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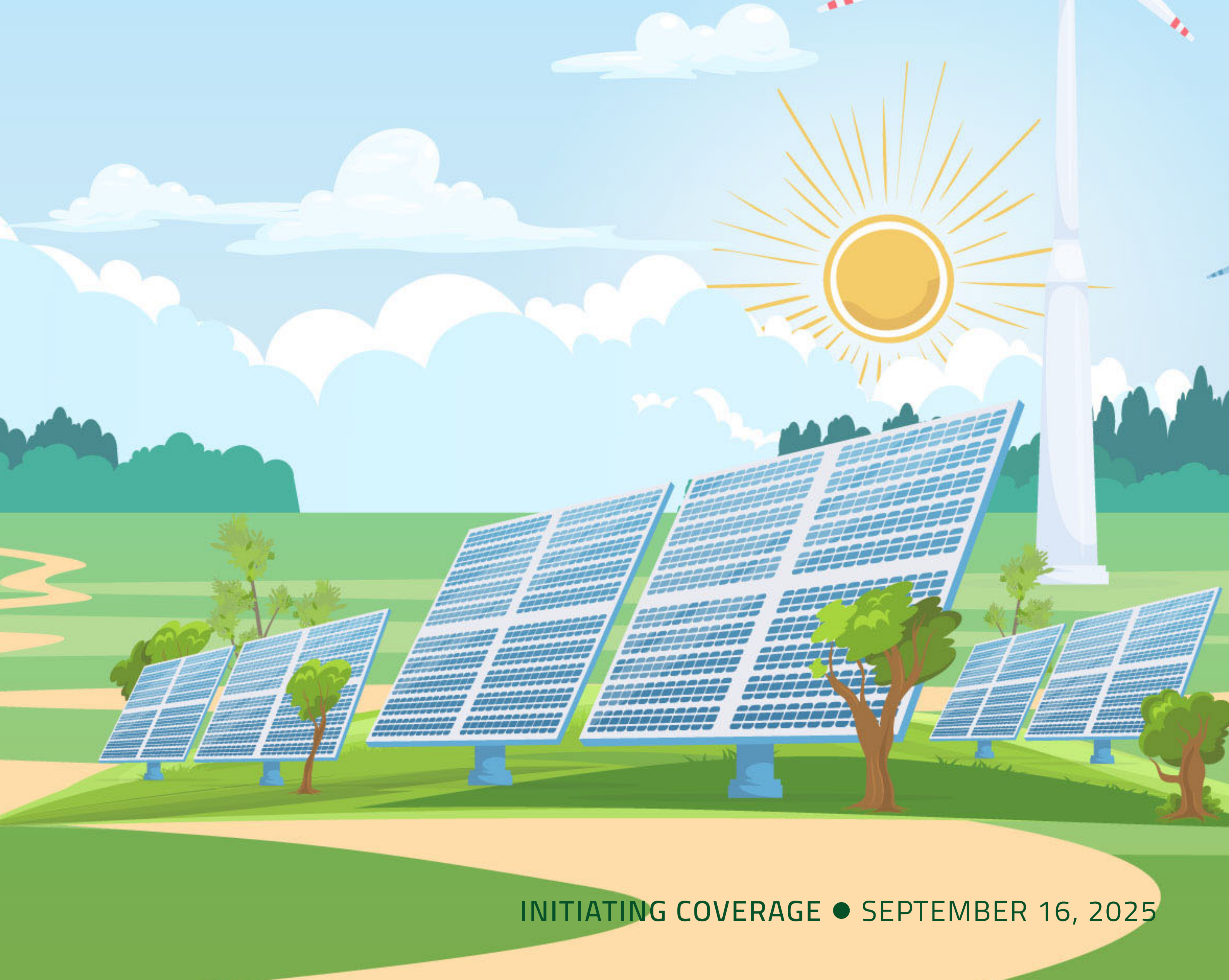
NEW ENERGY

Solar at the helm of clean energy transition



INITIATING COVERAGE ● SEPTEMBER 16, 2025

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September 16, 2025

INITIATING COVERAGE | Sector: Energy

New Energy

Solar at the helm of clean energy transition

India's GDP is expected to soar at a CAGR of ~6-6.5% by 2030 on the wings of humungous energy consumption. While the % share of coal and petroleum products is likely to drop, that of Natural gas and Renewables is expected to rise, with Renewables growing at a faster rate. This will ensure large capacity additions for the aggressive electrification and peak power demand, with Solar power leading the charge. India's solar component manufacturing capacity (solar modules and cells) has seen exponential growth, well endorsed by the government's ambitious target to reach 900GW by FY32 (CEA). Large players will drive the energy transition, thanks to their healthy balance sheets, as also the intent to capture significant value both through backward integration and forward integration into storage, and green hydrogen.

We initiate coverage on Waaree Energies and Premier Energies with BUY ratings.

