
Emerging Investment Opportunities in India's Clean Energy Sector

Indian Companies Expand their Clean Energy Ambitions Buoyed by Government Policies and Reforms

Executive Summary

India's installed renewable energy capacity stands at 166.4 gigawatts (GW) (including large hydro) as of November 2022.¹ The sector has grown exponentially over the last decade. The Indian government's reforms, policies, and an overall pro-business environment in the country have facilitated the growth of the renewable energy sector. These measures, coupled with a constant deflation in key renewable energy technologies' costs, have helped India record an all-time low solar tariff of Rs1.99/kilowatt-hour (kWh) in 2020.² However, recently, several headwinds, such as the rising module prices and increased taxes and financing costs, have changed the sector leading to an increase in discovered tariffs to Rs2.9/kWh.³

The sector's growth has attracted investors from all quarters of the global financial markets. Over the years, domestic clean energy players have raised substantial amounts of capital, both debt and equity, to fund their expansion plans. On the debt side, Indian companies have extensively raised green and sustainability-linked bonds and loans. On the equity side, the sector has had increasing interest from mature long-term passive investors such as sovereign wealth funds (Abu Dhabi Investment Authority and Singapore's GIC) and pension funds (Canada Pension Plan Investment Board and Caisse de dépôt et placement du Québec (CDPQ)). With the exit of several early investors and many capital recycling opportunities available, the Indian renewable energy market has matured to attract global capital.

Government reforms over the past decade have improved business conditions for the clean energy sector in India. This has also helped create a diverse set of capital sources available for sector players, both domestic and offshore. Industry players are getting ready to ride the next wave of sectoral reforms to accelerate India's growth as a sustainable energy economy. These reforms include the General Network Access (GNA) regulations, green energy corridor scheme, Production Linked Incentive (PLI) schemes, state electricity distribution companies (DISCOMs)

¹ CEA. [Installed capacity Report](#). November 2022.

² Ministry of Power. [MOP Annual report 2020-21](#). February 2021.

³ Mercom India. [SJVN, Juniper Green, Tata Power, SAEL, Avaada Win MSEDCL's 500 MW Solar Auction](#). August 2022.

privatisation bids, ancillary regulations and the green hydrogen/green ammonia policy.

The success of these reforms hinges on the government's ability to weed out implementation bottlenecks, facilitate the availability of long-term competitive finance and ensure that the concerns of industry players are duly addressed. India's success in scaling up renewable energy should give confidence to industry players and potential investors in this context.

Key Trends Emerging in the Renewable Energy Sector

Along with developments in the generation, distribution, and transmission of renewable energy business models, value-added products and services such as Energy-as-a-Service and corporate decarbonisation solutions are evolving at a rapid pace. While Tata Power has rolled out a turnkey package of energy efficiency services, JSW Energy and ReNew Power are providing on-demand firm dispatchable power for their customers. Greenko, too, recently rolled out cloud energy storage solutions offering on-demand storage to its customers.

Corporate decarbonisation is another growing trend buoyed by increasing net-zero commitments by Indian companies. Corporate Power Purchase Agreements (CPPAs) are proving to be a win-win proposition for independent power producers (IPPs) and corporates. The CPPA market is yet to reach its full potential. The rectification of hurdles, such as delays in the approval of projects and withdrawal of waivers on various charges, will play a prominent role in fulfilling its promise.

For deep decarbonisation, industry players are exploring the many use cases of green hydrogen with several projects and partnerships in storage, mobility, industrial supply, and natural gas blending.

With a target of 25% share of the power exchanges by 2024, the short-term and merchant markets are also growing rapidly. Market-based reforms, along with the integration of the national grid and multiple projects underway to strengthen the interstate transmission system (ISTS), provide tailwinds for the sector's growth. This could lead to companies keeping merchant or un-tied renewable energy capacities to trade through the exchanges.

In the renewable energy generation market, by diversifying upstream into solar module manufacturing and downstream through acquiring state-owned distribution companies, value chain integration provides the much-needed cost control and opens up new revenue streams for the sector's companies. DISCOM privatisation has achieved impressive results in the past. Going forward, the larger DISCOMS

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should also be privatised, where industry players will find several opportunities for value creation.

Lastly, with an installed capacity of approximately 104GW of wind and solar to date, the Indian renewable energy sector is making strides to provide solutions for the intermittency of the two generation sources. In India, the complementarity of solar and wind resources provides an opportunity to hybridise the two technologies to minimise variability and optimally utilise the infrastructure, including land and transmission systems. To rectify this, the government has now released tenders for renewable energy auctions for round-the-clock and hybrid projects instead of plain solar or wind tenders.

Figure 1: Key Trends and Technologies Providing New Business Opportunities in the Renewable Energy Sector



Source: IEEFA and Invest India Analysis

Key New Technologies and Associated Business Models

In line with global developments, several new technologies and associated business models are taking shape in the country's clean energy market.

- **Battery Energy Storage Systems (BESS)**

India plans to integrate large-scale solar and wind energy into its grid by 2030. In this context, battery storage is a vital technology solution as it allows time to shift the dispatch of solar and wind power. With several recent advancements in battery technology and massive cost deflation projections, it is estimated that India will add 140-200GW of battery storage capacity, the largest for any country, by 2040.⁴ Several emerging projects at the state and central levels are signs of the development of this segment. The production-linked incentive (PLI) scheme for setting up domestic battery storage production capacities will also facilitate the segment's growth. A key deliverable to scale up BESS capacities in the country will be ensuring the availability of sufficient bidding pipelines and the timely signing of the required offtake agreements for completed bids. This will give long-term visibility and prove to be a source of confidence for industry players and investors.

- **Offshore Wind**

India has set an offshore wind power capacity target of 30GW by 2030. The sector may have witnessed a slowdown due to supply-chain and policy-related bottlenecks, but the Ministry of New and Renewable Energy's announcement of a 4GW tender for offshore wind power off the coasts of Tamil Nadu and Gujarat has reinvigorated the sector. Offshore wind potential in India is pegged at 195GW along the 7,600km coastline with an ability to provide utilisation factors of more than 50-55%. Thus, adding offshore wind to India's generation mix would potentially provide better round-the-clock clean power resources and add resource diversification benefits.

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- **Green Hydrogen**

Green hydrogen is a prime source of non-polluting energy and has the highest energy output by weight and volume. It is, thus, the fuel that will drive the green energy revolution in the coming years across many hard-to-abate sectors. The government has launched the National Green Hydrogen

⁴ IEA. [India Energy Outlook 2021](#).

Mission to fulfil this target. Indian power sector companies have supported the policy with several commitments to invest in this nascent technology and provide solutions for industrial clients. The government forecasts a production capacity of at least 5 million tonnes per annum (MTPA) with an associated renewable energy capacity addition of about 125GW in the country by 2030⁵. Several sectors, such as refining, fertilisers, steel, and cement, will be the major demand drivers. For a scale-up of green hydrogen technology in the country, de-risking of investments is required through policy support such as offtake assurances, production incentives, and availability of long-term competitive financing.

⁵ Press Information Bureau. [National Green Hydrogen Mission](#). January 2023.

