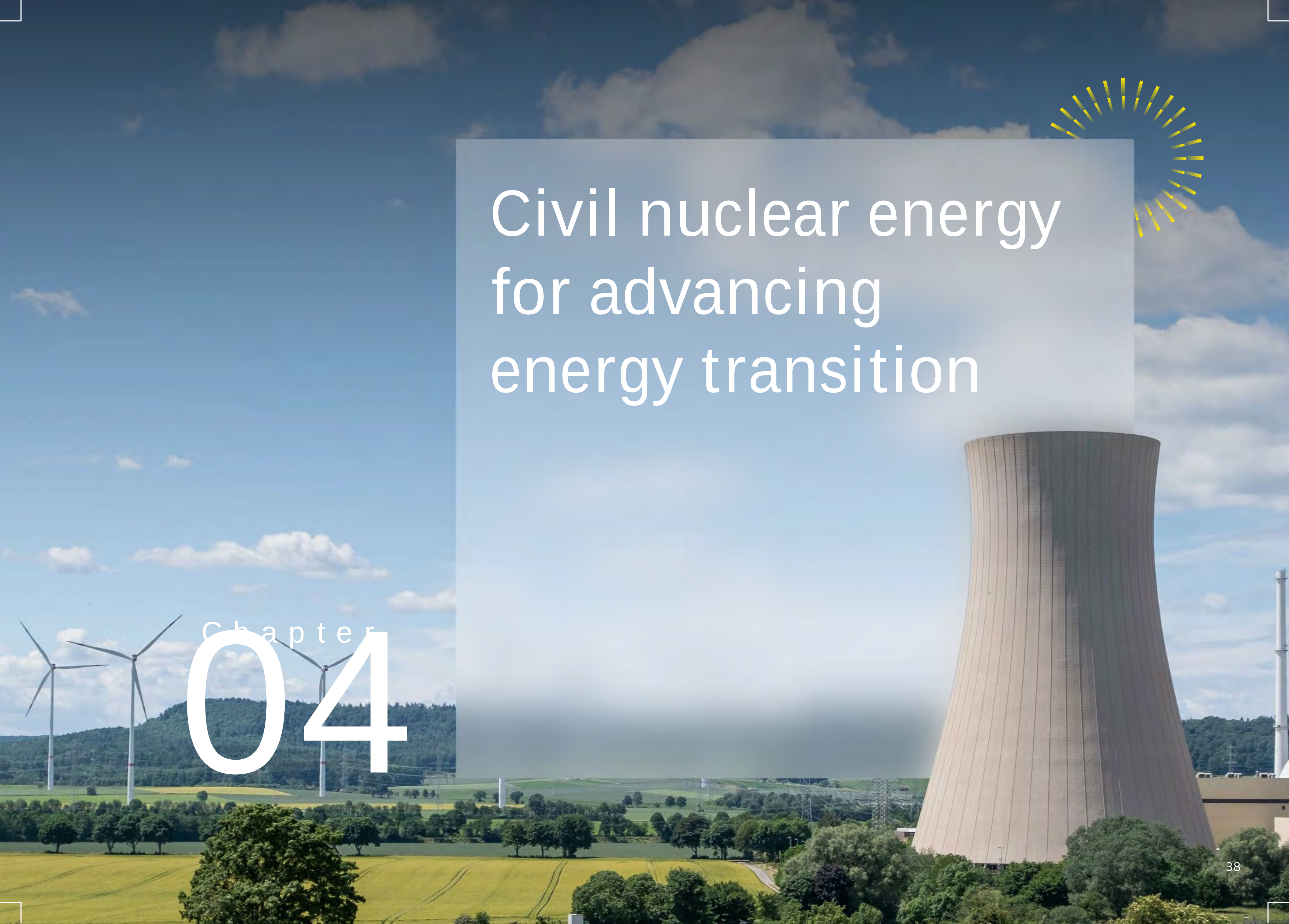
A Power Council, similar to the GST Council, should be established to promote coordinated policy development and implementation across states in the power sector. This would facilitate the resolution of inter-state challenges, create a unified regulatory framework, and ensure that reforms are consistently applied. By fostering collaboration, the council would support the sector's efficiency and sustainable growth, aligning state-level actions with national objectives

Source: EY analysis; MoP, MNRE, CERC

Chapter

04

Civil nuclear energy for advancing energy transition



Development of advanced small modular and safe nuclear energy systems has tremendous potential replace baseload coal power generation to decarbonize power system and drive long-term energy security

There are multiple drivers, such as cost-effectiveness and low carbon-footprint, which make nuclear energy another viable source of decarbonized base load power for India. India aims to increase nuclear power generation capacity to 22,480 MW by 2030. The additional capacity of 14,300 MW will come predominantly from indigenously developed IPHWR-700 reactors (10,300 MW) and rest from imported reactors (~4000 MW). While the imported reactors (~4 units) are under construction in collaboration with the Russian Federation, all indigenous reactor projects are either under construction or undergoing pre-project activities.

Cost-effective

- One of the cheapest sources of energy in India presently.
- High Plant Load Factor of nuclear power plants (averaging almost 80%)
- Long life of a nuclear power plant (sixty years for new generation plants)

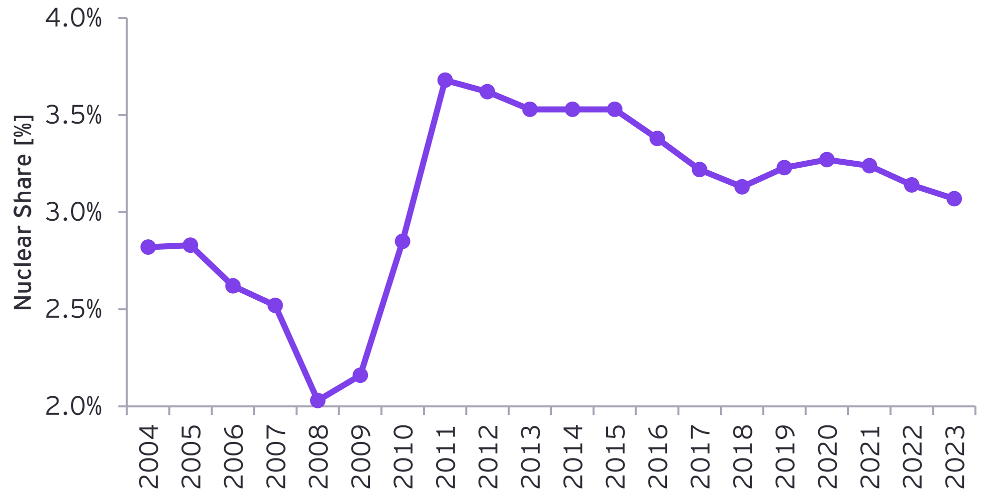
Climate-related advantages

- The carbon footprint of nuclear energy generation is less than other non-fossil fuel sources of energy (greenhouse gas emission for a nuclear power plant is almost one-fourth of that of a solar power plant)

Lesser land requirements

- Land-requirements of a nuclear power are also limited (nuclear power plant requires 20 times lesser land area as that of a solar power plant with the same installed capacity).

Share of Nuclear Energy in India's Power Generation



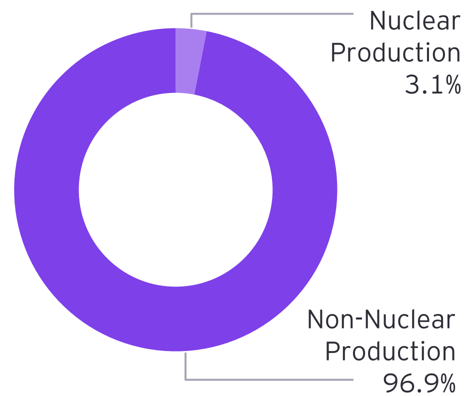
In operation

Total Net Capacity - 6,920 MW
No. of Nuclear Power Reactors - 20
4 reactors of total net capacity 639 MW are in Suspended Operation status

Under construction

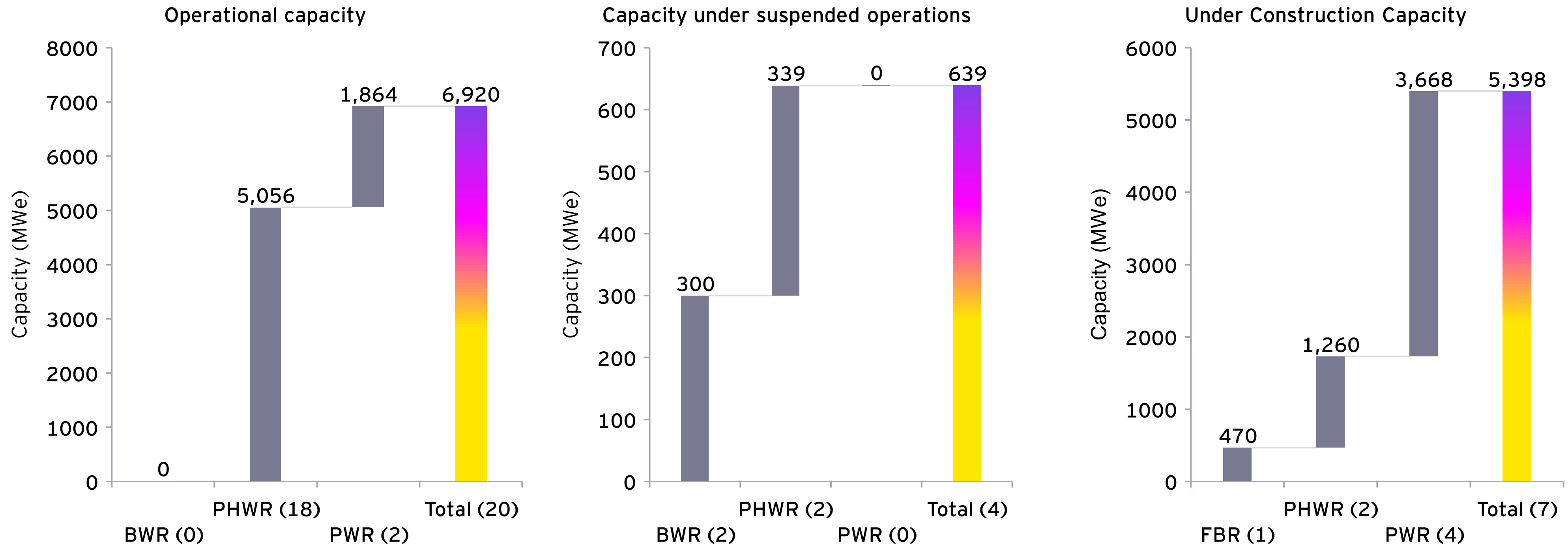
Total net capacity - 5,398 mw
No. Of nuclear power reactors - 7

Electricity production share in 2023



Source: IAEA Power Reactor Information System (PRIS), Country Nuclear Power Profiles (iaea.org)

Potential of nuclear energy systems in driving India's net zero energy transition pathways



Net-Zero Energy Transition Scenarios Modelled for India	Nuclear capacity (GW)			Additional capacity required from current capacity of 13GW to reach NZ(GW)		
	2030	2050	2070	2030	2050	2070
NZ1 – NZ 2070 scenario with a thrust on nuclear power	30	265	331	17	252	318
NZ2 – NZ 2070 scenario with a thrust on fossil fuels with CCUS	30	75	78	17	62	65
NZ3 – NZ 2070 scenario with a thrust on RE	30	75	207	17	62	194
NZ4 – Integrated NZ 2070 scenario	29	95	178	16	82	165

(*) - No. of reactors
BWR - Boiling water reactor, PHWR - Pressurized heavy water reactor, PWR - Pressurized water reactor, FBR - Fast breeder reactor
Source: Nuclear Power in India - World Nuclear Association (world-nuclear.org), ESN Report-2024_New-21032024.pdf (psa.gov.in)

Advanced small modular reactor designs are emerging globally with passive safety features for installation and operations closer to demand centres

Large NPP challenges	Benefits from SMR features compared to conventional reactors	
Cost and construction time	Simple design and standardization	Standardized designs and mass production reduce costs through efficient learning rates and delivery of nearly identical components in the project value chain.
	Modularization	SMRs are designed in large modules to be built and tested in a plant and integrated on-site shortening schedule and reducing the risk of construction delays.
	Co-siting	Constructing multiple SMRs in the same NPP optimizes construction and facility utilization, spreading investments and operating costs.
	Size	Smaller reactors can enable faster installation and replacement thanks to lower work requirements (construction schedule is reduced to 3 to 4 years versus 10 years for a large NPP).
Network integration		Distributed generation reduces transmission losses, provides flexible production, and meets diverse electricity and heat needs near end- users.
Nuclear safety	Integrated design	Integrated designs limit flows, junctions, and leaks with smaller size improving the surface/ volume ratio for controlling fission energy.
	Passive safety	Passive safety features for automatic shutdown are included in molten salt and some fast neutron reactors.
Nuclear waste	Fuel cycle closing	Use of nuclear waste from large NPPs and other SMRs allows to close the fuel cycle in fast neutrons reactors.

Gen. III/III+

Gen. IV

Source: IAEA - Advances in SMR Technology Developments 2022, NEA - The NEA SMR Dashboard 2023, Expert interviews, Desk research, EY Analysis

Nuclear energy governance and ecosystem in India

1

Atomic Energy Regulatory Board (AERB)

AERB serves as India's independent nuclear regulatory authority, committed to openness, transparency, and trust-building with stakeholders.