Table of Contents

Executive Summary	1
India's Achievement – Context of the Changing Indian Market	7
Key Trends Emerging in the Indian Renewable Energy Sector	11
Key New Technologies and Associated Business Models	18
Summary	28
About the Authors	30

Table of Figures

Figure 1: Key Trends and Technologies Providing New Business Opportunities in the Renewable Energy Sector	3
Figure 2: Capacity Versus Cost of Solar Photovoltaic Technology in India.....	8
Figure 3: Renewable Energy Financing Landscape in India	9
Figure 4: Sustainable Finance Raised by Indian Companies.....	10
Figure 5: Open Access Capacity Installation Trajectory in India	13
Figure 6: Typical Demand Curve of DISCOMs in India	17
Figure 7: Value Streams of Utility-Scale Battery Storage Assets.....	19
Figure 8: Battery Storage Projects in India.....	21
Figure 9: Green Hydrogen Commitments by Indian Companies.....	25
Figure 10: Projected Hydrogen Demand by Sector in India.....	27

India's Achievement – Context of the Changing Indian Market

The share of renewable energy in the world's electricity production, given the acceleration towards a low-carbon world, has increased exponentially over the last few decades, buoyed by several tailwinds from policy measures and technological advancements. India has been a frontrunner, and its renewable energy capacity growth is among the highest in the world. In the past 7.5 years, renewable energy capacity (including large hydro) grew 1.97 times, while solar energy capacity increased nearly 18 times.⁶ To further demonstrate its commitment to sustainable development, India has set a target to achieve about 50% of its total installed power capacity from non-fossil fuel-based sources by 2030⁷ as part of its revised Nationally Determined Contributions (NDCs).

Doing Business in India

A large part of the installed renewable energy capacity in the country comes from the private sector. The Indian government's reforms and policies and an overall pro-business environment in the country have largely facilitated the private sector's growth.

The Indian government has long provided a helping hand in the renewable energy sector. The accelerated depreciation scheme, long-term power purchase agreements, waiver of interstate transmission charges, generation-based incentives and other tax incentives are among the many policy actions undertaken by the government to increase the renewable energy's share in India's energy mix. This has led to cost and risk reduction for businesses and ensured constant cashflows to the asset owners, promoting growth for the nascent solar industry and helping establish it in the country. India is now facilitating indigenous development of the entire supply chain to ensure the inception and operation of new businesses. The production-linked incentive (PLI) scheme rolled out recently in the solar module manufacturing sector worth Rs195 billion (US\$2.35 billion) has the potential to make India a major producer of modules

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⁶ Press Information Bureau. [Press release](#). December 2021.

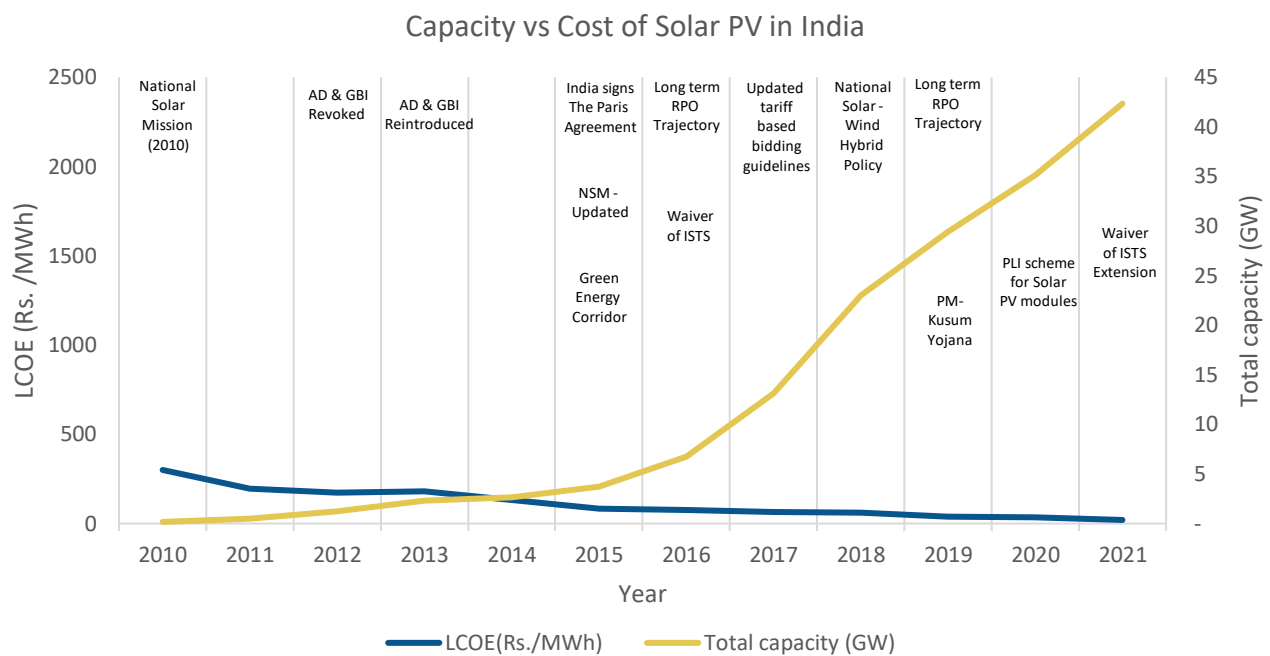
⁷ Government of India. [India's Updated First Nationally Determined Contribution Under Paris Agreement](#). August 2022.

globally.⁸ These developments reflect in India's levelized cost of electricity (LCOE) being one of the lowest globally, making the country's renewable sector the most investable worldwide.

Capacity Addition and Decreasing Costs

India's installed renewable energy capacity stands at 166.4 gigawatts (GW) (including large hydro) as of November 2022⁹, or about 40% of the country's total installed capacity. This is a far cry from a few megawatts (MW) of installed capacity at the start of the last decade. Besides policy support, technology has played its part in facilitating this growth. The LCOE for solar photovoltaic (PV) in India has declined sharply by 15 times since 2010 as global solar modules' costs plummeted. Onshore wind has followed a similar trajectory. This constant deflation in LCOE helped India record an all-time low solar tariff of Rs1.99/kilowatt-hour (kWh) in 2020.

Figure 2: Capacity Versus Cost of Solar Photovoltaic Technology in India



Source: Invest India Analysis

Recently, several headwinds, such as rising module prices and financing costs, have hit the sector leading to discovered tariffs rising to Rs2.9/kWh.

⁸ Ministry of New and Renewable Energy. [PLI scheme \(Tranche II\) under "National programme for High efficiency solar PV modules"](#). September 2022.

⁹ CEA. [Installed capacity Report](#). November 2022.

Financing and Investments Trends

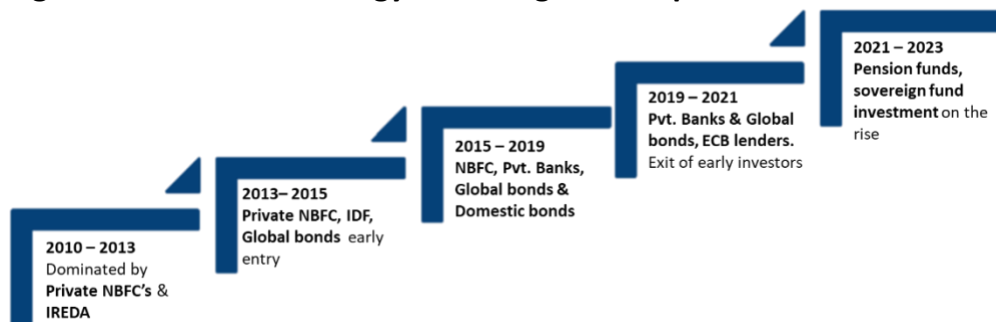
India aims to increase its solar capacity to 280GW and wind capacity to 140GW by 2030. According to BloombergNEF (BNEF), this requires a cumulative investment of US\$155 billion for solar and US\$86 billion for wind between 2020 and 2029.¹⁰

Domestic clean energy companies have raised substantial capital in the past to fund their renewable energy expansion plans. A large amount of domestic and global capital, both in the form of debt and equity, has come into the Indian renewable energy infrastructure.