Regulatory Communication

- AERB communicates safety requirements and guidelines through well-defined safety codes, standards, and guidance documents
- These are developed with inputs from stakeholders, ensuring their concerns and expectations are considered

Educational Outreach and Feedback

- AERB holds seminars, workshops, and conferences to educate and gather feedback on regulatory requirements and updates

Decision-Making Framework

- A structured, multi-tiered review system ensures inclusive yet non-intrusive decision-making
- Involves stakeholders like licensees, technical support organizations (TSOs), and domain experts, allowing for transparent and traceable regulatory decisions

Collaboration with Academia and TSOs

- AERB has formal agreements with institutions like BARC to leverage their technical expertise, particularly for safety research and collaborative projects, while managing potential conflicts of interest through written agreements

2

Interdependence of DAE Units

- Public sector enterprises under the control of DAE and their activities are as follows:
- **NPCIL:** Designs, constructs, commissions, and operates nuclear power plants (NPPs) with thermal reactors
- **UCIL:** Mines, mills, and processes uranium ore
- **IREL:** Mines and processes thorium and rare earth minerals, along with other processed minerals like ilmenite and zircon
- **ECIL:** Designs and manufactures reactor control systems, shutdown systems, radiation detectors, and nuclear instruments for monitoring and protection
- **BHAVINI:** Constructs and commissions the 500 MWe prototype fast breeder reactor (PFBR)
- Other government bodies supporting the activities
- **AMD:** Exploration of atomic minerals, site selection for NPPs
- **HWB:** Supplies heavy water and other materials for reactors
- **BARC & IGCAR:** R&D support for reactor technologies and waste management

3

Involvement of Indian Industry and Academia

Collaborative Research and Training

AMD and UCIL collaborate with academic institutions like IITs and NITs for training and research on nuclear exploration and mine development

Industry Collaborations

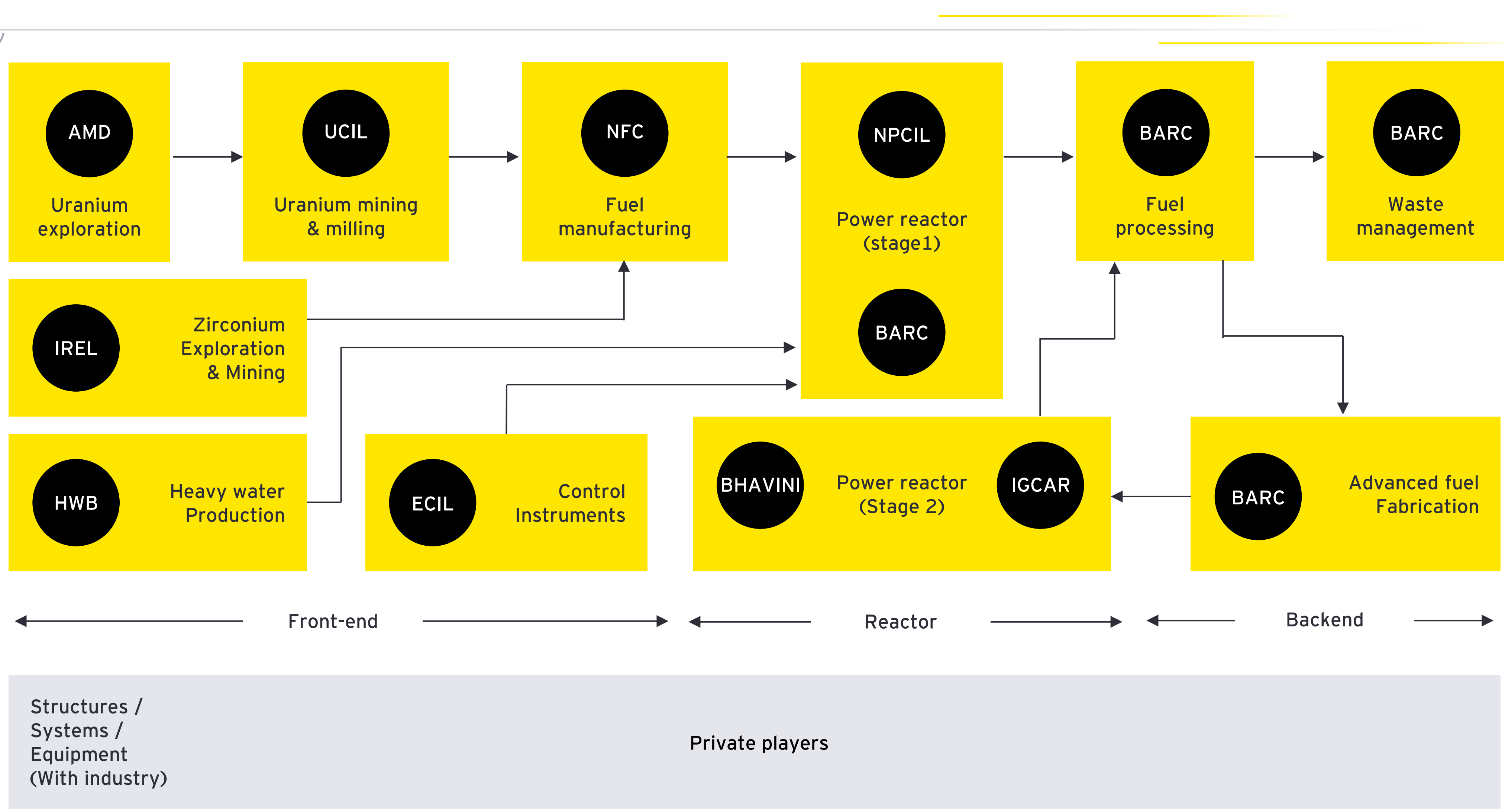
IREL's Joint Ventures boost atomic mineral processing of thorium and rare earth. Indian industries manufacture key materials like turbines, steam generators, pressure vessels

Quality Assurance

NPCIL ensures high-quality standards by deploying quality surveillance representatives at manufacturing facilities

Source: Country Nuclear Power Profiles (iaea.org)

Interdependence of DAE Units for development and operation of nuclear energy systems



NPCIL: Nuclear Power Corporation of India Limited, UCIL: Uranium Corporation of India Limited, IREL: IREL (India) Limited, ECIL: Electronics Corporation of India Limited, BHAVINI: Bhartiya Nabhikiya Vidyut Nigam Limited, AMD: Atomic Minerals Directorate for Exploration and Research, HWB: Heavy Water Board, BARC: Bhabha Atomic Research Centre, IGCAR: Indira Gandhi Centre for Atomic Research

Source: IAEA Power Reactor Information System (PRIS), Country Nuclear Power Profiles (iaea.org)

Uranium mining and processing landscape for securing nuclear energy fuel in India

Uranium Deposits

India possesses modest uranium reserves, primarily located in high-cost deposits. This necessitates significant reliance on imports to fuel its growing nuclear power program.

Key Deposits:

- **Jharkhand:** The Singhbhum Shear Zone in Jharkhand hosts the majority of India's uranium reserves, with mines like Jaduguda, Bhatin, Narwapahar, Turamdih, Bagjata, Mohuldih, and Banduhurang
- **Andhra Pradesh and Telangana:** The Cuddapah Basin in these states contains significant uranium deposits, including Tummalapalle and Lambapur-Peddagattu
- **Other States:** Meghalaya, Karnataka, Rajasthan, and other states have smaller uranium deposits

Challenges

India possesses modest uranium reserves, primarily located in high-cost deposits. This necessitates significant reliance on imports to fuel its growing nuclear power program.

Key Deposits:

- **Environmental Concerns:** Uranium mining and processing can have significant environmental impacts, including water pollution, soil degradation, and radiation exposure
- **Social and Health Issues:** Local communities often raise concerns about potential health risks and displacement due to mining activities
- **Opposition and Protests:** Environmental activists and local communities have frequently protested against uranium mining projects, citing concerns about safety and the environment

Source: IAEA Power Reactor Information System (PRIS), Country Nuclear Power Profiles (iaea.org)

Mining and Processing

Mining Methods

Underground Mining – Suitable for deep deposits, involves creating tunnels and shafts to access the ore

Open-Pit Mining – Used for near-surface deposits, involves removing overburden to expose the ore body

Ore Extraction
Ore is extracted from the mine using various techniques like drilling and blasting

Ore Milling
The extracted ore is crushed and ground into a fine powder

Leaching
The powdered ore is treated with chemicals to dissolve uranium. Acid leaching and alkaline leaching are common methods

Purification
The uranium-bearing solution is purified to remove impurities

Precipitation
Uranium is precipitated from the solution to form a solid compound, such as uranium dioxide or uranium tetrafluoride

Drying and Calcination
The precipitated uranium compound is dried and heated to remove moisture and impurities

Conversion to Uranium Dioxide
The dried uranium compound is converted into uranium dioxide powder, the primary feedstock for nuclear fuel fabrication

229,499 tonnes of Uranium resources

10,466 tonnes of Uranium as inferred resources

2,000 tonnes of Uranium imported in 2020 – 2021

Key policy reforms to attract investment and boost nuclear energy growth in India

Challenges	Policy Recommendation	Expected Outcome
Limited private sector participation in nuclear energy	**Open the Nuclear Sector to Private Investment** Enable private entry through joint ventures and full ownership	Attracts private capital and expertise, bridging capacity and technology gaps, driving faster sector growth and innovation
Restrictive Atomic Energy Act limits private involvement	**Amend the Atomic Energy Act** Permit private sector participation across the nuclear fuel cycle	Reduces government burden and creates a competitive environment, allowing private entities to drive efficiency and expansion
Centralized control by Department of Atomic Energy (DAE)	**Restructure the DAE's Role** Focus DAE on areas of expertise (safety, research, security)	Streamlines operations and enables a more dynamic sector, empowering private entities to lead power generation
Lack of regulatory independence for safety and transparency	**Establish an Autonomous AERB** Ensure AERB independence from DAE for unbiased safety oversight	Enhances regulatory transparency and accountability, increasing investor confidence and facilitating private sector entry
Challenges in scaling flexible, cost-effective nuclear power	**Develop PPPs for Small Modular Reactors (SMRs)** Support SMR development as replacements for coal plants	Provides cost-effective, flexible nuclear solutions, supporting sustainable energy transition and optimizing land use
Supplier liability concerns under the CLNDA	**Revise the Civil Liability for Nuclear Damage Act (CLNDA)** Amend to align with international standards	Resolves liability concerns, making India an attractive destination for foreign and domestic investment in nuclear technology

Current Scenario

7.4 GW Current Capacity + 5.4 GW Under Construction = 12.8 GW Total

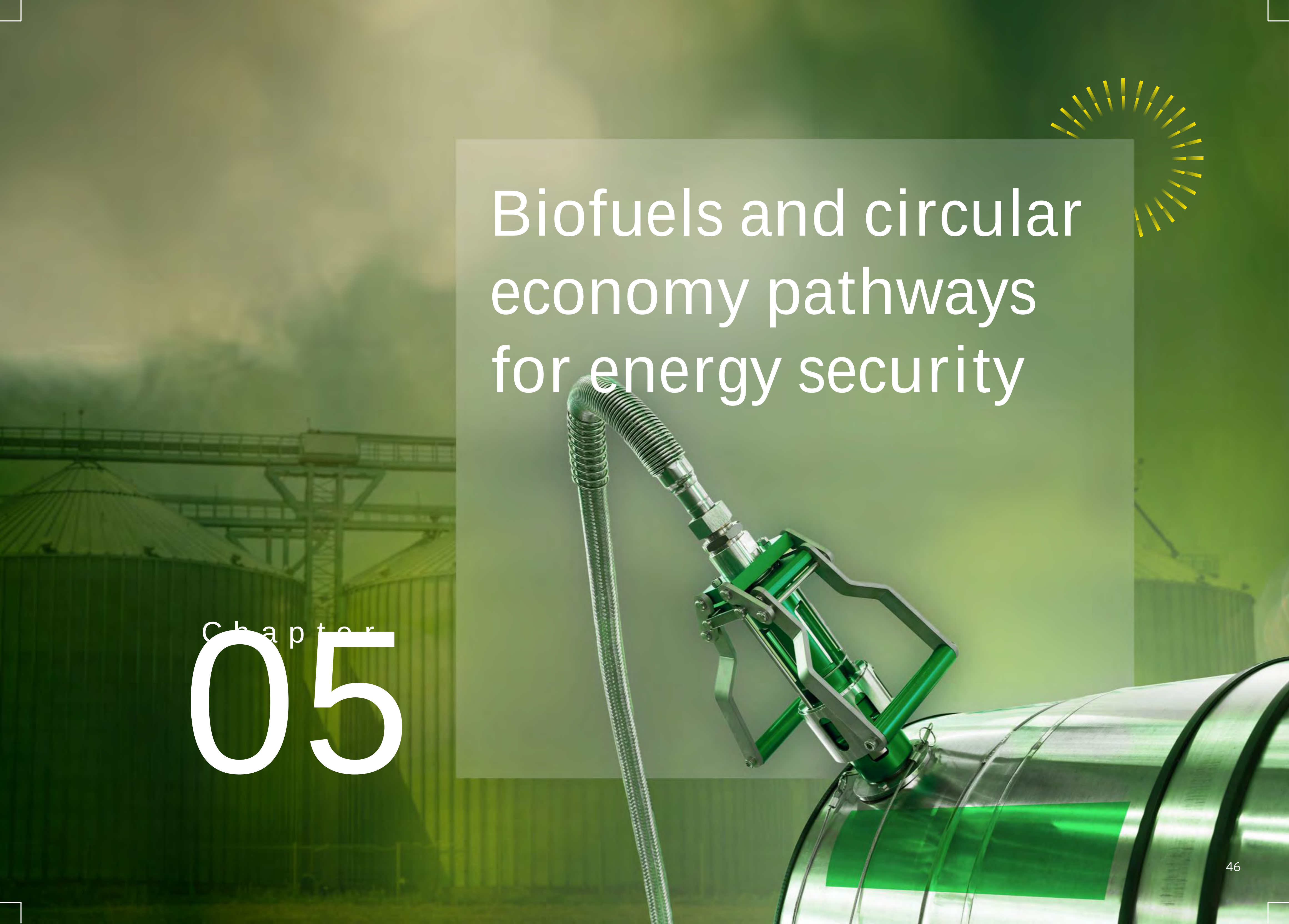
~22 GW Capacity goal by 2030

Global Investments in Nuclear Energy

from 2017 - 2023	required to meet the IAEA's high case projection for nuclear capacity in 2050
50b US$/yr	125b US$/yr

US$ 26b India seeking private investment for nuclear sector

Source: Reclaiming the Promise of Nuclear Power in India - Carnegie Endowment for International Peace | Carnegie Endowment for International Peace; India seeking $26bn in private investment for nuclear sector - Power Technology (power-technology.com); New IAEA Report on Climate Change and Nuclear Power Focuses on Financing | IAEA, EY Analysis



Chapter 05

Biofuels and circular economy pathways for energy security

Policy landscape of biofuels

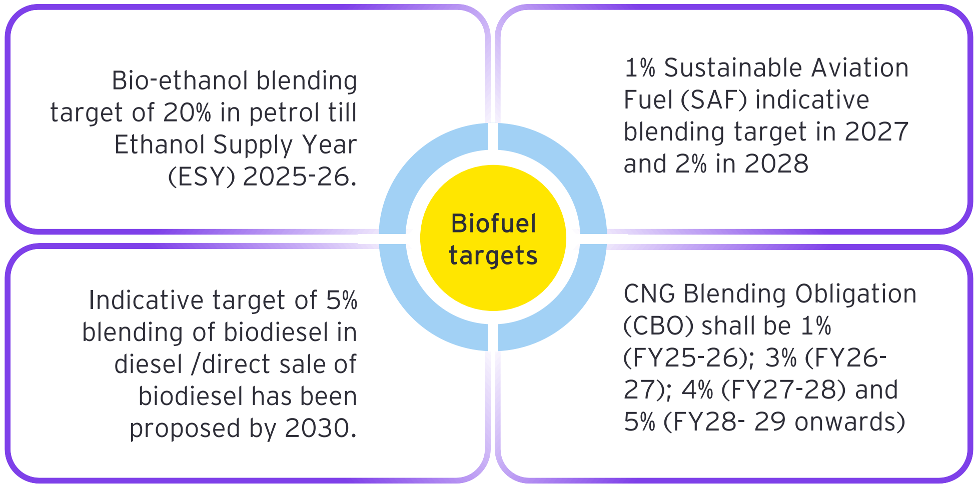
As countries embark on the journey to address the climate change crisis, biofuels emerge as a critical avenue for decarbonization, offering a compelling proposition for developing and developed countries. India has also rapidly become a foremost consumer and producer of biofuels, largely driven by rising transport fuel demand, robust government policies and abundant feedstock potential.