Debt, the main enabler for renewable energy projects, has come through various channels as the industry matured and financiers from all quarters gained a better understanding of its risk-return dynamics.

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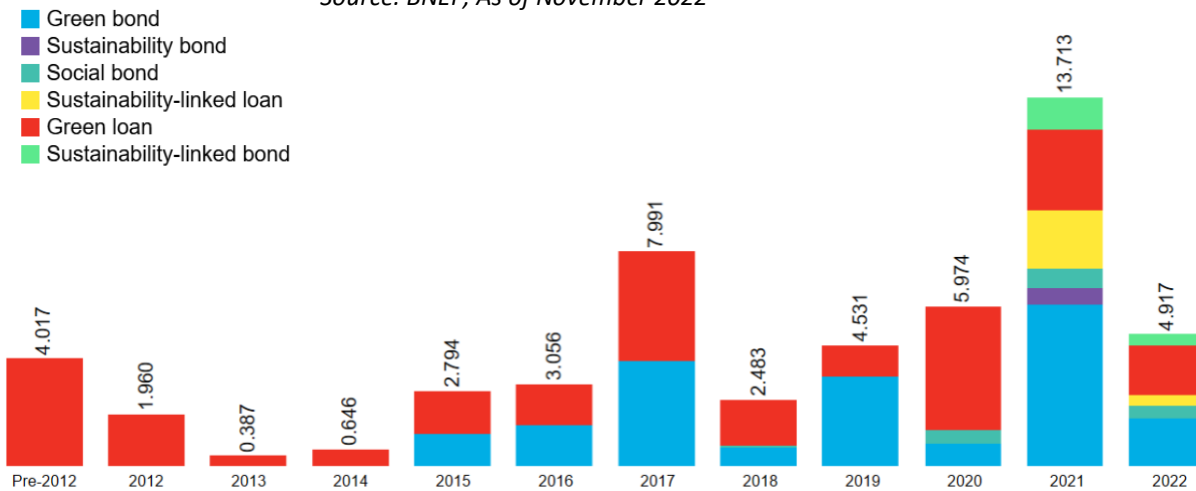
Figure 3: Renewable Energy Financing Landscape in India



Source: IEEFA Analysis

Lately, the global sustainable finance markets have been a major source of debt capital for domestic players. Indian clean energy companies have used two significant instruments: green and sustainability-linked bonds and loans, primarily for renewable energy generation projects.

¹⁰ BNEF. *Financing India's 2030 Renewable ambitions*. June 2022.

Figure 4: Sustainable Finance Raised by Indian Companies*Source: BNEF; As of November 2022*

On the equity side, the sector has garnered increasing interest from mature long-term passive investors, primarily due to the low cash flow volatility underpinned by long-term power purchase agreements (PPAs). Some of the largest sovereign wealth funds (Abu Dhabi Investment Authority and Singapore's GIC) and pension funds (Canada Pension Plan Investment Board and Caisse de dépôt et placement du Québec (CDPQ)) have already acquired stakes in Indian renewable energy companies.¹¹

Another sign of the Indian renewable energy market maturing is the exit of early investors – the recent deal between JSW Energy and Mytrah Energy for the sale of the latter's portfolio housing 1.7GW renewable energy assets is a case in point.¹² Domestic independent power producers (IPPs) have also received interest from global oil & gas majors, such as Total, Shell and BP, who have invested in operational assets or acquired entire companies operating in the sector. Lately, the infrastructure investment trust (InvIT) structure has been picking up pace in the sector to recycle capital in operational projects. The presence of several hands in the sector to recycle capital and redeploy in new assets speaks to its maturity.

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Improving business conditions, a facilitative and forward-looking policy regime, diverse capital sources and the industry's maturity have helped the Indian

¹¹ IEEFA. [Capital flows underpinning India's energy transformation](#). February 2021.

¹² The Economic Times. [JSW Energy unit to buy renewable assets from Mytrah Energy for Rs 10,530 crore](#). August 2022.

renewable energy sector emerge as one the most favoured investment destinations over the last decade. Industry players are now getting ready to ride the next set of sectoral reforms to accelerate India's transition to a more resilient and sustainable energy economy. The next sections will delve into some key new trends shaping the market and the several investment opportunities it will spawn.

Key Trends Emerging in the Indian Renewable Energy Sector

India has a vibrant and growing energy sector, with many participants across the value chain. Having already launched Indian renewable infrastructure sector capacities, domestic and international institutions are now gearing up for the next wave of sectoral reforms.

Value-Added Product Offerings

Several conventional utilities and renewable IPPs are diversifying their product offerings from commoditised electricity generation, distribution and transmission to providing value-added product offerings, which fetch higher margins and offer growth prospects in a fast-evolving energy economy. This is giving rise to an Energy-as-a-Service business model.

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Tata Power, one of the top private utilities in India, leads on this front with a dedicated energy service company (ESCO) business that helps commercial and industrial (C&I) clients embrace digitalisation and monitor energy savings. The company offers a turnkey package of energy efficiency services, including energy audit and demand-side management. Tata Power also provides Internet of Things-based (IoT) home automation solutions for its retail customers.

Another leading utility, JSW Energy, says it is migrating from a power to a services and products company supplying electricity for desired time blocks through the integration of storage technology. It also plans to provide products such as hydrogen, ammonia, or other chemical derivatives to industries to help them decarbonise their operations through an asset-light model. The following section elaborates more on corporate decarbonisation. Another leading IPP, ReNew Power, provides energy management services for public utilities and C&I customers.

Adani Transmission, India's top private transmission and distribution operator, has rolled out green power and a tariff option through its distribution arm in Mumbai to help consumers reduce their carbon footprint.

Lastly, Greenko has recently rolled out cloud energy storage solutions. The company says it is building the world's largest energy storage cloud platform.¹³ Greenko plans to offer energy storage solutions on demand to state electricity distribution companies (DISCOMs) and C&I customers through this service. This will provide the customer with firm and dispatchable clean energy solutions without incurring capital expenditure (CAPEX) on storage.

The Energy-as-a-service (EaaS) model has been evolving rapidly in several markets globally and transforming the very definition of power generation companies. As the market for value-added product offerings expands, so do the investment opportunities available for investors looking to invest in companies with higher margins and fewer commodity market-linked revenue lines.