India is the world's third largest producer of ethanol after US and Brazil. Developing countries like Brazil, Indonesia and India have witnessed rapid growth in biofuel production, mainly due to robust gasoline and diesel demand. On the contrary, developed economies like US, EU have witnessed growth supported by strong policies to meet bio jet fuel demand.

The National Policy on Biofuels, notified by the Government of India in 2018, mandates oil marketing companies to blend 20% ethanol, sourced from agricultural inputs, into petrol by 2030. To ensure effective implementation, the government has also set a price at which ethanol would be procured by the oil marketing companies and has facilitated financial incentives towards setting up of ethanol manufacturing capacity in India.

India has achieved an intermediate target of 10% blending of ethanol much ahead of target by November 2022. Therefore, the target of 20% ethanol blending was advanced from 2030 to 2025-26. National Biofuels Coordination Committee (NBCC) under the aegis of Ministry of Petroleum and Natural Gas has proposed to blend compressed bio-gas (CBG) with compressed natural gas used for transportation and piped natural gas used for domestic purposes by entities licensed to supply city gas in India. As per the current plans, CBG blending obligations will be voluntary until FY2025 and become mandatory thereafter. In line with the experience of blending ethanol with petrol, the blending obligation will increase with time. The Ministry of Power issued revised guidelines for biomass policy and now mandates 5% biomass co-firing in Thermal Power Plants (TPPs) from FY 2024-25. This obligation shall increase to 7% from FY 2025-26.

To expedite the energy transition and balance energy security with emissions reduction, India has been actively promoting the use of biofuels as an alternative source of energy. Biofuels come in various forms, but in India, the two primary types are bioethanol and biodiesel.



The Government of India has set a target to increase the share of gas in the energy mix by up to 15% in 2030 to make India a gas-based economy. Based on consumption, India relies on imports for approximately 47% of its natural gas. However, the integration of biogas could enhance the viability and sustainability of this transition. Biogas has multiple benefits, including reduced dependency on fossil fuel imports, lower emissions compared to natural gas, decreased agricultural residue burning and an additional revenue source for farmers.

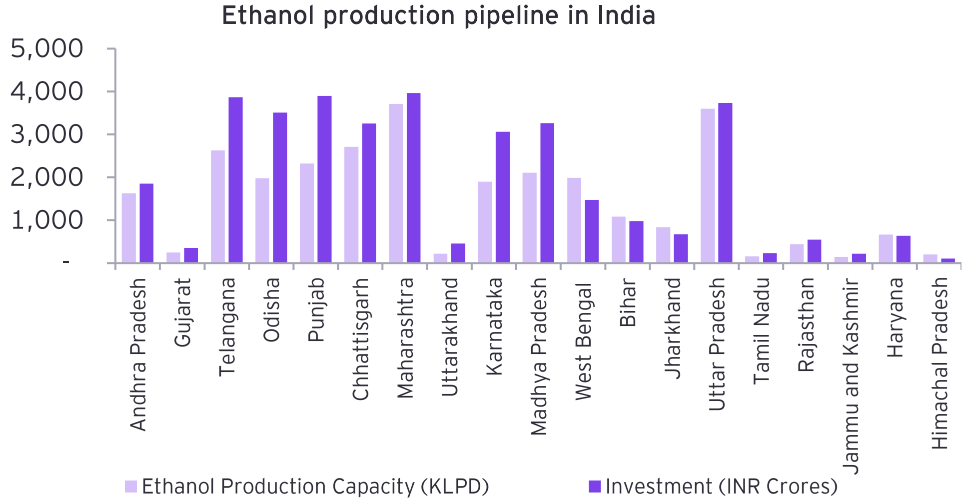
The policy landscape of biofuels includes ethanol interest subvention scheme through which the government is facilitating entrepreneurs to set up new distilleries or the expansion of existing distilleries throughout the country. Interest subvention at 6% p.a. or 50% of ROI charged by banks/ financial institutions, whichever is lower, on the loans to be extended by banks/ financial institutions is being borne by the central government for five years including one-year moratorium. Installation of new ethanol distilleries and expansion of existing ethanol distilleries has brought investment opportunities worth over INR40,000 crore (US$4.87 billion) in urban as well as rural areas. To promote ethanol blending, the government has lowered the GST rate from 18% to 5% on ethanol meant for blending under the Ethanol Blended Petrol (EBP) Programme. PM JI-VAN Yojana provides financial support to Integrated Bioethanol Projects using lignocellulosic (plant-based) biomass and other renewable feedstock.

Source: EY Analysis based on various schemes announced by MoPNG, https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1945245 , https://pib.gov.in/PressReleasePage.aspx?PRID=1844630 , https://pib.gov.in/PressReleasePage.aspx?PRID=1988727

Bioethanol demand supply scenario

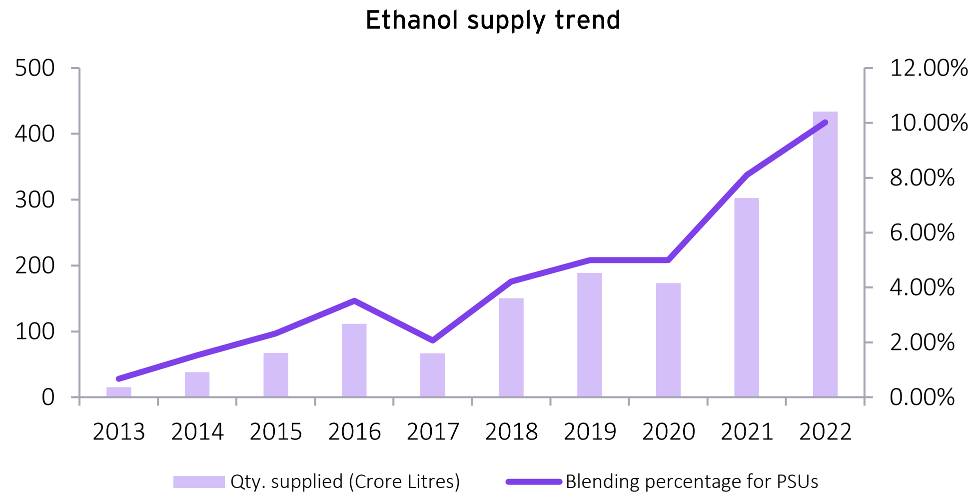
India's present approach to biofuel production is dominated by 1G feedstocks (e.g., sugarcane, rice, and maize) and has to overcome challenges from a lifecycle perspective. The low yield for sugarcane and maize will require land use change, which necessitates the exploration of new production pathways.

The advancements in 2G bioethanol produced from lignocellulosic biomass, such as crop residues, woody crops or energy grasses, are gaining momentum. Though they still represent less than 3% of total bioethanol production globally, the GHG reduction potential is higher than for 1G bioethanol. The environmental impacts of bioethanol production are dependent on feedstock availability and conversion technology. The biochemical conversion route must overcome technological and economic challenges such as pre-treatment, fermentation, hydrolysis and separation. India has four operational advanced biofuel plants, including a pilot and a demonstration plant, with a cumulative annual production capacity of 1.75 million Liters of cellulosic ethanol. Consistent availability of feedstock from crop residues, and the establishment of a necessary infrastructure for aggregation, logistics, and handling of large amounts of biomass, all with the least carbon footprint, will be a step toward 2G ethanol production.



Under Planning refers to a stage where developer announced the intent to set up a project
Under development and construction refers to a stage where project is getting approvals or under construction
Source: ETIM, EY Analysis; Pipeline includes projects under planning, development and construction
Source: https://task33.ieabioenergy.com/wp-content/uploads/sites/33/2022/06/India_2021.pdf

Feedstock	Cost / MT of the feedstock (INR)	Quantity of ethanol per MT of feedstock	Ex-mill Ethanol Price (INR/liter)
Sugarcane juice / Sugar / Sugar syrup	2850	70 litres	62.65
B Molasses	13,500	300 liters	57.61
C Molasses	7,123	225 liters	45.69
Damaged Food Grains (Broken Rice)	16,000	400 liters	51.55
Rice available with FCI	20,000	450 liters	56.87
Maize	15,000	380 liters	51.55



Source: NITI Aayog Roadmap for Ethanol Blending 2020-25
Source: Final Report: Energy Transition Advisory Committee, MoP&NG, 2023

Compressed biogas (CBG) demand supply scenario

Waste and bio-mass sources like agricultural residue, cattle dung, sugarcane press mud, distillery spent wash, municipal solid waste, sewage treatment plant waste, etc., produce biogas through the process of anaerobic decomposition. The biogas is purified to remove hydrogen sulphide (H2S), carbon dioxide (CO2), and water vapor, and compressed to form Compressed Biogas (CBG) or Bio-methane, which has methane (CH4) content of more than 90%. Biogas can serve as a suitable replacement for imported fossil natural gas with close to net zero emissions while boosting energy security supported by competitive economics.

The Ministry of Road Transport and Highways, Government of India, vide the Gazette Notification no. 395 dated 16.6.2015, has permitted the usage of CBG for motor vehicles as an alternative to CNG. CBG can be used in vehicles using CNG fuel without making any modifications to the vehicle. CBG has a high potential to replace CNG in automotive, industrial as well as commercial areas, given the abundant biomass availability within the country. 'SATAT' (Sustainable Alternative Towards Affordable Transportation) initiative on CBG was launched by the Hon'ble Minister of Petroleum & Natural Gas on 1.10.2018. The scheme envisages the production of 15 MMT CBG and 50 MMT of manure from 5,000 plants. Under the SATAT scheme, Oil & Gas Marketing Companies (OGMCs) viz. IndianOil, HPCL, BPCL, GAIL and IGL have been inviting EOIs from potential investors/entrepreneurs to procure CBG.

Salient features of the SATAT scheme

Plant owner shall be responsible for the installation, operation and maintenance of the plant. Oil and gas marketing companies shall offtake CBG from the plant.

Oil and gas marketing companies shall execute a Commercial Agreement of 15 years with the CBG Plant owner, to be extended on mutual consent.

There are various technologies available for the production of CBG. Anaerobic Digestion is used for the production of biogas which includes technologies like continuous stirred tank reactor (CSTR), plug flow, 2-stage reactors, Upflow Anaerobic Sludge Blanket (UASB), etc. After the production of biogas, hydrogen sulfide is purified through ferric chloride, iron chelate, biological process, activated carbon, etc. Fermented Organic Manure (FOM) produced varies from 15% to 30% of the feedstock of the CBG plants. FOM is useful for maintaining soil health, particularly organic carbon, which helps microflora to flourish. It is a source of nitrogen (N), phosphorus (P), and potassium (K) and also has essential micro and macro nutrients that are vital for the balanced growth of plants. Creating an effective marketing strategy for FOM is critical for CBG Plants. The promotion of FOM can create an ecosystem of organic/natural farming in the country. Further, FOM can be enriched to Phosphate Rich Organic Manure (PROM), which can reduce India's import dependency on phosphate fertilizers.

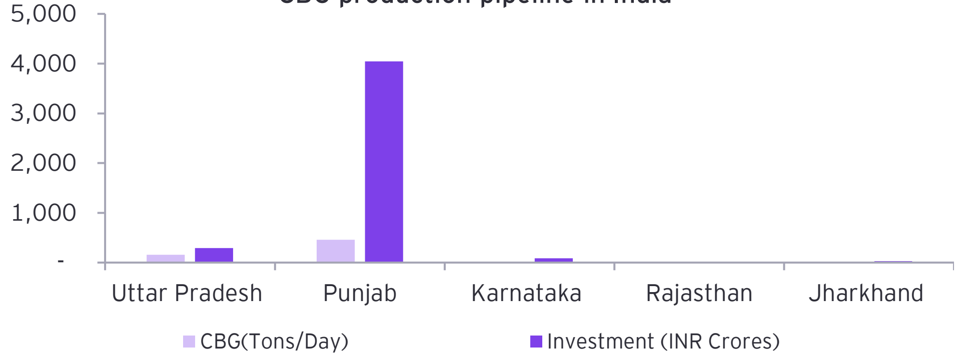
The various feedstocks of biogas are waste and bio-mass sources like agricultural residue, cattle dung, sugarcane press mud, municipal solid waste, etc. CBG production varies as per technology, feedstock quality, etc.

The Government of India has set a target to increase the share of gas in the energy mix from the current levels of about 6.5% to 15% by 2030 to make India a gas-based economy. CBG can form a critical domestic supply source to contribute to this build-up.

Production of CBG shall increase the green energy mix, reduce import dependence, create employment, especially in semi-urban and rural areas and reduce pollution. This will create value and employment in the rural economy across the supply chain, from biomass collection to plant operation.

The minimum procurement price of CBG will not be lower than INR 46/kg + applicable taxes for the period up to 31.3.2029. The Retail Selling Price (RSP) of CBG in a market shall be at par with the RSP of CNG. Under MoP&NG policy guidelines on co-mingling of domestic gas for supply to CNG (Transport) and PNG (Domestic) of CGD, the biogas procurement price set by GAIL is INR 1,082/MMBTU (equivalent to INR 46/kg). Compression and CBG transportation charges of INR. 8/kg are provided additionally.

CBG production pipeline in India



Source: https://pib.gov.in/PressReleasePage.aspx?PRID=1917439 , https://iocl.com/NewsDetails/52531 , https://pib.gov.in/PressReleasePage.aspx?PRID=1844630 , https://pib.gov.in/Pressreleaseshare.aspx?PRID=1557898

Policy recommendations

Incentivize adoption of biomass feedstock aggregation, storage and processing equipment

Government is providing subsidies on biomass aggregation and storage equipment under the SMAM and state-specific schemes. Presently, about 50% subsidy is available for biomass aggregation and storage equipment under the SMAM scheme.

State governments may provide an additional subsidy of a minimum of 30% to make the procurement of equipment more viable. The subsidy may be provided upfront during the procurement of equipment and may also be extended to set up CBG Plants. Promote engagement of FPOs/CHCs etc., for aggregation and storage of biomass. Create awareness and promote activities for biomass aggregation in the catchment area. Deploy biomass aggregation equipment (Cutter+Racker+Baler) in the catchment area of CBG plants by state governments.

Identify and notify biomass clusters for CBG plants and other biomass-based biofuel projects and grant of an exclusive area for a long tenure. Provide incentives on operating expenses of biomass aggregation and storage equipment by state governments. Local governments to allot land for a decentralized storage facility for the development of biomass depots.

Enhance the scope of biofuel blending mandates

Provide CBG blending mandates to all City Gas Distribution (CGD) entities marketing CNG and PNG. Promotion of CBG and CNG vehicles in locations with upcoming CBG plants and convert existing vehicles and tractors to CNG based vehicles. Issue comprehensive guidelines on marketing of CBG through CNG outlets and vice versa. Dedicated "Green Hours" can be designated for undertaking sale of CBG through CNG outlets.

Source: https://pib.gov.in/PressReleasePage.aspx?PRID=1917439 , https://iocl.com/NewsDetails/52531 , https://pib.gov.in/PressReleasePage.aspx?PRID=1844630 , https://pib.gov.in/Pressreleaseshare.aspx?PRID=1557898 , Source: EY Analysis; Pipeline includes projects under planning, development and construction

Policy recommendations

Introduce offtake mandates for bio-manure by fertiliser industry and promote adoption of Fermented Organic Manure (FOM)

Mandatory offtake arrangement of bio manure from CBG Plants @ INR5000-6000/ton by chemical fertilizer companies with minimum mandated offtake of bio manure as a percentage of chemical fertilizers in a 'Basket Approach.'

Exemption from retail license requirement for the sale of FOM in small quantities, including packages less than 5 Kg and stock less than 10 MT at any given time. Creation of natural farming and organic farming ecosystems. The Government may declare the vicinity of CBG Plants as 'Green Zones' where only FOM may be used for organic and natural farming. Creation of a national brand and certification for organic and natural food produced by FOM.

State driven policy incentives for attracting biofuel production investments

Government of Andhra Pradesh recently announced the integrated clean energy policy 2024 to attract investments in various clean energy technologies including establishment of 1500KLPD ethanol plants and 10,000 TPD CBG plants. Capital subsidies up to 20%, subsidized electricity supply, reimbursement of state GST and exemption of electricity duty are announced for biofuel investments. Similar benefits can be targeted by other states. to attract private investment to the ethanol and CBG sectors.

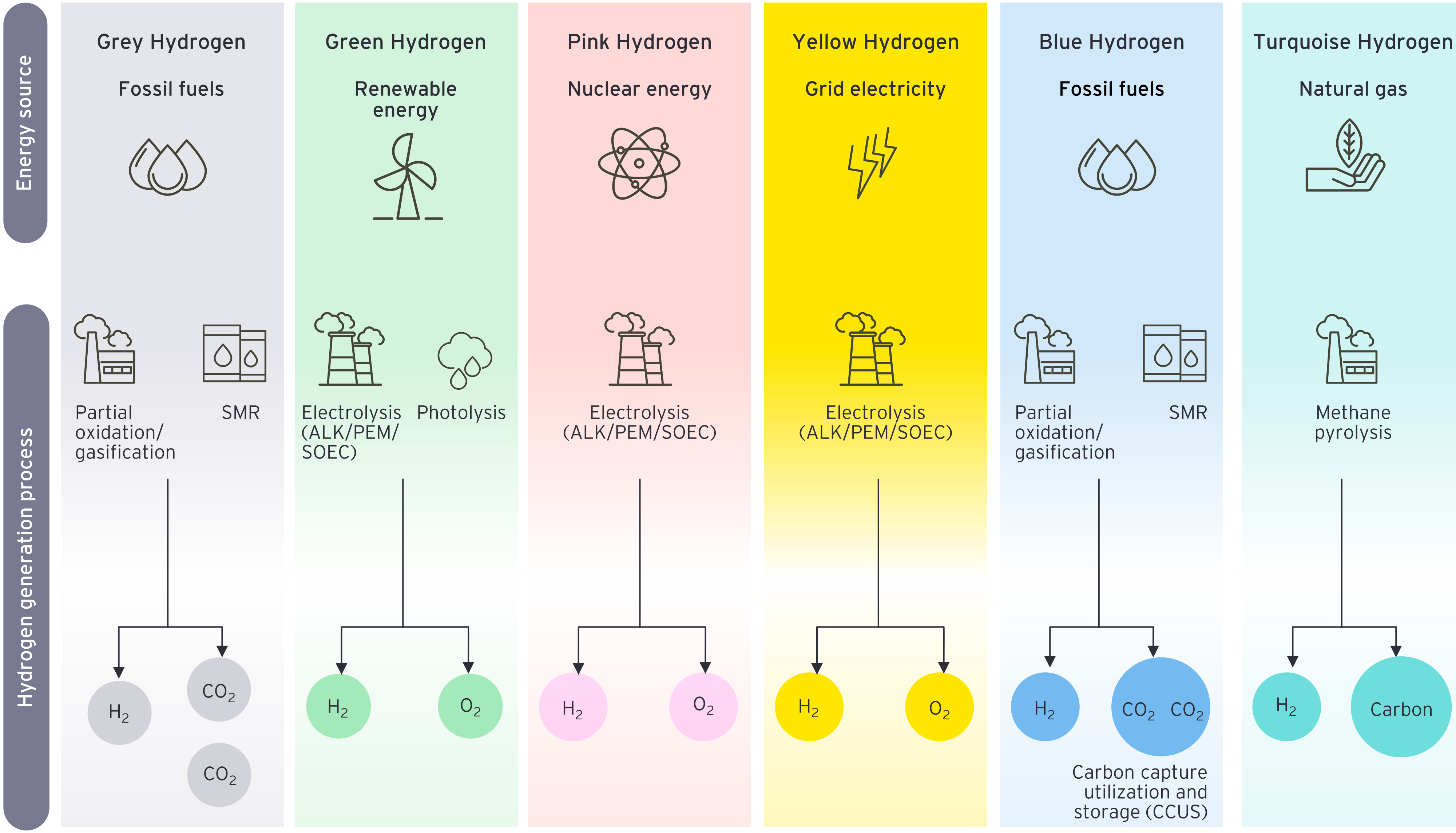
Source: https://pib.gov.in/PressReleasePage.aspx?PRID=1917439 , https://iocl.com/NewsDetails/52531 , https://pib.gov.in/PressReleasePage.aspx?PRID=1844630 , https://pib.gov.in/Pressreleaseshare.aspx?PRID=1557898 , Source: EY Analysis; Pipeline includes projects under planning, development and construction

Opportunities in the green hydrogen and derivatives value chain

Chapter

06

96% of hydrogen produced globally is grey, which has the highest carbon intensity;
12-13 kg CO2/kg H2 is the average emissions intensity of global hydrogen production in 2021



Source: EY Analysis

India: Green hydrogen investment drivers and policy landscape

The Government of India aims to make India a global hub for the production, use, and export of green hydrogen and its derivatives. There are several drivers behind this ambition:

- As a tool for decarbonization of hydrogen and ammonia production (currently being produced with natural gas as a feedstock) for application in refineries and fertilizer. India's hydrogen consumption stands at ~6 MMTPA; predominated by oil refineries accounting for 3 MMTPA and another 2.5 MMTPA is used for urea and other fertilizer.
- The industrial sector, particularly the hard-to-abate industries with high carbon footprints such as steel, ammonia, methanol, chemicals etc. where hydrogen is used as chemical feedstock requires effective means for decarbonization.
- Government aims to achieve self-reliance in energy and decrease dependence on fossil fuel with the implementation of green hydrogen mission in India.
- India has the potential of being a low-cost producer of hydrogen as its cost of generating solar and wind energy is among the lowest in the world. It is assumed that the cost of electrolyzer would decrease over time due to increasing economies of scale, R&D spends and policy push worldwide.
- India can take advantage of emerging as a low-cost producer of hydrogen and become an exporter of hydrogen and green ammonia. Countries like India, Argentina, Australia, Saudi Arabia (rich in renewable energy resources), have the potential to emerge as a future powerhouse in green hydrogen production and export.
- Investments in hydrogen production can drive jobs and create a new ecosystem for fresh investments. Moreover, various public sector enterprises are taking initiatives to propagate faster deployment of green hydrogen in the country. For instance, Oil India Limited had set up one of India's first 99% pure green hydrogen plant in Jorhat, Assam. NTPC also initiated blending operations in Surat's PNG network, receiving an approval of 5% and gradually will be increased to 20%. Such initiatives have been possible due to supporting government policies.

National green hydrogen mission

The mission was launched with a total outlay of INR 19,744 crore (US$2.4 billion) up to FY2029-30. It provides a comprehensive action plan for establishing green hydrogen ecosystem and envisages the addition of 125 GW of RE generation capacity and a total investment of INR 8 lakh crore (US$100 billion) in the GH ecosystem by 2030. Objectives include:

- Build capabilities to produce at least 5 MMT of GH per annum by 2030, with the potential to reach 10 MMT per annum with the growth of the export market.
- Make India a leader in technology and manufacturing of electrolyzers.

Under the Green Hydrogen Mission, the government has allocated INR17,490 crore for Strategic Interventions for Green Hydrogen Transition (SIGHT) Programme. Of this, INR4,440 crore has been set aside for manufacturing electrolyzers, while the remaining INR13,050 crore will fund green hydrogen production between FY2025-26 to FY29-30. The program includes two distinct financial incentive mechanisms to support domestic manufacturing of electrolyzers and green hydrogen production.

- Mode 1 – Electrolyzer: On 12 January 2024, the government awarded production linked incentives (PLI) for electrolyzer manufacturing to eight companies under the SIGHT Scheme, supporting a capacity of 1,500 MW per year under the first tranche. Thirteen more companies received awards for an additional 1,500 MW in the second tranche.
- Mode 2- Green hydrogen: On 9 January 2024, the government awarded contracts for green hydrogen production under the SIGHT Scheme to 10 companies, totaling a production capacity of 412,000 tons per year. The second tranche, aiming for another 450,000 tons per year, is currently active.
- Mode 2A – Green ammonia: On 22 June 2024, the Ministry of New and Renewable Energy (MNRE) increased the annual production capacity for green ammonia under Mode 2A of the SIGHT scheme from 550,000 to 750,000 tons per year. Fourteen fertilizer plants identified in the Solar Energy Corporation of India's (SECI) tender will consume this green ammonia.84
- Mode 2B – Green hydrogen: On July 24, 2024, the Ministry of New and Renewable Energy (MNRE) introduced a major policy for acquiring green hydrogen. As per the announcement, each oil and gas company will be responsible for aggregating demand and inviting bids to ensure the lowest-cost production and supply of green hydrogen for their individual refineries or across multiple refineries. Additionally, the Centre for High Technology (CHT) will provide secretarial, managerial and implementation support, and will manage additional tasks as assigned by the Ministry of Petroleum and Natural Gas (MoPNG).
- In addition, the government has announced allocations for pilot projects in the transport, steel and shipping sectors, aimed at replacing fossil fuels and fossil fuel-based feedstock with green hydrogen and its derivatives.

Source: https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1888334 , https://mnre.gov.in/en/hydrogen-schemes-guidelines/ , https://mnre.gov.in/en/national-green-hydrogen-mission/

Timeline of green hydrogen policies and guidelines announced under the National Green hydrogen mission

- **Feb 2022** – National Hydrogen Policy
- **Jan 2023** – National Green Hydrogen Mission (NHGM)
- **Jun 2023** – SIGHT Programme – Component I: Incentive Scheme for Electrolyser Manufacturing
- **Jun 2023** – SIGHT Programme – Component I: Incentive Scheme for Electrolyser Manufacturing
- **Aug 2023** – Green Hydrogen Standards Notified
- **Oct 2023** – Research and Development Roadmap
- **Jan 2024** – Scheme Guidelines for Implementation of SIGHT Programme Component-II: (under Mode-2A)
- **Jan 2024** – Scheme Guidelines for Implementation of SIGHT Programme Component-II: (under Mode-2B)
- **Feb 2024** – Scheme Guidelines for Pilot Projects for Use of Hydrogen in Shipping Sector
- **Feb 2024** – Scheme Guidelines for Pilot Projects for Use of Hydrogen in Steel Sector
- **Feb 2024** – Scheme Guidelines for Pilot Projects for Use of Hydrogen in Transport Sector
- **Mar 2024** – Scheme Guidelines for R&D Scheme
- **Mar 2024** – Guidelines for Skill Development
- **Mar 2024** – Scheme Guidelines for Implementation of SIGHT Programme Component-I, Tranche-II
- **Mar 2024** – Scheme Guidelines for setting up Hydrogen Hubs in India
- **July 2024** – Scheme Guidelines for funding of testing facilities, infrastructure, and institutional support for development of Standards and Regulatory framework
- **Nov 2024** – Scheme to support Pilot Projects on New and Innovative production techniques and applications of Green Hydrogen

Source: https://mnre.gov.in/hydrogen-schemes-guidelines/

Progress and achievements under the National Green Hydrogen Mission

Electrolyzer Manufacturing

- Production linked incentives for ~3000 MW annual electrolyzer manufacturing capacity has been awarded to 15 companies.

Green Hydrogen and Derivatives Production / Supply

- Production linked incentives are awarded to 10 companies for 412,000 TPA of Green Hydrogen.
- Tender for additional capacity of 4.5 lakh TPA of Green Hydrogen production is currently live.
- Tender for production and supply of 7.39 lakh TPA of Green Ammonia is currently live.
- Tenders for a total capacity of 42,000 TPA of green hydrogen for adoption by oil refineries is currently live.

Green Hydrogen Hubs with INR 200 crore budgetary outlay

- Proposals for setting up of Hydrogen Hubs is awaited from market participants for evaluation and award of projects.

Research and Development

- Proposals for setting up Centres of Excellence (CoEs) is awaited from market participants for evaluation and award of projects.

Pilot Projects in Shipping with INR 115 crore budgetary outlay

- Shipping Corporation of India (SCI), the implementing agency has selected ships for retrofitting and completed feasibility studies. Designs to convert AHTS vessels for running on green methanol are under evaluation.
- V.O. Chidambaranar Port is working to develop a Green Hydrogen bunkering and refuelling facility.