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Corporate Decarbonisation

Indian corporates are increasingly committing to emission reduction targets, with eight of the country's top ten companies by market capitalisation setting net-zero targets to be achieved between 2030 and 2050. Further, several Indian companies have pledged to reduce greenhouse gas (GHG) emissions under the Science-Based Target Initiative (SBTi)—a global alliance enabling businesses to establish their own climate pledges. There are 79 companies in India currently committed to science-based targets.¹⁴

These pledges have nudged corporates to decarbonise their operations by initially targeting their electricity use. Several C&I customers are off-taking green energy through open access from renewable energy IPPs. In the first nine months of 2022, India added about 1.9GW of open access solar capacities surpassing 1.2GW of additions in the whole of 2021.¹⁵

Corporate Power Purchase Agreements

Corporate Power Purchase Agreements (CPPAs) are a win-win proposition for IPPs and corporates. The average price to purchase power from the grid for C&I

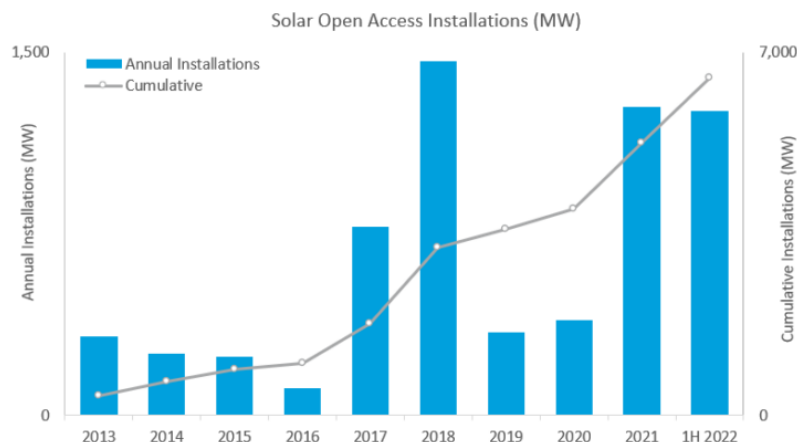
¹³ Greenko. [Greenko IR FY 2020-21](#).

¹⁴ Science Based Targets. [How can the Indian corporate sector drive net-zero?](#) April 2022.

¹⁵ Economic Times. [India's open access solar capacity grows 91% to 596 MW in July-September, December 2022.](#)

customers is in the range of Rs8-10/kWh in India¹⁶, while the cost of off-taking renewable energy from IPPs is up to 50% lesser (for captive and group captive projects). This incentivises C&Is to sign CPPA agreements to lower energy costs and fulfil decarbonisation pledges. For IPPs, CPPAs provide higher tariffs & returns than "plain vanilla" bids where competition is more intense.

Figure 5: Open Access Capacity Installation Trajectory in India



Source: MERCOM India

The Indian government has been implementing several policy reforms to reinvigorate the segment's growth. In the past, the CPPA market has faced several issues, such as delayed approval of projects, withdrawal of waivers on various charges for open access projects and increased penalties for power schedule deviation. The Green Open Access policy, issued in June 2022, has the potential to reform the CPPA market landscape completely by weeding out these problems.

The CPPA market is growing in India through the captive and group captive model. In a captive capex model, IPPs sell to off-taking companies' stakes (minimum 26%) in special purpose vehicles (SPVs) holding such open access capacities. In September 2022, Amazon India entered into a contract with IPPs such as ReNew Power and Amp Energy to co-invest in three solar farms, one of the largest solar CPPA deals in the country.¹⁷ It recently sealed another CPPA deal with Vibrant energy to set up a 300MW capacity.¹⁸ The co-investment model is an opportunity for investors, too, to gain exposure to individual projects rather than entire companies by providing equity capital.

¹⁶ ReNew Power. Renew Power Analyst Presentation Q1 2023.

¹⁷ Saur Energy. [Amazon Scales Up Green Ambitions In India, 3 Solar Plants of 420 MW Planned In Rajasthan](#). September 2022.

¹⁸ IEEFA. [Amazon signs deals with Vibrant Energy for two wind-solar hybrid projects in India](#). December 2022.

Solutions for Hard-to-Abate Sectors

According to the World Economic Forum (WEF), heavy industry and heavy-duty transport are responsible for nearly a third of global carbon dioxide (CO₂) emissions. This share will double by mid-century in the absence of concerted action.¹⁹ In India, the industrial sector, which includes iron & steel, cement, petrochemicals, aluminium, and fertilisers, is second only to the power sector in terms of energy consumption. Many of these emissions are hard to abate as mitigating these emissions requires a fundamental shift in raw materials and chemical processes.

For deep decarbonisation, green hydrogen holds great promise for such hard-to-abate sectors. Green hydrogen also finds end uses in the transport sector through fuel cells or as green ammonia in the shipping industry.

The dominant route to diversify into this business has been through partnering with global companies with expertise in green hydrogen technology. Renewable energy companies focus on large-scale clean power generation. Industry players are taking up several projects and partnerships, such as storage, mobility, industrial supply and blending with natural gas, to capitalise on the technology's promises and opportunities. Most of these projects are in a pilot or demonstration stage at the moment due to the nascent stage of the technology globally, but they will pave the way for taking up commercial-scale projects in the future.

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Deep decarbonisation calls for substantial investment in the research and development (R&D) efforts of IPPs, requiring investment outlays, which have to be funded by equity capital. Several strategic alliances are underway in the Indian markets where companies with technological prowess are entering into partnerships with IPPs to develop decarbonisation solutions. Adani and Greenko's partnerships with Snam²⁰, JSW's agreement with Australian Fortescue Future Industries²¹ and ReNew Power's partnership with L&T²² are prominent examples.

¹⁹ Weforum. [Five steps to get industries on track for net zero](#). July 2022.

²⁰ Mint. [Italy's Snam ties up with Adani Group and Greenko](#). November 2020.

²¹ Financial Express. [JSW Energy partners Fortescue Future Industries](#). July 2021.

²² Larsen&Tubro. [L&T and ReNew announce partnership](#). December 2021.

These efforts present promising opportunities for global strategic investors to collaborate with and invest in local players.

Short-Term Markets and Merchant Capacities

Indian Energy Exchange (IEX), India's largest power exchange, has witnessed increasing volumes and high prices for green energy traded through green term-ahead and day-ahead markets (GTAM and GDAM). The draft National Electricity Policy 2021 envisions a 25% share of the power exchanges by 2024, implying a fourfold growth from the present 6% share.

Several market-based reforms, such as the Central Electricity Regulatory Commission's (CERC) ancillary services regulations 2022, implementation of the national open access registry (NOAR) and the general network access (GNA) regulations will contribute towards the growth of power markets in the country.²³ Further, the integration of the national grid and several projects underway to strengthen the interstate transmission system (ISTS) encourages renewable energy-rich states to develop capacity beyond their obligations and offer it for sale pan-India through exchanges. This will lead companies to keep merchant or un-tied renewable energy capacities to trade through the exchanges. There are currently no pure-play merchant capacities in the renewable energy segment in the country. But the scenario may change, buoyed by the several tailwinds listed above.

Payment disruptions and regulatory price caps, in the recent past, have posed issues for power exchanges in the country. For instance, price caps have led to reduced trading on exchanges.²⁴ As the reforms kick in, volume increases and liquidity improves, regulatory interventions on the operations of exchanges should also subside for the country to achieve its target of a 25% share of power markets.

Backward Integration

The power sector's competitive strength lies in its cost structure. From capital expenditure (important for renewable energy companies with front-loaded costs) to operation and maintenance (O&M) and finance costs, a company that can achieve efficiencies will be more competitive. Several Indian renewable energy companies participated in and oversubscribed to the government's PLI scheme for solar module manufacturing rolled out last year to diversify upstream in the solar value chain. The tender saw bids for 54.8GW against the requirement for 10GW, with participation from Adani

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²³ IEX. IEX Annual Report FY 2021-2022.