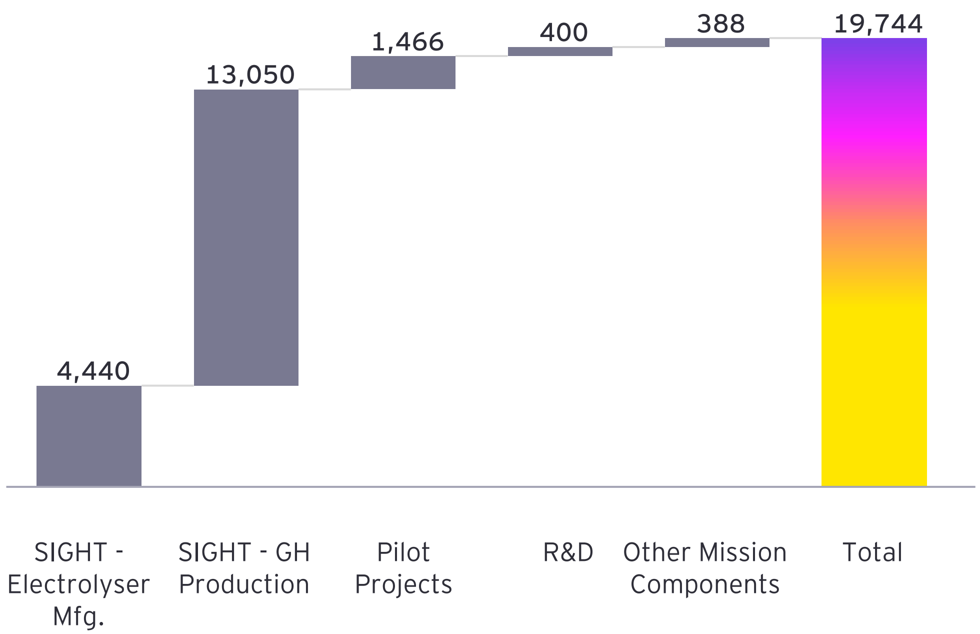
Pilot Projects in Steel with INR 455 crore budgetary outlay

- MECON Limited, the implementing agency is working to award pilot projects for hydrogen injection in a Direct Reduced Iron (DRI) plant, existing Blast Furnace, and existing DRI vertical shaft

Pilot Projects in Transport with INR 496 crore budgetary outlay

- Automotive Research Association of India (ARAI), the implementing agency is working to deploy 11 Hydrogen Re-Fuelling stations

Financial outlay envisaged in National Green Hydrogen Mission (INR Cr)



Source: EY Analysis based on NGHM announced by GoI

Overview of state policies for attracting green hydrogen investments

Green H2 Policy (Draft)

- 50% exemption on In-STS & wheeling
- 100% exemption on CSS & ASC
- INR 50/Kg consumption subsidy for 5 yrs
- 15 Cr/Project capex subsidy for bio-mass to GH2 producers

Green H2 Policy (Draft)

- 100% exemption of In-STS (Intra state transmission), wheeling, CSS (cross subsidy surcharge) & ED (electricity duty) for 10 years
- 100% exemption on demand charges
- 100% exemption on stamp duty and land conversion charges

Green H2 Policy

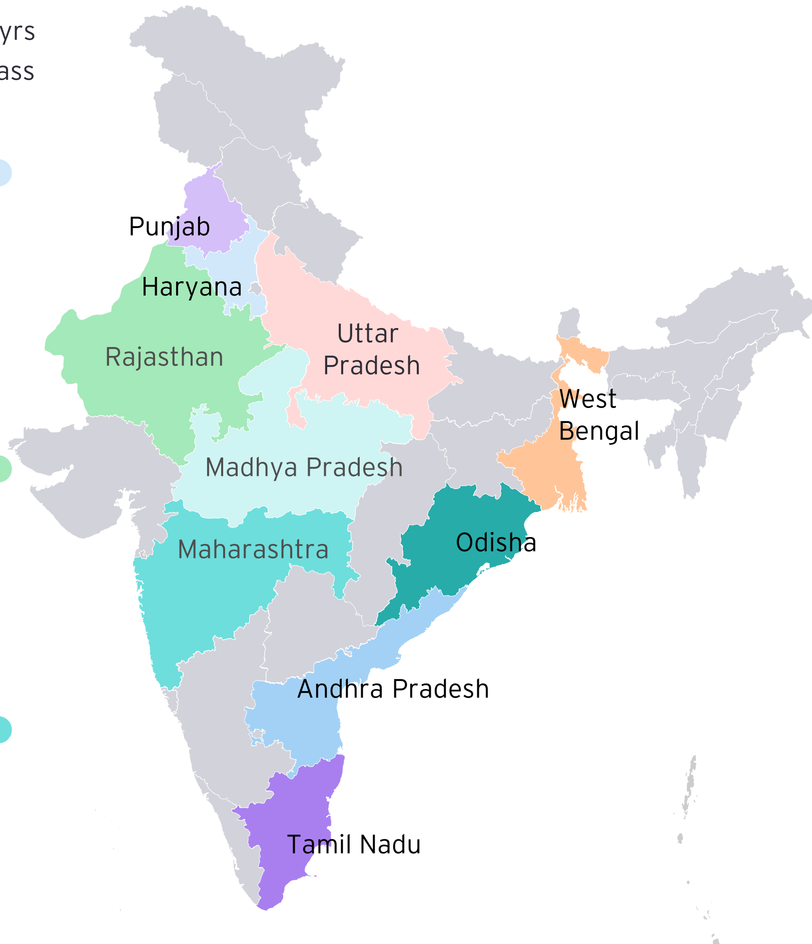
- 100% exemptions from duties, land taxes and conversion charges etc.
- Reimbursements for acquiring advanced tech
- Investment and capital subsidies

Green H2 Policy

- 100% exemptions from duties, land taxes and conversion charges etc.
- 50-100% concessional open access tariffs
- Investment and capital subsidies

Industrial Policy, 2021

- ED and SGST exemption.
- Up to 20% capex incentive



Green Hydrogen Policy

- Land tax & stamp duty Exemptions
- SGST, Cross Subsidy Surcharge & Distribution Charges Reimbursements
- Subsidy for green urea produced in the state

Green Hydrogen Policy 2023

- 100% exemption of ED till Dec-2028
- 100% exemption on stamp duty
- 100% exemption on land conversion & mutation charges

Green Hydrogen Policy 2023

- 100% exemption in ED and energy dev. cess for 10 years
- 50% in wheeling charges for 5 years
- 50% reimbursement of stamp duty charges on land purchase

Industrial Policy Resolution, 2022

- Up to 30% capex subsidy
- Reimbursement of power tariff @ Rs 3 p.u for 20 years, SGST reimbursed
- Monthly banking
- ED and transmission charges exempted

Integrated clean energy policy 2024

- Capital subsidy (25%)
- State GST reimbursement for five years
- Power supply from grid at INR 1 / kWh for 5-10 years
- 25% exemption of industrial water tariff
- 50% Reimbursement of InSTS, exemption of CSS and AS charges

SGST - State GST tax | p.u - per unit | ASC - additional surcharge | CSS - Cross subsidy surcharge | ED - electricity duty, Source: EY analysis

Export-oriented projects and investments for supply of green ammonia to Japan and EU are advancing at scale

Disparity in production sources and consumption of green hydrogen could catalyze the emergence of markets for green hydrogen as a tradeable energy commodity in the long term.

While supply side incentives have been a good starting point to push the green hydrogen development in the country, domestic demand will be an important driver for its growth.

Presently in India, 90% of the hydrogen produced is used for captive use (in refineries and fertilizer plants), resulting in a relatively small market for hydrogen. More importantly, there is a huge cost disparity between grey and green hydrogen, which impacts economics and investments.

Consequently, until green hydrogen demand is not established in the market, the export market can be a crucial strategy for expanding local production, creating economies of scale, and reducing costs. Recent tenders for supply of green hydrogen by Japan and countries in the EU have attracted interest from Indian players.

01

ACME (India) proposes to supply green ammonia to Japan's IHI Corporation. The Green Hydrogen and Ammonia Project, with a planned capacity of 1.2 MTPA, is proposed to be developed by ACME in the state of Odisha. The IHI Corporation has signed an offtake term sheet with ACME for the supply of green ammonia from Odisha to Japan.

02

Singapore's Sembcorp Industries has signed an agreement with power generation companies and conglomerates in Japan to export India-made green hydrogen to Japan. Under this arrangement, three companies will be exploring opportunities to produce green ammonia in India and export it to Japan.

03

YARA Clean Ammonia (world's largest trader and distributer of ammonia) and Greenko ZeroC (green ammonia production arm of India-based AM Green) are reported to have recently signed a term sheet for supply of renewable ammonia from Phase 1 of Ammonia production facility in Kakinada in the state of Andhra Pradesh in India.

Source: IH2A, EY Analysis, https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1998871 , https://www.sembcorp.com/media/q3epdsrz/sembcorp-partners-sojitz-and-kyushu-electric-to-supply-japan-with-green-ammonia-produced-in-india.pdf , https://www.yara.com/corporate-releases/yara-clean-ammonia-and-am-green-earlier-greenko-zeroc-sign-term-sheet-for-sale-of-renewable-ammonia-from-india-to-yara-clean-ammonias-global-market/

Policy recommendations

Grid flexibility enhancement for integrating giga-watt scale renewable energy sources for green hydrogen production

Green hydrogen production via electrolysis of water requires continuous round the clock supply of electricity for achieving maximum capacity utilization factors and minimizing levelized cost of hydrogen production. This means the installed capacity of intermittent renewable energy sources such as wind and solar need oversizing of at least 2-3 times the electrolyser load along with adequate market liquidity to absorb surplus electricity generation without curtailment. CEEW estimates that the national peak electricity requirement will increase by 67 GW and consumption will rise by 310 billion units (BU) to meet India's ~5 Million TPA green hydrogen production target by 2030. India will need to integrate 135 GW of additional RE capacity (51 GW solar and 84 GW wind) with the grid to serve 74 GW of electrolyser capacity. This means that system flexibility requirement will quadruple between 2022 and 2030. The net load will need to ramp up/down at a faster rate to integrate this larger share of intermittent renewables. This will increase the net load flexibility requirement from approx. 250 MW per minute to approx. 1,100 MW per minute for the top 10 % of hours.

Recognizing green hydrogen under the harmonised infrastructure list

Recognizing green hydrogen and its derivatives as infrastructure under the Harmonised List of Infrastructure sub-sectors would provide a formal framework for supporting the sector, making it eligible for financial incentives, tax breaks, and easier access to funding from public and private sectors. This recognition would attract both domestic and international investment, driving innovation and scaling up production capacity. It would also encourage the development of the necessary infrastructure for producing, storing, and distributing green hydrogen, such as electrolyzers, storage facilities, and pipelines. This strategic move would ensure that the country is well-positioned to meet growing energy demands sustainably while contributing to global climate change mitigation efforts

Focus beyond electrolytic pathways for GH2 production that offer the best energy efficiency advantage

Hydrogen production through pyrolysis of bio-gas (methane) is considered one of the transition pathways to a green hydrogen-based economy. Turquoise hydrogen's low energy requirement, minimal water use, and byproduct (solid carbon) benefits has potential to fuel significant market growth. At scale, turquoise hydrogen can achieve favourable cost competitiveness through carbon black sales, potentially outpricing green hydrogen.

Several methane pyrolysis technologies can be explored for commercial development and production of turquoise hydrogen, however, plasma thermal decomposition is the commercially proven technology in the present scenario.

Turquoise hydrogen production requires lesser energy requirement (20-30 kWh per kg of H2), depending on the pathway as compared to Green Hydrogen production which requires 50-60 kWh per kg of H2. Further, approximately 3 kg carbon black is produced per kg of methane which holds commercial value as an additive within the materials sector, akin to the application of biochar. The emissions intensity of hydrogen produced with electrolysis is less than 0.4 kg CO2-eq/kg H2. Similarly, hydrogen produced using natural gas through methane pyrolysis process can lead to an emission intensity of 0.9 kg CO2-eq/kg H2.

GST rationalization of green hydrogen and its derivatives

GST rates for several low carbon energy sources and technologies including biogas (5%), electric vehicles (5%) are rationalized for mass adoption. Similar rationalization of GST rates for green hydrogen and its derivatives from 18% to 5% for domestic adoption can help stimulate demand for such low carbon commodities.

Chapter 07

Financing India's energy transition

India's decarbonization journey will need US$150 - 200 billion annually representing ~ 4-6% of GDP

Climate finance landscape

India is on an ambitious path to transform its energy landscape and achieve significant climate goals, including reaching 500 GW of renewable energy capacity by 2030 and achieving net-zero emissions by 2070. This transition to a low-carbon economy requires massive capital investment, with estimates ranging between US$150-200 billion across various sectors, such as renewable energy generation, electric mobility, green hydrogen, and energy storage. The Council on Energy, Environment and Water (CEEW) projects that India's cumulative investment needs could reach as high as US$10.1 trillion by 2070 to meet these targets. While public funds are critical, private capital both domestic and international will play an essential role in filling the financing gap.

India's track record in raising green finance is noteworthy but still insufficient to meet these goals. According to the Climate Policy Initiative (CPI), India mobilized around US$44 billion in green finance in 2019-20, with half of this coming from domestic private sources. Despite an encouraging 150% increase from the previous years, this level of investment remains far from what is required. Financial institutions (FIs) and corporates are increasingly encouraged to participate, yet they face considerable challenges. Green technologies, which are often newer and riskier, come with extended payback periods and limited historical data, making them less attractive to investors who typically prefer shorter investment cycles. This lack of commercialization and scalability in certain green sectors further deters capital inflow.

The Indian government has implemented several supportive policies and regulatory measures to foster a conducive environment for green finance and accelerate the energy transition. Recent initiatives include the issuance of sovereign green bonds, which in FY23 raised INR16,000 crore (approximately US$2 billion) to support green infrastructure projects aimed at reducing carbon emissions. Moreover, the Reserve Bank of India (RBI) has issued green deposit guidelines, encouraging banks to direct funds toward sustainable projects, including renewable energy, clean transportation, and green buildings. In alignment with global trends, the RBI has also committed to enhancing climate-related risk disclosures and has joined the Network for Greening the Financial System (NGFS) to strengthen its climate finance commitments.

The Securities and Exchange Board of India (SEBI) has further strengthened the regulatory framework by mandating Business Responsibility and Sustainability Reporting (BRSR) for top listed companies. SEBI also introduced a consultation paper on sustainable finance, seeking to broaden the scope of green debt instruments to include social bonds, sustainability-linked instruments, and sustainable securitized debt, reflecting a more holistic approach to sustainability. Additionally, the recent budget announcement introduced a Climate Finance Taxonomy and a Carbon Credit Trading Scheme under the Indian Carbon Market Framework. These initiatives aim to incentivize investment in climate-resilient infrastructure, providing a financial mechanism to reward low-carbon initiatives across sectors such as shipping, aviation, steel, and chemicals.

Deal activity in crucial energy transition sectors and themes

India's clean energy sectors solar, wind, green hydrogen, EVs, and battery energy storage systems (BESS) are seeing robust investment activity. In solar, over US$2 billion has been raised for residential rooftop installations since 2015. Financing trends show that solar continues to attract both equity and debt, with international finance playing a key role. Offshore wind energy has the potential to benefit from viability gap funding, while green hydrogen is seeing significant corporate commitment alongside public sector support. EVs are also experiencing a surge in venture capital, with record-breaking funding, and BESS is seeing US$9-10 billion in yearly investment, driven by venture capital growth and government-backed tenders.

The quadrupling of venture capital funding in climate tech since 2019 highlights the significant role technology plays in addressing climate change. Climate tech startups secured substantial funding in 2023, with momentum continuing into 2024. Investors are expanding their focus beyond traditional areas, scouting for startups in sub-sectors like agri-tech, technologies that increase resource efficiency (energy, water, waste), sustainable packaging, and the circular economy. Supportive government policies and a growing consumer demand for sustainable solutions are further enhancing the sector's appeal. This surge in investment activity within India's climate tech space is fueled by the maturation of technologies, stronger R&D capabilities, greater consumer awareness, and the government's clear push toward a green energy transition, offering abundant opportunities for both investors and startups.

Source: EY analysis based on desk research, https://www.ceew.in/press-releases/india-will-require-investments-worth-over-usd-10-trillion-achieve-net-zero-2070-ceew , https://www.climatepolicyinitiative.org/publication/landscape-of-green-finance-in-india-2022/ , https://pib.gov.in/PressReleasePage.aspx?PRID=1983770 , https://jmkresearch.com/majority-of-equity-investments-in-indias-rooftop-solar-segment-are-from-foreign-entities/ ,

Unlocking private capital: Challenges and key recommendations

Barriers to private capital flow

One of the primary challenges hindering private investment in India's climate sector (beyond the mainstream sectors) is the high capital requirements, particularly for early-stage companies. These ventures often require significant investment for research and development, and scaling up production, which can exceed the risk appetite and liquidity preferences of traditional investors. The uncertainty surrounding long development timelines, uncertain return profiles, untested market adoption, and the potential for unfavorable policy shifts further compounds the risk and renders the companies less investible, making it difficult for these companies to secure the necessary funding.