²⁴ Business Standard. [Power exchanges clock growth despite pending discom dues worth Rs 1.32 trn.](#) September 2022.

Infrastructure (affiliated to Adani Green Energy), ReNew Solar, Tata Power Solar, Avaada Ventures, Acme Eco Clean Energies, among others.²⁵

DISCOM Privatisation

Several utilities, such as Tata Power, Adani Transmission and Torrent Power, have previously acquired state-owned and privately-owned DISCOMs, integrating the last link of the power sector value chain. Adani Transmission's Mumbai distribution business recorded lower distribution losses and better collections after its acquisition from Reliance Infrastructure in 2018.²⁶ Tata Power has achieved impressive results in Delhi DISCOM over the past decade, where aggregate technical and commercial (AT&C) losses have decreased drastically.²⁷ It expects similar results from its recently acquired Odisha DISCOM.

The government has mulled over the idea of allowing the privatisation of state-owned DISCOMs,²⁸ which have proved to be a bottleneck in the power value chain and have faced financial issues in the past.²⁹ Such a move will invite interest from private players, which promises enormous potential for efficiency gains in the distribution business.

Expansion into module manufacturing and DISCOM privatisation are plays to integrate across the value chain. Besides providing a strong hold on costs, these also open up new revenue lines for players. While module manufacturing has natural tailwinds from the government's push for 'Make in India,' DISCOM privatisation has growth triggers from value unlocking (through efficiency gains), increasing per capita power consumption and electrification of everything theme playing out currently. Being capital intensive, these corporate plans will look for new investor capital.

Hybrid Renewable Energy Projects

India has installed approximately 104GW of wind and solar capacity, about 25% of the total installed capacity as of November 2022.³⁰ Solar and wind power being variable, pose certain challenges to grid security and stability. These include variability in nature, output constrained to specific hours of the day and lower grid utilisation due to generation variability.

These challenges create issues in matching peak power demand with renewable output, for instance, the unavailability of solar power in the evening, and raise transmission costs. A typical demand curve of DISCOMs can be seen below.

²⁵ IREDA. [MNRE - Bucket-Share of Beneficiaries and Waiting List](#).

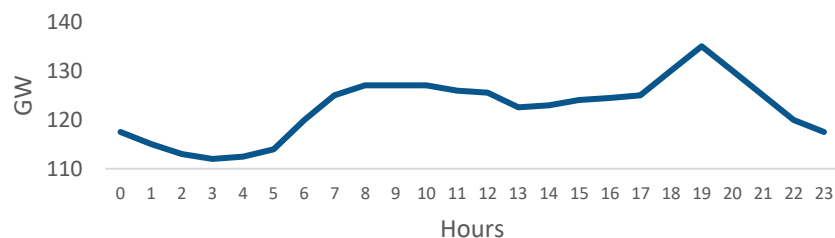
²⁶ Adani Transmission. [Adani Transmission Annual Report 2021](#).

²⁷ Tata Power. [Tata Power Delhi Distribution Transforming Power Distribution in Delhi](#).

²⁸ ORF. [Electricity \(Amendment\) Bill 2022: Getting the regulatory incentives right](#). August 2022.

²⁹ Business Standard. [Discoms' outstanding dues towards gencos to be eliminated by 2026: RK Singh](#). September 2022.

³⁰ CEA. [Installed Capacity Report](#). November 2022.

Figure 6: Typical Demand Curve of DISCOMs in India

Source: GWEC - Invest India Analysis

In India, solar and wind resources are complementary and hybridising these two technologies would help minimise variability and result in the optimal utilisation of infrastructure, including land and transmission systems.

A hybrid system can combine wind and solar with an additional resource of generation or storage. It is observed that solar output is maximum between 11AM and 3PM, while wind output is highest during late evenings and early mornings. Power demand, as observed, peaks in the hours of 6-9PM, which wind and solar cannot fulfil.

This is where a combined hybrid system can produce round-the-clock clean energy in response to varying demand levels throughout the day. Storage can take many forms, such as batteries and pumped hydro systems (PHS). The overall output of the hybrid system can thus be matched against a required load hourly. In this way, it can provide both baseload and flexible power.

The Ministry of New and Renewable Energy (MNRE) adopted the National Wind-Solar Hybrid Policy on 14 May 2018.³¹ The policy's objective is to provide a framework for promoting large grid-connected wind-solar PV hybrid systems for efficiently utilising transmission infrastructure and land. It also aims to reduce renewable power generation variability and achieve better grid stability.

The policy seeks to promote new hybrid projects and the hybridisation of existing wind/solar projects. Current wind/solar projects can be hybridised with a higher transmission capacity than the sanctioned transmission capacity, subject to margin availability in the existing transmission capacity.

Several leading renewable energy companies are now setting up hybrid renewable energy projects, leveraging their experience in setting up standalone solar/wind projects.

³¹ MNRE. [National Wind-Solar Hybrid Policy](#). May 2018.

Hybrid systems are now cost-competitive, driven by reduced battery storage costs and solar energy. An optimal combination of solar, wind and storage can deliver stable round-the-clock power at costs comparable to several past plain vanilla solar and wind tariffs. The government is now releasing tenders for renewable energy auctions for round-the-clock and hybrid projects instead of plain solar or wind tenders. In May 2022, Tata Power, Amp Energy, NTPC and SJVN were winners in the Solar Energy Corporation of India's (SECI) 1.2GW Wind-Solar Hybrid Auction, where the discovered price was Rs2.53/kWh.³²

Hybrid systems are now cost-competitive, driven by reduced battery storage costs and solar energy.

In the following section, we discuss the key new technologies and associated business models taking shape in the country's clean energy market.

Key New Technologies and Associated Business Models

Globally, energy markets are transforming as energy transition efforts gain momentum. Several new technologies are being touted as integral to the transition journey. While technologies centred around offshore wind have been around for a longer time and have thus achieved commercial viability, others, such as green hydrogen, are still in a nascent stage. Businesses and government leaders will need to make a concerted effort to secure the potential benefits of these technologies and aid their commercialisation.

These technologies are fast gaining ground in the country. Initial government efforts are aiding corporate development efforts.

Battery Energy Storage Systems (BESS)

As India plans to integrate large-scale solar and wind energy on its grid by 2030, battery storage will be a vital technology solution as it allows time to shift the dispatch of solar and wind power. Solar generation peaks during the afternoon when the grid demand is lower. Batteries would help store cheap solar when it is available in excess and supply power to the grid during peak demand hours, creating a valuable arbitrage opportunity if a time-of-day (ToD) pricing structure evolves.






Like solar and wind generation technology, battery storage technology has also made massive advancements. The cost of standalone Lithium-ion battery systems

³² Mercom India. [Tata Power, Amp Energy, NTPC & SJVN Winners in SECI's 1.2 GW Wind-Solar Hybrid Auction](#). May 2022.

globally has fallen from US\$1,220/kWh in 2010 to US\$151/kWh in 2022.³³ BNEF projects a further reduction in the cost to US\$59/kWh by 2030.³⁴ However, in the absence of a fully developed value chain for batteries in India, the cost deflation curve could be slightly flatter compared to already developed markets in the U.S., Europe, Australia and China.