This capital-intensive nature makes them more sensitive to funding cycles and can create barriers to accessing the capital needed to demonstrate product viability and scale operations effectively. Mobilizing private investment requires navigating the complexities of debt versus equity funding. Companies must carefully assess their financial strategies, considering the long-term viability and control implications of equity funding against the fixed obligations of debt financing. The choice is influenced by the company's lifecycle stage, risk tolerance, and the nature of the investment itself. These challenges highlight the need for strategic risk transfer mechanisms and innovative financing instruments that can accommodate these distinctive aspects and offer incentives for sustainable returns with a lower risk profile.

Innovative financing mechanisms

Financial incentives and mechanisms such as blended finance and patient capital are crucial in supporting and mobilizing private investment. Blended finance instruments like concessional loans, guarantees, first-loss, subordinated debt and performance driven incentives, as well as advisory and technical assistance, can offer a strategic approach to commercialize and de-risk early-stage and non-traditional sectors and facilitate their scalability. By filling funding gaps in collaboration with public, private, DFI and philanthropic capital, particularly in sectors where the economic impact is yet to be fully monetized, blended finance plays a crucial role in ensuring that impactful innovations receive the necessary support, regardless of their development stage. It is especially vital for technologies with longer gestation periods, where traditional funding mechanisms may fall short. Blended finance's ability to combine grants, equity, and debt creates a powerful tool for supporting climate projects throughout their lifecycle. DFIs have a particularly important role to play in more risky or unconventional sectors, wherein they can provide grants and technical assistance from their global portfolio to support ongoing R&D, pilot projects and make these sectors more viable.

Source: EY analysis based on industry interaction and desk research

Unlocking private capital: Challenges and key recommendations

The role of government in bridging the gap

The role of government policy in bridging the financing gap cannot be overstated. Clear, long-term policy signals and regulatory certainty can reduce the perceived risks associated with green investments, making the transition more affordable and attractive to investors. By fostering an environment conducive to investment through supportive policies and incentives, India can attract the necessary global and domestic capital to fund its ambitious green transition. The government can provide support by facilitating public-private partnerships (PPPs), especially in sectors and technologies where investors may hesitate due to uncertainties and delayed returns. PPPs can offer private investors the confidence they need, attracting private capital to underfunded sectors and creating a win-win situation for all involved.

Source: EY analysis based on industry interaction and desk research

Takeaways

Companies must continue to innovate and integrate sustainability into their core strategies, leveraging green technologies and enhancing transparency in climate disclosures. They must leverage their company's opportunities and strengths and engage with the right pools of capital to raise green finance.

Private investors have a crucial role in this transition, not only by diversifying their portfolios with green assets but also by venturing into riskier (than usual) investments that have long-term environmental impact and financial returns. They should consider investing across a company's lifecycle and engage with blended finance instruments to balance risk and reward.

Development Finance Institutions (DFIs) are tasked with the critical function of de-risking investments in the green sector. By offering guarantees and other financial instruments, DFIs can provide the assurance needed to spur private sector investment into climate technologies and essential infrastructure.

Venture capital firms have the distinct opportunity to fuel innovation by supporting early-stage green startups, thus seeding the market with transformative solutions that can scale.

Private equity, with its substantial capital reserves and long-term investment horizon, is strategically positioned to fund large-scale green infrastructure projects, playing a pivotal role in the energy transition narrative.

The stakeholders need to work together not only to meet climate targets but also to take advantage of the economic opportunities that come with this transition. To access these opportunities, they must be prepared and make deliberate collective efforts. By aligning their actions towards a common goal, stakeholders can unlock the full potential of climate aligned capital. This will drive India towards a greener and more resilient future, making it an attractive destination for climate-focused capital.

State owned electric utilities are lagging in their efforts to scale renewable energy transition investments

Capital constraints

Sustained financial losses for many years has eroded net-worth and worsened debt service coverage ratio for state-owned DISCOMs. Discom losses propagate up the vertical chain (generation, transmission and trading companies) largely from unpaid/delayed dues. Most state-owned electric utilities are financially stressed with accumulated losses and a high level of debt. To sustain operations and invest in infrastructure upgrades, these utilities rely on loans from state-owned NBFCs, particularly PFC and REC underscoring a deep-rooted dependency for both day-to-day operations (current liabilities) and long-term projects (non-current CAPEX).

Without structural reforms, state-owned utilities remain in a state of financial instability, perpetuating the cycle of borrowing and distress. The vicious cycle of capital constraints is driven by a combination of operational inefficiencies, inadequate tariff structures, and lack of structural reforms.

- The cycle begins with persisting operational inefficiency resulting in financial distress, increased borrowing, escalating debt and interest burden, worsening financial health, inadequate structural reforms, which in turn leads to further distress.
- Operational inefficiency stems from high T&D losses including due to outdated infrastructure, power theft, and technical inefficiencies, inadequate tariff structures to cover cost of supply, under recovery of direct subsidies, delayed payments from government institutions, stagnating revenues from C&I consumers.
- Lack of accountability result in operational inefficiency and mismanagement. There is often a lack of consequences for poor performance or malpractice, undermining organizational effectiveness.
- Limited transparency in financial management erodes public trust and confidence in state-owned utilities. Stakeholders lack visibility into how resources are allocated and utilized.
- Siloed organizational structures and departmental rivalries impede collaboration and coordination within state-owned utilities. This fragmentation hampers efficiency, innovation, and the ability to implement integrated solutions to complex challenges.

Source: EY analysis based on industry interaction and desk research

Corporate governance challenges in state owned electric utilities

Governance within India's state-owned electric utilities faces multiple challenges that weaken operational efficiency and impede strategic decision-making. The current board structures are not sufficiently equipped to guide these utilities through the complexities of the energy transition. Many boards lack independent directors with specialized knowledge in renewable energy, digital transformation, or energy storage. Instead, these positions are often filled by politically appointed individuals with limited industry experience. Furthermore, audit committees, risk management frameworks, and performance evaluation mechanisms are either absent or ineffective, causing poor oversight of operations and finances. Political interference from government officials and ministries adds another layer of complexity, compromising the autonomy of these utilities to make decisions based on long-term strategic goals.

As a result, many utilities continue to rely on traditional business models, failing to capture new revenue streams from energy transition market opportunities. India's regulatory landscape offers a variety of governance guidelines for public sector enterprises, including the Companies Act, SEBI's Listing Obligations and Disclosure Requirements (LODR), and the Department of Public Enterprises (DPE) guidelines for Central Public Sector Undertakings (PSUs). However, state-owned electric utilities often fail to comply with these standards effectively. The Ministry of Power, Government of India has notified 'Revised Corporate Governance Guidelines for Discoms, Gencos & Transcos' in 2023. These guidelines are used for assessment of the performance of Utilities in the Annual Integrated rating exercise as well as in the schemes of the Ministry, where the release of grants to Utilities is tied up with the performance.

State owned electric utilities are lagging in their efforts to scale renewable energy transition investments

Best practices for corporate governance:

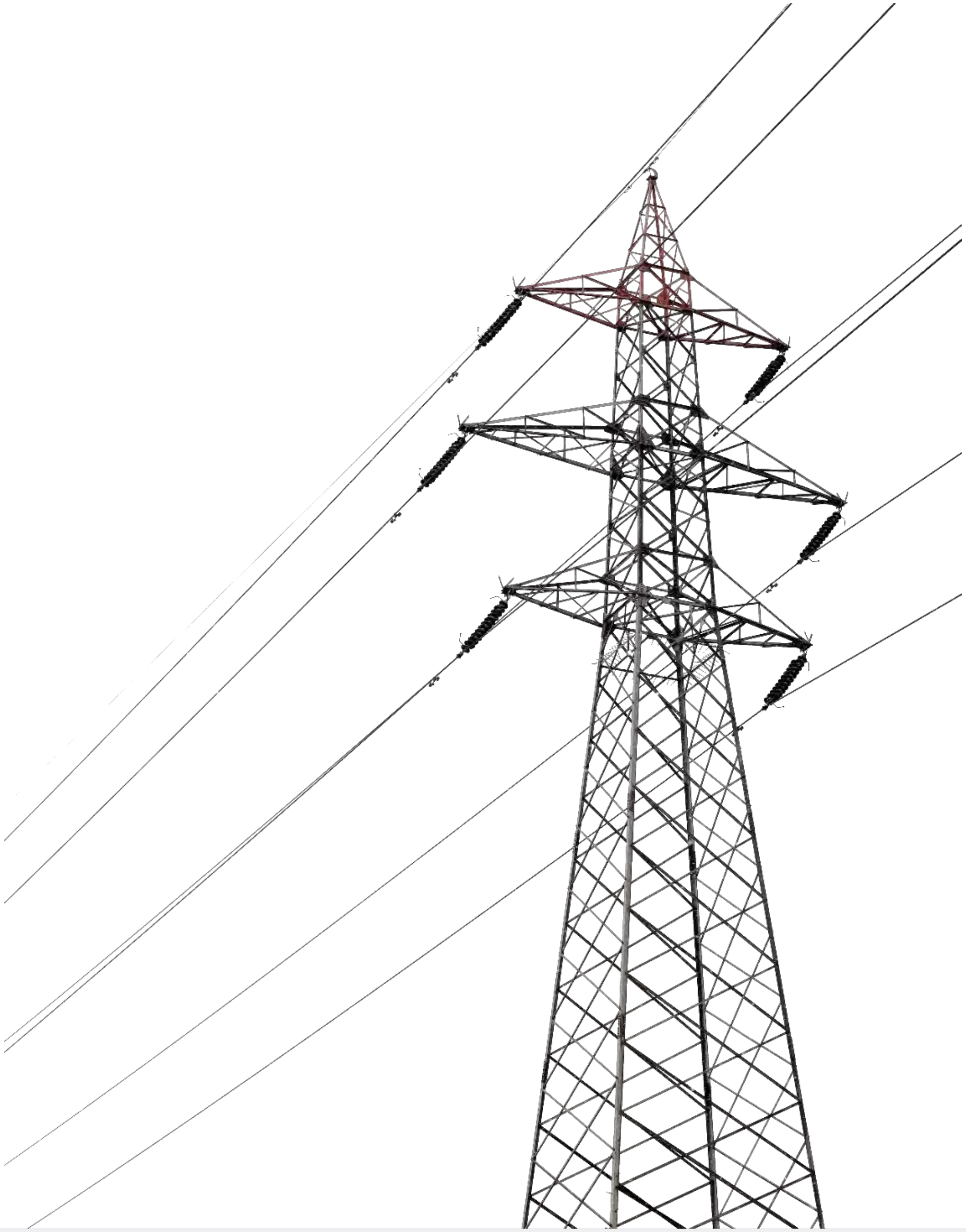
- Board Composition: At least 50% of the board should comprise non-executive directors, with 1/3rd being independent directors to ensure impartial oversight
- Audit and Risk Committees: These committees are essential for ensuring compliance with regulatory standards, improving risk management, and increasing financial transparency
- Board Performance Evaluation: Boards should implement formal performance evaluation mechanisms aligned with key result areas (KRAs)

These governance guidelines are crucial for fostering transparency, ensuring accountability, and enhancing the operational efficiency of utilities. However, many utilities have yet to fully adopt these practices, resulting in continued financial distress and operational inefficiency.

The 12th Annual Integrated Rating and Ranking of Power DISCOMs identified more than 30 out of 42 state DISCOMs did not comply with 1/3rd independent directors. More than 12 state DISCOMs were rated with specific disincentives for lack of operational audit committee, exclusive Managing Director and Director Finance and quarterly accounts duly approved by Board of Directors or Audit Committee. Independent compliance evaluations of corporate governance guidelines among state-owned electric utilities is required to inform meaningful structural reforms.

The failure to implement strong governance practices has far-reaching consequences for the financial and operational health of state-owned utilities. Delays in payment to suppliers, combined with political interference, have led to massive debt accumulation. Many DISCOMs operate with long-standing revenue deficits, compounded by unrealistic tariff structures that do not cover the full cost of supply. This financial instability has a cascading effect on the entire electricity value chain, affecting GENCOs and TRANSCOs as well. Without governance reforms, state-owned utilities will continue to struggle with debt, poor creditworthiness, and missed opportunities for investment in critical areas such as renewable energy infrastructure and integration.

Source: EY analysis based on industry interaction and desk research



Recommendations for utility of future reforms to navigate the disruption of energy transition technologies

Prioritize corporate governance in the Government's annual integrated rating and ranking exercise for DISCOMs and other electric utilities

The latest annual integrated rating evaluation had only one corporate governance metric (i.e. 1/3rd independent directors) carrying 1 mark out of 100. Other governance metrics such as operational audit committee, exclusive MD & DF and quarterly accounts allowed for specific disincentives up to negative 3 marks in the overall scoring. To emphasize the significance of corporate governance in state-owned electric utilities, the following governance standards / guidelines / metrics can be prioritized in the future rating exercises with much higher scoring potential up to 10 marks out of 100.

Selection of Non-executive and Independent Directors with proven experience in scaling profitable energy transition services

Boards of state-owned electric utilities should appoint directors with proven experience in energy transition technologies, including renewables, smart grids, and digital utilities. Independent directors should constitute at least one-third of the board, and there should be a focus on professional expertise rather than political appointments. At least 10% of directors should demonstrated experience and merit in heading top tier utility businesses providing energy transition and RE integration related services. Another 10% of directors can be selected from major lenders like PFC / REC / other financial institutions to support endeavours of better operational practices.

Stock exchange listing of state-owned electric utilities

Listing state-owned utilities on stock exchanges offers a pathway to improved governance through market-driven discipline. Publicly listed companies are subject to stringent disclosure requirements, improving transparency and reducing political interference. Additionally, listing can provide much-needed access to capital, allowing utilities to fund their transition to renewable energy and digital technologies. Strategic listing without significant dilution of government ownership and control can help build consensus with employee unions.

Source: EY analysis based on industry interaction and desk research

Recommendations for utility of future reforms to navigate the disruption of energy transition technologies

Source: EY analysis based on industry interaction and desk research

Initial Public Offering (IPO) with Non-Dilutive Equity: State-owned electric utilities can consider offering non-voting shares (such as preference shares) or a lower equity percentage for sale during the IPO, ensuring that the government retains a controlling stake in the company. This can help raise capital while maintaining government ownership and addressing employee concerns about privatization.

Offer Employee Stock Ownership Plans (ESOPs): Providing shares or stock options to employees can align their interests with the company's performance. It would reduce potential resistance from employee unions by making them shareholders and beneficiaries of future growth.

Align with SEBI's Listing Obligations and Disclosure Requirements (LODR): Implementing SEBI's corporate governance mandates, such as forming independent audit committees, board compositions with independent directors, and robust internal control mechanisms will boost stakeholder confidence and improve governance standards, making the company more attractive to consumers and potential investors. This enhances transparency and reassures investors that the company is on a sound governance track.

Engage with Employee Unions: Create a dialogue with employee unions to explain the benefits of listing and ensure they understand that government ownership will not be immediately diluted. Offer reassurances that the company is not being privatized but is taking a step to modernize and improve competitiveness.