IEA's India Energy Outlook 2021 predicts that India could have 140-200GW battery storage capacity, the largest for any country, by 2040.³⁵ India's draft national electricity plan (NEP) has also underlined the importance of battery storage in the overall energy mix, with projections of 51.5GW of BESS installations by 2031-32.³⁶

Figure 7: Value Streams of Utility-Scale Battery Storage Assets

Energy & Capacity	Ancillary Services	Transmission & Distribution	Inertia	Black Start
 Arbitrage: Charging the battery when energy prices are low and discharging during more expensive peak hours. Firm capacity: peak shaving and capacity adequacy.	 Grid management services – frequency and voltage regulation. Ramping services: rapidly charge or discharge in a fraction of a second to manage grid imbalances.	 Act as virtual transmission and distribution systems. Defer the need for expensive transmission and distribution network upgrades.	 Provide synthetic inertia for stability in the grid as the large thermal power plants with spinning machines will phase out.	 After a grid-failure, large conventional generators need a source of electricity to start-up, this is called a Black Start. BESS can replace traditionally used diesel generators to provide these services.

Source: IEEFA

Besides allowing time shifting, BESS assets have several other uses across the power value chain. These uses provide several value-stacking opportunities to developers. The provision of ancillary services is fast becoming one of the dominant uses of BESS globally. Increased frequency and voltage variability on the grid requires supporting services, broadly defined as Frequency Control and Ancillary Services (FCAS). These services mainly support the grid operation in maintaining its power quality, reliability and security. Achieving effective frequency control requires some form of capacity reserve. Energy storage systems, such as utility-scale batteries, can be important grid tools for frequency control operations.

Besides allowing time shifting, BESS assets have several other uses across the power value chain.

³³ BNEF. 2022 Lithium-Ion Battery Price Survey: First Price Rise. December 2022.

³⁴ BNEF. 2021 Lithium-Ion Battery Price Survey. November 2021.

³⁵ IEA. India Energy Outlook 2021.

³⁶ CEA. NATIONAL ELECTRICITY PLAN. September 2022.

In January 2022, CERC finalised new regulations for ancillary services.³⁷ As opposed to the previous mechanism for frequency response services, the new regulations aim to procure ancillary services through the open market mechanism to make it more cost-competitive. Also, it paves the way for storage assets more suitable for fast frequency response than coal-fired power plants.

CERC's new regulation has recognised energy storage and demand response, which are digitally controllable, as dispatchable energy and power resources that can respond rapidly and accurately to maintain grid frequency within close boundaries of 50Hz.

Also, interstate transmission charges have now been waived for battery storage and pumped hydro systems commissioned until June 2025, in addition to solar and wind assets.³⁸ This will allow storage systems to operate viably to support interstate grid networks.

Currently, BESS assets are predominantly deployed for utility-scale renewable energy projects, with limited traction in the rooftop solar segment. Even for utility-scale projects, the focus of developers is now on providing round-the-clock and hybrid solutions rather than engaging fiercely in competitive tariff regimes.

The market for storage assets in India is going to grow exponentially going forward. There are several value streams attached to a single BESS asset. As the market for these assets develops, technology matures, and financing improves, there will be ample investing opportunities. Regulation needs to evolve further for BESS assets to exploit their full potential through value-stacking opportunities. The upcoming policy on energy storage systems needs to address this.³⁹

The market for storage assets in India is going to grow exponentially going forward.

Momentum in Battery Development

Battery storage projects in India are rapidly evolving. The increasing number of state and central-level projects have evinced interest from several IPPs.

³⁷ CERC. [Central Electricity Regulatory Commission \(Ancillary Services\) Regulations, 2022 — Statement of Objects & Reasons \(SOR\) Thereof.](#)

³⁸ Ministry of Power India. [Waiver of inter-state transmission charges on transmission of the electricity generated from solar and wind sources of energy Amendment Thereof.](#) 21 June 2021.

³⁹ Mint. [The big plans cooking for clean energy storage.](#) February 2022.

Figure 8: Battery Storage Projects in India

Projects	Storage capacity	Proponent	Status	Functions	Cost/Tariff
Tata Power Distribution Corp-grid scale battery	10MW/10MWh	Tata Power, AES and Mitsubishi	Operational	Grid stabilisation, peak load management for a network of 2 million customers	
City of Leh big battery	50MW/50MWh	Tata Power	Construction		
SECI RE plus storage for peak supply	300MW	Renew Power	Construction	Peak time power supply	Rs6.85/kWh
SECI standalone battery storage project	500MW/1000MWh	JSW Energy	Awarded	60% capacity contracted with SECI and 40% capacity to be merchant	Rs1.08mil/MW/month
NTPC standalone battery storage project	250MW/500MWh		Announced	Meet NTPC's round the clock renewable energy needs with a wind solar profile	
NTPC standalone battery storage project	1000MWh		Announced		
Gujarat RE plus storage for peak supply	250MWh		Announced	Peak time power supply	

Source: Media reports, company disclosures, IEEFA analysis

Renewable Energy Plus Storage Tender

In January 2020, India held its first renewable energy plus storage auction of 1.2GW capacity with a differentiated tariff for peak and off-peak supply. It contracted for 25 years to underpin bankability. Greenko and ReNew Power won 900MW and 300MW capacity at an off-peak tariff of Rs2.88/kWh (US\$40/MWh).⁴⁰ The peak-time power supply tariff quoted was Rs6.12/kWh (US\$86/MWh) and Rs6.85/kWh (US\$96/MWh) by Greenko and ReNew Power, respectively.⁴¹ ReNew Power joined hands with one of the top battery storage developers—Fluence—to commission India's largest grid-scale battery in Karnataka.⁴²

Gujarat's State-owned power distribution company Gujarat Urja Vikas Nigam (GUVNL) rolled out a similar tender to procure 500MW of hybrid renewables capacity combined with 250MWh of energy storage capacity. The storage capacity seeks to serve six hours of peak demand during the morning and evening.⁴³

⁴⁰ Mercom India. [Greenko, ReNew Win SECI's 1.2 GW Solar, Wind Auction with Storage for Peak Power Supply](#). 31 January 2020.

⁴¹ Mercom India. [Greenko, ReNew Win SECI's 1.2 GW Solar, Wind Auction with Storage for Peak Power Supply](#). 31 January 2020.

⁴² Renew Power. [Fluence and ReNew to set up a JV to boost energy storage sector in India](#).

⁴³ Mercom India. [RfS to Buy Power from Renewable Projects with Energy Storage](#). 15 June 2022.

Standalone Battery Storage Tenders

India's state-owned entities have now also become responsible for facilitating grid-scale battery storage development. In the last couple of months, SECI and NTPC have rolled out tenders for developing 2,000MWh⁴⁴ and 1,000MWh⁴⁵ of battery storage capacity, respectively. JSW Energy recently won SECI's 1 gigawatt-hour (GWh) standalone BESS tender by quoting an Rs1.08 million (US\$13,566)/MW/Month tariff.⁴⁶ SECI and NTPC have built strong track records as credible counterparties by enabling renewable energy capacity development of more than 40GW.