Guarantee Employee Protections and Share Benefits: Secure agreements with employee unions for job security, salary protections, and additional benefits. By making employees shareholders, they stand to benefit from improved governance and financial performance.

Explore SEBI's Regulatory Flexibilities for PSUs: SEBI provides some flexibility to Public Sector Undertakings (PSUs) in terms of minimum public shareholding, which can be leveraged for smoother compliance while preserving government control.

Chapter

08

Vertical Integration of renewable energy supply chains

Vertical integration of renewable energy supply chains is vital for strengthening India's long-term security and independence of energy transition

Renewable Energy Sectors and Vertical Integration

- India's projected solar module manufacturing capacity is expected to exceed 100 GW by 2026, indicating need for significant vertical integration efforts into solar cells, wafers and polysilicon
- Integration of turbine and its sub-components including towers, blades, nacelles, foundations, and grid interconnection equipment is necessary to optimize wind energy supply chains.
- Battery manufacturers need to integrate cell components such as the cathode materials, anode materials, separator, electrolyte along with cell production, module assembly and BMS systems to consolidate the supply chain.

Challenges and Opportunities

Scale and Cost

- Achieving economies of scale is crucial as it brings down the cost and increases the profit margin. The vertically integrated solar cell companies reported profit margins of INR 3.2/Wp in 2023.

Global Pricing Impact

- Market competitiveness is affected by global price trends, with some companies struggling when prices hit record lows.

Infrastructure Investment

- High capital expenditure challenges for new entrants, especially in upstream markets like solar wafers and battery cells.

Policy Framework and Market Dynamics

- DCR: Mandates preferential procurement of domestically produced components.
- Import Tariff Duties: Implementation of safeguard duty (SGD), anti-dumping duty (ADD), and basic customs duty (BCD) to reduce cost disparity between domestic and imported products.
- PLI Schemes: Financial support to increase integrated manufacturing capacity, strengthening the India's clean energy supply chain.
- High-Level Committee on Resilient Supply Chains: Recommendation to establish a committee consisting of representatives from various government departments to ensure well-coordinated policies.
- Green Open Access Rule: Facilitates access to clean energy for small industries and commercial consumers, supporting domestic manufacturing by allowing companies to charge a premium for low-carbon intensity.

Vertical integration is crucial for India to ensure energy security, reduce import reliance, and build a self-reliant renewable energy sector with a strong domestic manufacturing base.

It enables cost reduction, efficiency enhancement, and global competitiveness, while mitigating supply chain risks and fostering job creation and sustainable economic growth.

Source: EY Analysis based on industry interactions and desk research, DCR: Domestic Content Requirement; PLI: Production Linked Incentive

Solar PV value chain: Challenges and opportunities for Indian industry

Steps in Value Chain	Consumables	Process
Solar-grade polysilicon	Metallurgical-grade silicon	▪ Begins with the Siemens process, requires high temperature, energy consumption and low-cost electricity for viability.
Ingot pulling and Wafer slicing	Doping material, Diamond wire	▪ Polysilicon is transformed into an ingot for further processing. ▪ Involves slicing ingots into thin wafers. ▪ Most capital-intensive and energy-intensive step in solar manufacturing.
Cell manufacturing	Chemical precursors, metallisation paste (silver, aluminium)	▪ Wafers undergo chemical texturing and doping with boron or phosphorus. ▪ Coated with silver metal paste to enhance current collection.
Module assembly	Backsheet, encapsulant, ribbons, solar glass, aluminium frame and junction box	▪ Least capital-intensive stage in solar manufacturing. ▪ Involves assembling solar cells with components like copper ribbons, glass, EVA, and junction boxes, then laminating for waterproofing and adding aluminium frames for support. ▪ Major cost contributors include solar cells, EVA, and glass.
PV system installation	Inverter, combiner boxes, cabling, transformers and mounting structure	▪ Mounting systems, inverters, and cabling connect solar modules to the grid or storage. ▪ Includes site assessment, design, permits, installation, and grid connection. ▪ Involves electrical work for safe integration and compliance with regulations.

Challenges

- **High Import Dependence:** Significant reliance on imported solar components, particularly wafers, cells and manufacturing equipment, which can lead to supply chain vulnerabilities.
- **Technological Gaps:** Limited domestic capabilities in advanced stages like wafer and cell manufacturing.
- **High Capital Costs:** Energy-intensive processes and high initial investment for establishing manufacturing facilities.

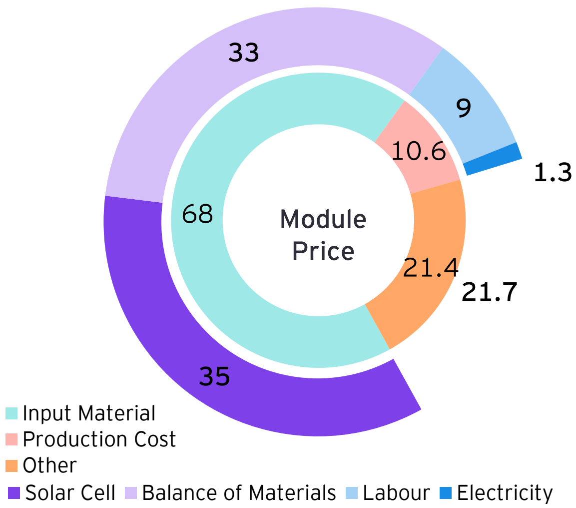
Opportunities and Advantages

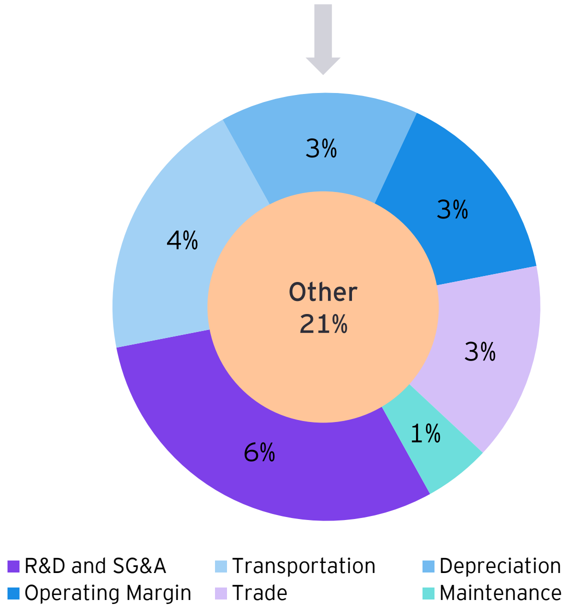
- **Strong Demand:** Growing domestic demand for renewable energy supports local manufacturing initiatives.
- **Comparative Advantages:** India holds potential strengths in producing certain components, such as junction boxes and EVA.
- **Government Incentives:** PLI schemes promote local manufacturing.
- **Skilled Workforce:** Availability of a technically skilled workforce can aid the growth of solar manufacturing.
- **Strategic Location:** Proximity to key markets in Asia and potential for export growth.
- Potential for growth in EVA and silver paste manufacturing

Source: EY Analysis, https://www.ceew.in/sites/default/files/clean-energy-supply-chains-to-build-manufacturing-competitiveness-in-renewable-energy-market.pdf

Policy landscape for vertical integration of solar PV supply chains

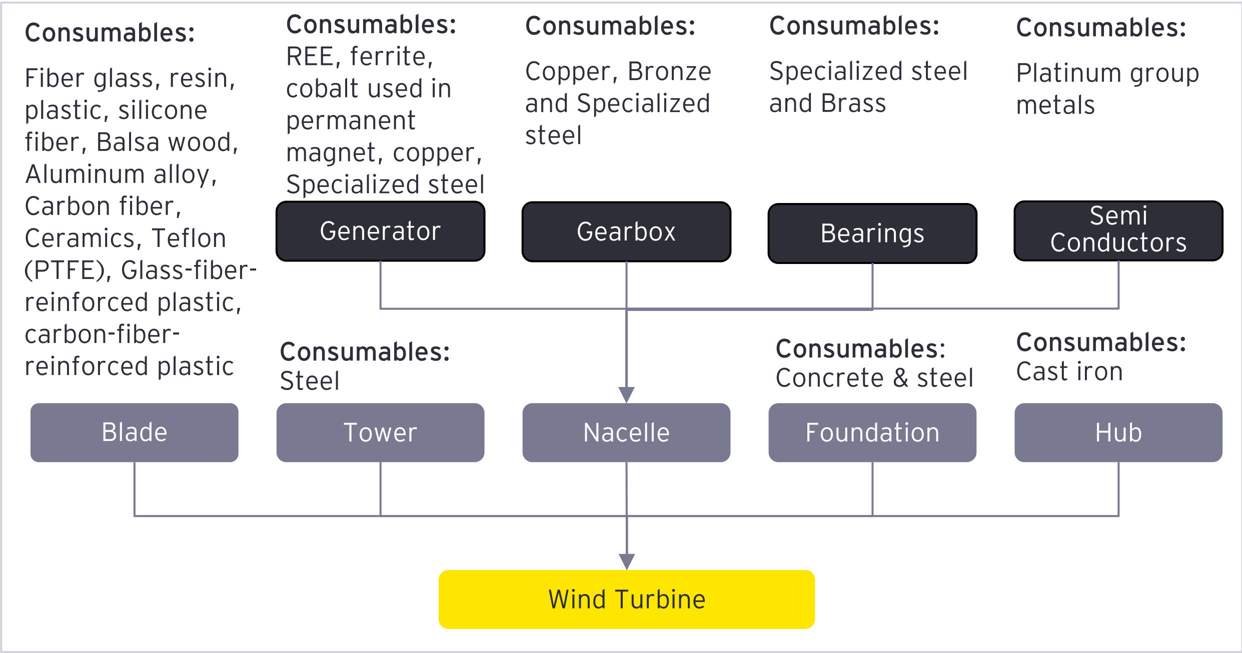
Policy Levers	Description	Financial incentive	Eligibility for public projects	Tariff measure	Non-tariff measure
DCR	Mandates the use of domestically produced solar modules and cells for utility-scale solar projects		✓		✓
M-SIPS	Capital subsidy of 20% for investments in SEZs and 25% in non-SEZs	✓			
PM-KUSUM Scheme	Subsidy of up to 30% or 50% of the total cost to install standalone solar pumps or to solarize existing grid-connected pumps	✓			
SGD 2018 - 2021	July 2018: 25% duty on solar cell and module imports, July 2019: 20% duty for six months, Further reduction: 15% duty for another six months			✓	
ALMM 2021	Only enlisted solar cell and module manufacturers with a specified minimum module efficiency could participate in government projects. Implemented for modules in April 2024, proposed to implement for cells from April 2026		✓		✓
PLI Scheme - Tranche I and II, 2021 and 2022	Tranche I - outlay of INR4,500 crore for high-efficiency solar PV modules Tranche II - outlay of INR19,500 crore for combinations of vertical integration of polysilicon, wafer, cell and module	✓			
BCD 2022	Imposed BCD of 40% imported modules and 25% on imported cells			✓	
ADD	US$403 - US$577 per tonne on imports from China of anodized aluminium frames for solar panels for 5 yrs from Sep 2024. Recommendation of duty of up to US$565 - US$677 per tonne on imports of solar glass from China and Vietnam			✓	

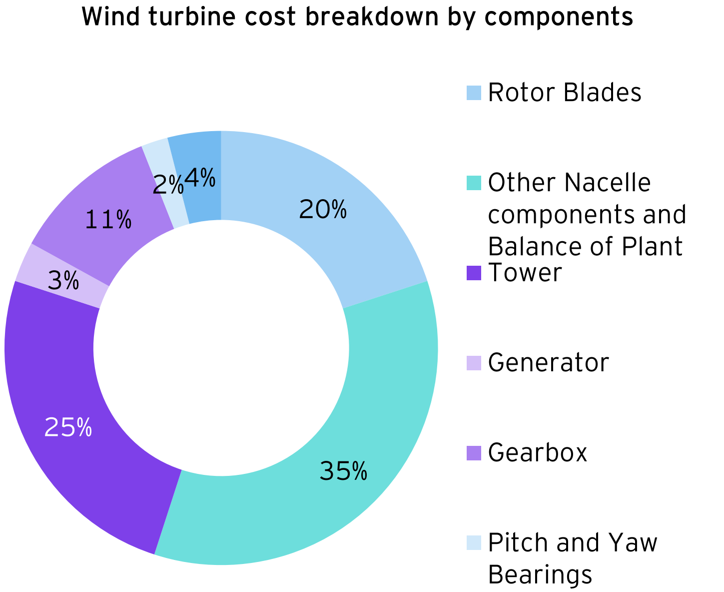




DCR - Domestic Content Requirement, M-SIPS - Modified Special Incentive Package Scheme, PM-KUSUM - Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyan, SGD - Safeguard Duty, ALMM - Approved List of Module Manufacturers, PLI - Production-Linked Incentive, BCD - Basic Customs Duty, ADD - Anti-Dumping Duty.
Source: EY Analysis, Economic assessment of local solar module assembly in a global market - ScienceDirect, https://www.ceew.in/sites/default/files/clean-energy-supply-chains-to-build-manufacturing-competitiveness-in-renewable-energy-market.pdf