Recently in December 2022, Greenko won NTPC's standalone energy storage (technology agnostic) tender for 3000MWh quoting Rs2.8 million (US\$33,985)/MWh/year.⁴⁷

PLI Scheme Battery Manufacturing

The Indian government is progressing towards creating a localised value chain for the battery industry through a PLI scheme. The PLI scheme offers incentives in 14 key sectors, including drones. This includes financial allocations of Rs181 billion (US\$2.46 billion) for Advanced Chemistry Cell (ACC) batteries under the National Programme on Advanced Chemistry Cell (ACC) Battery Storage⁴⁸ and Rs259.38 billion (US\$3.41 billion) for automobiles and auto components with an emphasis on promoting local manufacturing.⁴⁹

The scheme received a massive response, with 10 companies bidding for 128GWh of battery manufacturing capacity. In July 2022, the Ministry of Heavy Industries signed and awarded contracts to three companies—Reliance Industries, Ola Electric Mobility and Rajesh Exports Limited—to set up a battery manufacturing capacity of 50GWh combined.⁵⁰

The Indian government is making efforts to develop local manufacturing capabilities for energy storage. Further, as auctions of storage-based auctions, which have assured PPAs in place, pick up the pace, the bankability of such projects will also improve.

The Indian government is making efforts to develop local manufacturing capabilities for energy storage.

⁴⁴ Mercom India. [SECI Floats Tender for 2,000 MWh of Energy Storage Systems](#). 31 August 2021.

⁴⁵ Mercom India. [NTPC Floats Tender for 1,000 MWh of Storage Systems](#). 29 June 2021.

⁴⁶ Mercom. [JSW Renew Energy Wins SECI Tender for 1 GWh BESS](#). August 2022.

⁴⁷ Mercom India. [Greenko Wins NTPC's Tender for 3,000 MWh Energy Storage Project](#). December 2022.

⁴⁸ Press Information Bureau. [Cabinet approves PLI scheme "National Programme on Advanced Chemistry Cell Battery Storage"](#). May 2021.

⁴⁹ Press Information Bureau. [Proposed investment of ₹ 29,834 crore expected from approved applicants under Component Champion Incentive Scheme](#). March 2022.

⁵⁰ Press Information Bureau. [Three Companies signed Program Agreement under \(PLI\) Scheme for Advanced Chemistry Cell \(ACC\) Battery Storage](#). July 2022.

Corporate efforts at this stage are being funded almost entirely through the promoters' balance sheets.

For developing a domestic battery manufacturing ecosystem in India, industry players will look for capital and technological prowess from seasoned investors.

Offshore Wind

The MNRE rejuvenated India's offshore wind power plans by issuing a draft tender to lease seabed areas off Tamil Nadu and Gujarat for 4GW equivalent offshore wind project capacity during the Fiscal Year 2022-23. The announcement came during the MNRE's recent meeting with the Central Transmission Utility (CTU) on network planning for offshore wind, a challenging aspect of offshore wind power development.⁵¹

Offshore wind is emerging as a new and viable clean energy solution in the global market. China installed 16.9GW of offshore capacity in 2021 alone. This is 30% of the 57.1GW operational capacity in the world.⁵²

The costs for offshore wind power projects have significantly reduced, and technology improvements have played a huge role. The rotor diameters of wind turbines have increased from 80 metres to up to 140 metres.⁵³ Average turbine capacity has also grown, with the first 4.2MW wind turbine generator recently being installed in Tamil Nadu.⁵⁴

India's Offshore Wind Sector Gaining Momentum

The Indian government promulgated the National Offshore Wind Energy Policy in 2015. Offshore wind costs are significantly higher in India compared to solar and onshore wind. This has led to significant challenges.

The country has targeted harnessing 30GW of offshore wind by 2030, offering policy reforms for the sector's growth. Along with that, a lack of local supply chain, logistics, and port infrastructure offers multiple highly investible avenues for potential investors. These opportunities and the 2030 goal make India a potential key player in the global offshore wind sector. Despite the higher costs today, offshore wind is an important clean energy resource for decarbonising India's power sector. India's offshore wind potential is pegged at 140GW along the 7,600km coastline. Half of this potential can be harnessed off the coasts of Tamil Nadu and Gujarat.

⁵¹ Press Information Bureau. [Offshore Wind Energy in India](#). June 2022.

⁵² The Eurasian. ['Storming Ahead' – China Surpassed All of Europe In 2021 To Take Pole Position In Offshore Wind Power Race](#). 16 June 2022.

⁵³ Sany. [Wind Turbines](#).

⁵⁴ The Hindu. [India's first 4.20-MW wind turbine generator to be commissioned soon in Tirunelveli district](#). October 2022.

Offshore wind could deliver utilisation factors of more than 50-55% with a better wind resource profile in deep oceans. These are materially higher than its onshore counterpart, which can only reach up to 30-35%. Also, India's wind generation profile, which peaks during the evening to early morning hours, is complementary to solar, which peaks during the afternoon hours.

Offshore wind could deliver utilisation factors of more than 50-55% with a better wind resource profile in deep oceans.

Adding offshore wind to India's generation mix would provide better round-the-clock clean power resources and benefits resource diversification.

Key Developments

In 2018, MNRE invited an 'Expression of Interest' (EoI) for a 1GW offshore wind energy project in the Gulf of Khambhat, located off the coast of Gujarat. The invite garnered immense interest from domestic as well as foreign developers. Prominent participants from India included Sterlite Power, Greenko, and ReNew Power. Well-known foreign participants included Ørsted, Alfanar, Deep Water Structures, E. ON Climate and Renewables, Terraform Global, Macquarie Group, Shell and Senvion. Recently in November 2022, MNRE floated a draft tender to lease a sea bed for 4GW of offshore wind projects off the coast of Tamil Nadu.⁵⁵

India's electricity demand experienced a massive jump this year. Additionally, the recent spells of power shortage crisis had forced DISCOMs to buy power in the open market at Rs20/kWh, which were then capped at Rs12/kWh. Even with higher costs today, offshore wind provides energy security against shocks from the price volatility of fossil fuels.

The domestic potential for offshore wind and its diversification benefits to the grid renders it essential in the overall generation mix. Unlike its onshore counterpart, offshore wind is a much more complex technology. The lack of a domestic ecosystem means industry players will rely on technical collaborations either with global players who have championed this technology or with equipment manufacturers to provide turnkey solutions (as witnessed for offshore wind in its initial years). For either set of players, the Indian market can be a substantial opportunity to tap.

⁵⁵ Mercom India. [MNRE Issues Draft Tender to Lease Sea Bed for 4 GW of Offshore Wind Projects](#). November 2022.

Green Hydrogen

Green hydrogen is defining the pathway to decarbonisation. Being a prime source of non-polluting energy and having the highest energy output by weight and volume, green hydrogen is the fuel that will drive to decarbonise many hard-to-abate sectors in the coming years. Green hydrogen will help India achieve its emission goals under the Paris Agreement and reduce import dependency on fossil fuels.

The Indian government has approved National Green Hydrogen Mission.⁵⁶ The mission will facilitate demand creation, production, utilisation and export of green hydrogen. It will have wide ranging benefits – creation of export opportunities for green hydrogen and its derivatives, decarbonisation of industrial, mobility and energy sectors, reduction in dependence on imported fossil fuels and feedstock, development of indigenous manufacturing capabilities, creation of employment opportunities and development of cutting-edge technologies.