Wind turbine supply chains and vertical integration opportunities

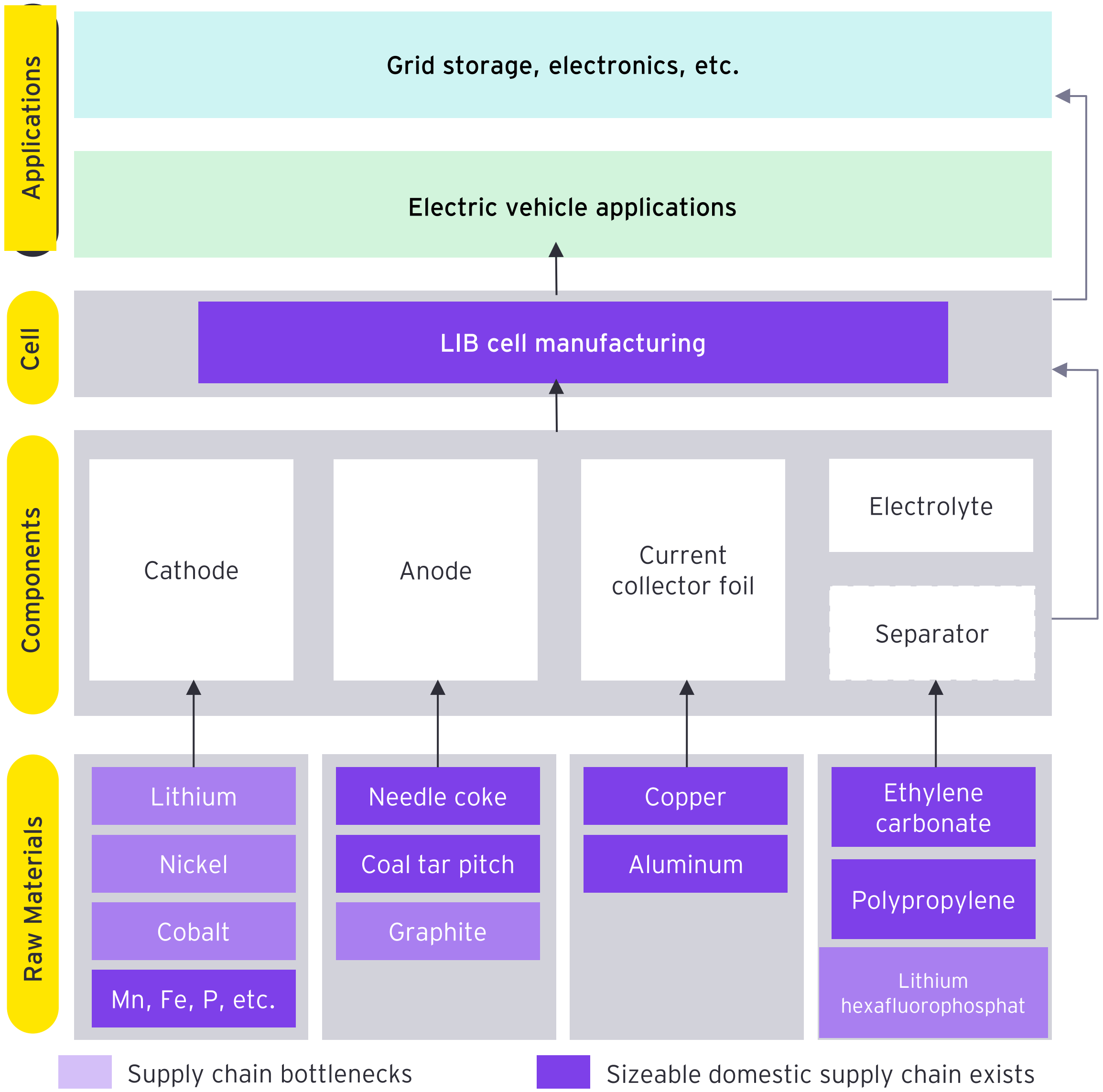




- **Blades:** Typically, wind turbines use three blades connected to a hub. Rotor sizes have expanded over time, from 30 m in 1998 to nearly 125 m in 2020.
- **Towers:** Structures made mainly of steel, though concrete or a steel-concrete hybrid is also used, supporting the turbine's height and stability.
- **Nacelles:** Enclosures housing the drivetrain and components like the generator, gearbox (for geared systems), yaw system, and power electronics. Nacelles are crucial for converting wind kinetic energy to mechanical energy and subsequently electricity. Key nacelle components include:
  - **Generators:** Utilized types include doubly fed induction generators (DFIGs), which are preferred for grid compatibility and cost efficiency, and permanent magnet synchronous generators (PMSGs), valued for higher efficiency and variable speed generation but needing cooling due to temperature sensitivity. DFIGs are predominant in India for their cost-effectiveness.
  - **Gearbox:** Transforms torque from the turbine blades into electrical power. High-speed gear systems lead the market with 68%, followed by direct drives at 22% and hybrid drives at 10%.
- **Foundation:** The foundation anchors the wind turbine to the ground, providing stability and strength to withstand wind forces. It is typically made of reinforced concrete.
- **Hub:** The hub connects the blades to the main shaft, enabling consistent rotation for energy capture. It is designed to endure high mechanical stress.

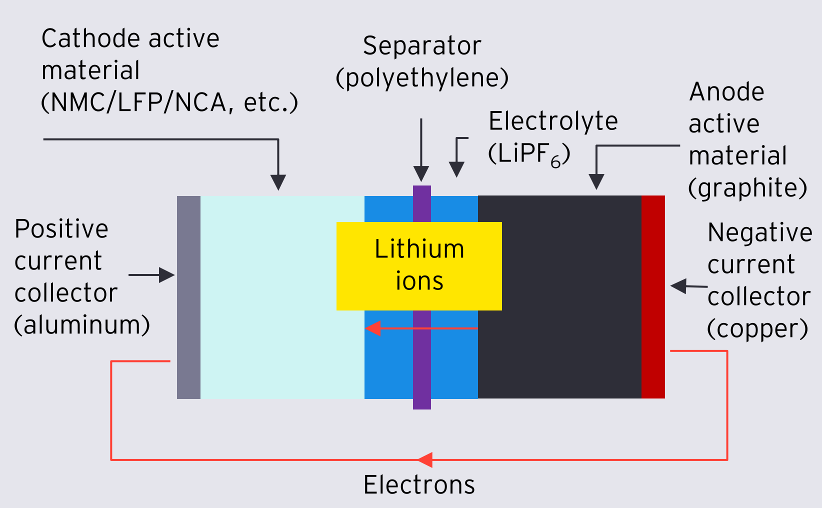
Source: EY Analysis, https://www.youtube.com/watch?v=Tp26k30o_z8&ab_channel=YedaCenter, https://www.ceew.in/sites/default/files/clean-energy-supply-chains-to-build-manufacturing-competitiveness-in-renewable-energy-market.pdf

Lithium-ion battery value chain: Challenges and opportunities for Indian industry



- Commercially available LIB cell cathode and anode production will need active materials, such as NMC, LFP, NCA, LCO, LMO, spherical graphite, for different types of electrode chemistry. Active material synthesis will require battery grade processed chemical precursors of critical mineral commodities (e.g., lithium carbonate, nickel and cobalt sulfates).
- Moreover, Li-ion cells use polyolefin as ion exchange separators. This material has excellent mechanical properties, decent chemical stability and low-cost. Polyolefins are a class of polymer derived from olefins (alkenes) through the polymerization of ethylene, which is sourced from petrochemicals. Polyolefins can be manufactured using polyethylene, polypropylene, or a combination of both materials in the form of laminates. The separator must be permeable with pore size ranging from 30 nm to 100 nm. The recommended porosity is 30% to 50%.

Components of a lithium-ion cell

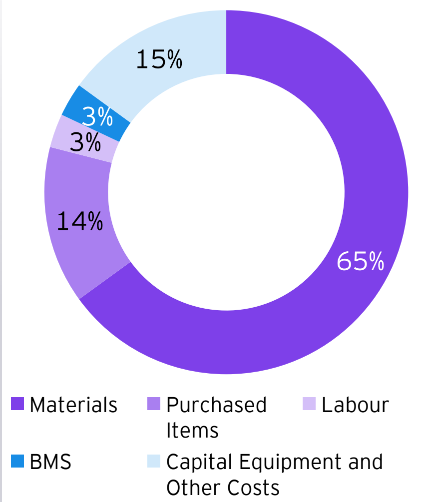


Source: EY Analysis, https://www.ceew.in/sites/default/files/clean-energy-supply-chains-to-build-manufacturing-competitiveness-in-renewable-energy-market.pdf, how-can-india-scale-lithium-ion-battery-manufacturing-sector-and-supply-chain.pdf

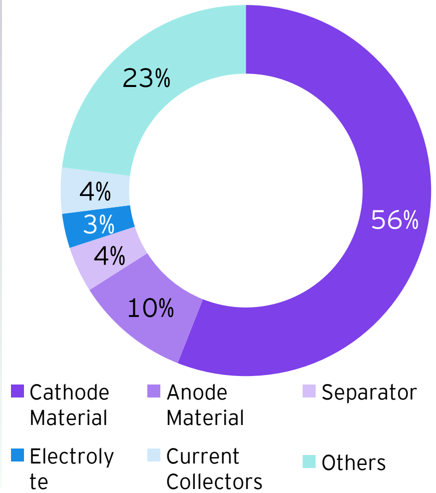
Policy landscape for vertical integration of Li-ion battery supply chains

Policy Levers	Description	Financial Incentive	Eligibility for public projects	Tariff measure	Non-tariff measure
Advanced Cell Chemistry (ACC) Production-Linked Incentive (PLI) Scheme, 2021	Establish a competitive ACC battery manufacturing setup in India with a **budgetary outlay of INR18,100 crore.** It targets achieving a manufacturing capacity of **50 GWh** of ACC batteries. It is designed to reduce import dependency and promote investment in domestic manufacturing with an expected **direct investment of around INR45,000 crore.** **Outcome:** The scheme has attracted significant interest, with major companies investing in battery cell manufacturing. It is expected to **save INR2,00,000 crore to INR2,50,000 crore on oil imports** due to increased EV adoption.	✓			✓
Viability Gap Funding (VGF) Scheme for stationary battery storage, 2023	Develop **4,000 MWh of BESS by 2030-31.** It provides financial support of up to **40% of the capital cost.** It is expected to lower the cost of BESS, making them more viable for distribution companies and consumers with an initial outlay of INR9,400 crore, including a budgetary support of INR3,760 crore. **Outcome:** The scheme aims to achieve a Levelized Cost of Storage of INR 5.50-6.60 per/kWh. This will enhance the viability of stored renewable energy for managing peak power demand.	✓	✓		
Basic customs duty (BCD)	Exemption of customs duty on the import of critical minerals like lithium, cobalt, and nickel, essential for battery manufacturing. This exemption reduces the input costs for manufacturing lithium-ion batteries, promoting domestic production and supporting the EV industry. **Outcome:** This exemption is expected to lower the production costs of batteries, making EVs more affordable and support in achieving 30% electrification of the vehicle fleet by 2030.			✓	

Cost share of steps involved in battery manufacturing process



Cost share of steps involved in battery manufacturing process



Source: EY Analysis, https://pib.gov.in/PressReleasePage.aspx?PRID=1955112, https://pib.gov.in/PressReleasePage.aspx?PRID=1809037, https://www.ceew.in/sites/default/files/clean-energy-supply-chains-to-build-manufacturing-competitiveness-in-renewable-energy-market.pdf, Budget 2024: Customs duty removed on import of lithium, boost for domestic battery production - India Today

Policy recommendations to strengthen vertical integration of renewable technology supply chains

Public private partnerships led by energy PSUs for critical upstream component manufacturing (e.g. polysilicon and critical minerals)

India's energy transition relies heavily on establishing robust domestic manufacturing in critical areas such as polysilicon and advanced chemistry battery cells. However, these sectors face significant barriers due to high capital expenditure (capex), long gestation periods, and technology risks. Public Sector Undertakings (PSUs) such as IOCL and BHEL, with their financial strength and long-term investment capability, can collaborate with private sector players to scale these technologies. Establish 50:50 joint ventures to pool resources, de-risk large-scale projects, and share operational expertise. Private players bring technological know-how and market agility, while PSUs ensure financial backing and policy alignment.

Access to competitive low carbon energy services for renewable energy technology manufacturing industry

Polysilicon and solar glass production are highly energy-intensive, making electricity costs a critical factor in competitiveness. Reducing electricity costs can enhance the viability of domestic manufacturing. Classify these industries as bulk power consumers, enabling them to negotiate lower tariffs directly with power producers. Preferential open access treatment allowing these industries to procure power directly from renewable energy sources (e.g., captive solar/wind plants) without wheeling and transmission charges.

Implement a mandatory 60% domestic content requirement and enhance cyber security measures for RLMM listed wind turbine generator models

This would ensure a significant portion of components are sourced locally, fostering local industry growth and job creation. NITI Aayog proposed a minimum 60% local sourcing requirement by value for wind turbine generators. NITI Aayog report also acknowledged that wind turbines' capability to exchange information through Power Plant Controllers (PPC) poses a significant cybersecurity threat. The PPC software is of critical importance and associated with risks used in the device which connects the wind farm directly to the national/state grid. The report emphasizes the potential risks associated with cyberattacks on wind turbines, including the compromise of grid operations, especially when managed remotely by owners stationed outside India. Certification and approval of PPC software and device/hardware from the OEMs of foreign origin especially from neighboring countries by CEA, MeitY and STQC.

Expand access to export credit incentives for solar and wind component OEMs

India has the potential to become a global export hub for solar and wind components, leveraging economies of scale and competitive labor costs. The US Inflation Reduction Act (IRA 2) and similar upcoming EU frameworks offer new export avenues. Fast-track export opportunities through tax rebates, export credit guarantees, and faster customs clearances. Align Indian products with international standards to ensure seamless integration into global supply chains. Negotiate favorable terms under Free Trade Agreements (FTAs) with key markets, ensuring tariff-free access for Indian OEMs.

By capitalizing on the anticipated 25-30% export opportunity, India could generate INR 50-60k crore annually (US$6-7 billion), boosting foreign exchange reserves and creating jobs.

Production Linked Incentives (PLI) for domestic manufacturing of wind turbine generator components including forging, gearbox, castings, bearings, wind sensors and other small electronic components

PLI can help improve competitiveness of domestic manufacturing for imported wind turbine generator components, enable domestic content requirement, improve supply chain resilience and promote local MSMEs. The scheme can be linked to modify the RLMM guidelines to enable a process for declaration of Local Content in the WTG and DCR in value terms.

Develop dedicated renewable energy technology manufacturing zones with world-class infrastructure and reliable green energy open access

Special Economic Zones (SEZs) focused on renewable energy could serve as catalysts for growth, akin to China's success in establishing manufacturing hubs for solar panels. The manufacturing of polysilicon and solar glass, which is energy-intensive, benefits significantly from lower electricity costs. For instance, China's subsidized electricity for renewable energy industries has helped reduce production costs, making its solar panels highly competitive in the global market. India can develop similar zones with low-cost, reliable power, fostering competitiveness and driving investment in domestic renewable energy technology manufacturing.

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Confederation of Indian Industry

The Confederation of Indian Industry (CII) works to create and sustain an environment conducive to the development of India, partnering Industry, Government and civil society, through advisory and consultative processes.

CII is a non-government, not-for-profit, industry-led and industry-managed organization, with around 9,000 members from the private as well as public sectors, including SMEs and MNCs, and

an indirect membership of over 365,000 enterprises from 294 national and regional sectoral industry bodies.

For more than 125 years, CII has been engaged in shaping India's development journey and works proactively on transforming Indian Industry's engagement in national development. CII charts change by working closely with Government on policy issues, interfacing with thought leaders, and enhancing efficiency, competitiveness, and business opportunities for industry through a range of specialized services and strategic global linkages. It also provides a platform for consensus-building and networking on key issues.

Through its dedicated Centres of Excellence and Industry competitiveness initiatives, promotion of innovation and technology adoption, and partnerships for sustainability, CII plays a transformative part in shaping the future of the nation. Extending its agenda beyond business, CII assists industry to identify and execute corporate citizenship programmes across diverse domains including affirmative action, livelihoods, diversity management, skill development, empowerment of women, and sustainable development, to name a few.

For 2024-25, CII has identified "Globally Competitive India: Partnerships for Sustainable and Inclusive Growth" as its Theme, prioritizing 5 key pillars. During the year, it would align its initiatives and activities to facilitate strategic actions for driving India's global competitiveness and growth through a robust and resilient Indian industry.

With 70 offices, including 12 Centres of Excellence, in India, and 8 overseas offices in Australia, Egypt, Germany, Indonesia, Singapore, UAE, UK, and USA, as well as institutional partnerships with about 300 counterpart organizations in almost 100 countries, CII serves as a reference point for Indian industry and the international business community.

Confederation of Indian Industry

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