India aims at developing green hydrogen production capacity of at least 5 million tonnes per annum (MTPA) in the country by 2030, resulting in creation of over 0.6 million jobs and abatement of nearly 50MTPA greenhouse emissions. India's union cabinet of ministers has approved these targets envisaged under the latest National Green Hydrogen Mission. The initial outlay for the mission will be US\$2.5 billion, including an outlay of US\$2.2 billion for the Strategic Interventions for Green Hydrogen Transition (SIGHT) programme, US\$150 million for pilot projects, US\$50 million for R&D (Strategic Hydrogen Innovation Partnership – SHIP) and US\$50 million towards other components of the mission.⁵⁷

The SIGHT programme will provide two distinct financial incentive mechanisms targeting domestic manufacturing of electrolyzers and production of green hydrogen. The mission will also support pilot projects in emerging end-use sectors and production pathways. Regions capable of supporting large-scale production and/or utilisation of hydrogen will be identified and developed as Green Hydrogen Hubs.

The Indian government has already rolled out a green hydrogen and green ammonia policy.

⁵⁶ Press Information Bureau. [Cabinet approves National Green Hydrogen Mission](#). January, 2023

⁵⁷ Press Information Bureau. [Cabinet approves National Green Hydrogen Mission](#). January 2023.

Figure 9: Green Hydrogen Commitments by Indian Companies

Company	Green Hydrogen Commitment/ Development
Adani Enterprises	<ul style="list-style-type: none"> US\$50 billion investment in green hydrogen along with Total SE with an initial target of 1MTPA by 2030⁵⁸ MoU with South Korean steel company POSOCO for a US\$5 billion investment in an integrated green steel mill which will make use of green hydrogen⁵⁹
Reliance Industries	Announced investments of US\$75 billion in renewable energy infrastructure development, including green hydrogen production
Acme Solar	MoU with Karnataka government for development of 1.1MTPA of ammonia synthesis powered by a 5GW solar ⁶⁰
Greenko	JV with Belgium's John Cockerill to set up a 2GW electrolyser factory in India ⁶¹ <ul style="list-style-type: none"> Awarded India's first hydrogen fueling station project⁶²
NTPC	<ul style="list-style-type: none"> Initiative to blend green hydrogen with piped natural gas (PNG)⁶³ Develop a project of standalone fuel cell based 50kW microgrid pilot project⁶⁴
Avaada	MoU signed with the Rajasthan government to build a 1MTPA green hydrogen facility powered by a 6GW RE capacity ⁶⁵
Jakson Group	MoU signed with the Rajasthan government to invest US\$2.8 Bn to set up green hydrogen and green ammonia projects in phases ⁶⁶

Source: Company Updates, IEEFA Analysis

The above table lists several commitments and ongoing developments in the green hydrogen sector in India. There are several other MoUs (Memorandum of Understanding) and partnerships undertaken by clean energy companies.

The Indian hydrogen market is set to grow from 6MT in 2020 to 28 MT in 2050.⁶⁷ The share of green hydrogen in the said market is projected to be 80%, which will lead to the growth of the electrolyser manufacturing sector. As a result, the internal electrolyser market size could reach US\$31 billion.⁶⁸

The key driving sectors in the growth of the hydrogen sector in the short term are the refinery and fertiliser industries. The steel manufacturing and power generation sector are preparing to play an integral role in the sector's growth. India is the world's second-largest steel producer and relies heavily on coal for many operations, rendering the sector the most significant contributor to industrial energy demand. Green hydrogen can majorly contribute to decarbonising steel operations.

⁵⁸ Adani. [Adani And Total To Create The World's Largest Green Hydrogen Ecosystem](#). June 2022.

⁵⁹ Outlook India. [Adani Group Partners With POSCO](#). January 2022.

⁶⁰ ACME media release. [ACME Group and Govt of Karnataka sign MoU to invest Rs 52000 crore for Green Hydrogen project](#).

⁶¹ Mint. [Greenko in tie-up for electrolyser plant](#). April 2022.

⁶² Economic Times. [NTPC awards Amara Raja Group India's first green hydrogen fueling station project](#). June 2022.

⁶³ Moneycontrol. [NTPC inks pact with Gujarat Gas](#). April 2022.

⁶⁴ ET Energy World. [NTPC to develop standalone fuel cell-based microgrid project](#). March 2022.

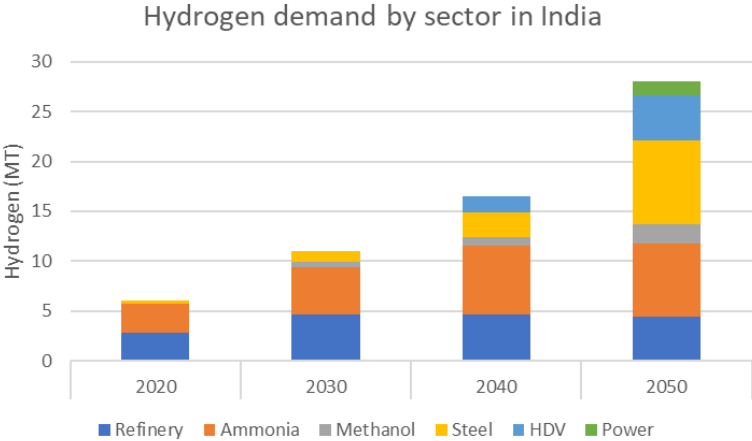
⁶⁵ PV Magazine. [Avaada to invest \\$5 billion in green hydrogen](#). August 2022.

⁶⁶ Hindu Business Line. [Jakson Group to develop \\$2.8 bn green ammonia and hydrogen project in Rajasthan](#). October 2022.

⁶⁷ PIB. [National Hydrogen Mission](#). March 2022.

⁶⁸ NITI Aayog. [Harnessing Green Hydrogen](#). June 2022.

Figure 10: Projected Hydrogen Demand by Sector in India



Source: NITI Aayog

India is just scratching the surface in terms of the use cases of green hydrogen in its economy. India's industrial sector is one of the biggest contributors to GHG emissions, and for the country to achieve its stated net zero target, decarbonisation of this sector is imperative. Green hydrogen is currently among the most viable solutions in this respect globally.

Summary

India's vision to reduce its CO₂ emissions by 45% from 2005 levels and increase the cumulative share of non-fossil fuel energy to 50% by 2030 hinges on facilitative government policies and reforms. The clean energy sector in the country has grown exponentially over the last decade owing to improved business conditions, a conducive and forward-looking policy regime and diverse capital sources. This has helped the sector emerge as one of the most favoured renewable energy investment destinations. Industry players are now getting ready to ride the next set of sectoral reforms to accelerate India's transition to a more resilient and sustainable energy economy.

Key trends, such as Energy-as-a-Service and corporate decarbonisation, are transforming incumbents' business models. The industry is also adopting nascent technologies, such as green hydrogen and battery storage, to leapfrog the competition and emerge as frontrunners in the new energy ecosystem.

These developments are spawning several new investment opportunities, with many global, strategic and financial investors vying to get a piece of the growing clean energy market in the country.

Several pieces still need to come together for all these potential opportunities to fructify. Policy support is needed to develop and uptake new technologies through the reduction of bottlenecks, growth of a domestic market and creation of incentive structures to help them scale. Further, due to the capital-intensive nature of these technologies, the availability of capital will be a key determinant of the development trajectory they take. Investors will benefit from clarity on the government's energy transition targets and its ability to support long-term capital providers.

Government efforts have helped de-risk and scale up the solar and wind sector massively over the last decade, and similar efforts are now needed for the clean energy sectors' next leg of growth.

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The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends and policies. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org

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