India's Electricity Outlook: Electricity demand in India is growing at a CAGR of over 4.5% annually since FY15. India's electricity generation in FY25 has more than doubled since 2000, Coal remains dominant at ~71%, but its contribution in serving the new demand has declined given environmental pressures, carbon costs, and stranded assets. Renewables now supply ~22% of generation, driven by falling costs, policy incentives, and need for cleaner alternatives. Within this, solar has emerged as the fastest-growing source, moving from negligible levels only a decade ago to over 8% of generation in FY25. Coal will persist as a balancing fuel, but the pace and scale of solar expansion is now the principal architect of India's electricity transition.

India's Solar outlook: India's solar sector has grown rapidly, with installed capacity rising from 17 GW in 2017 to over 106 GW by Mar'25 (22% of the energy mix), and the government targets 280GW by 2030, making solar PV central to India's renewable ambitions. While policies such as PM-KUSUM, rooftop solar schemes, and the PLI programme are driving adoption, the sector still relies heavily on Chinese imports of modules, cells, wafers, and polysilicon. However, domestic manufacturing is scaling up quickly, with module capacity expanding from 4.2 GW in FY17 to 74 GW in FY25 and projected to reach ~160-170 GW by FY28, while solar cell capacity is expected to grow to ~90GW by FY28 under ALMM and duty protection. This increasing domestic manufacturing is expected to replace imports entirely while opening opportunities to expand the export footprint. With improving technology, hybrid plants delivering higher PLFs, and a host of government incentives, India's solar ecosystem is poised for sustained growth and reduced import dependence, positioning solar as the backbone of the country's clean energy transition.

Waaree Energies: Waaree Energies is India's largest solar PV module manufacturer with over 13.3 GW of module capacity and 5.4 GW of cell capacity. It continues to expand aggressively, having inaugurated a 1.8 GW plant in Gujarat and targeting 25.7 GW modules, 15.4 GW cells, and 10 GW wafer capacity by FY27. Internationally, Waaree is scaling up its U.S. operations, doubling its Texas capacity to 3.2 GW. Based on our estimates, we expect Waaree's EBITDA to increase to Rs82.4bn in FY28e which is **3x** from its FY25's Rs27.2bn, exhibiting a margin expansion of ~500bps to ~24%. We assign a PER multiple of 22x to arrive at a TP of Rs4,610 and initiate coverage on the stock with a BUY Rating.

Premier Energies: Premier Energies is fast emerging as a vertically integrated solar manufacturer in India, with current capacities of 5.1 GW modules and 3.2 GW solar cells. The company is aggressively scaling up, targeting capacities of 11.1 GW modules and 8.4 GW cells by mid-2026, along with ingot/wafer (10GW by FY28) integration, 3 GW inverter production, and 12 GWh BESS by FY28. FY25 revenue more than doubled to Rs 66.5bn over the previous year. Based on our estimates, we expect Premier's EBITDA to increase to Rs48.3bn in FY28e which is **2.7x** from its FY25's Rs17.8bn, exhibiting a margin expansion of ~50bps to ~27.8%. We assign a PER multiple of 22x to arrive at a TP of Rs1,310 and initiate coverage on the stock with a BUY Rating.

Recommendation table

Stock	Rating	TP (Rs)
Waaree Energies	BUY	4,610
Premier Energies	BUY	1,310

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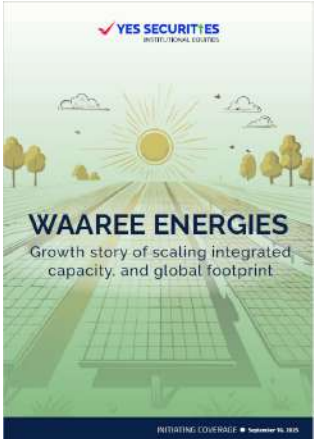
Waaree Energies



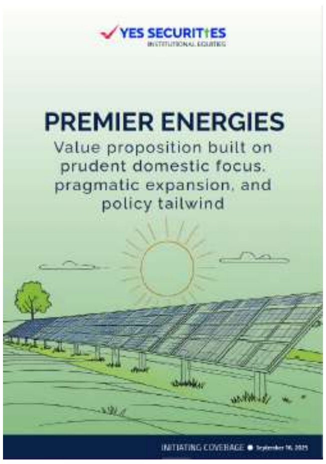
Waaree Energies is transitioning from a module-centric manufacturer into India's most integrated solar platform, positioned at the intersection of India's DCR-led localization and the U.S. IRA manufacturing push. ~14.9GW of module (1.6GW in US) and 5.4GW of cell capacity operational in as of Q1FY26.

The domestic momentum is accelerating as IPPs and government schemes scale, and the inherently shorter Indian execution cycle means near-term revenue recognition skews local even as the order book is U.S.-heavy. As of Jun'25, the module backlog stood at ~25GW (~Rs490bn), ~41% domestic and ~59% international, with certain U.S. call-offs stretching to FY30; Q1FY26 added ~3GW despite seasonal softness.

The capacity blueprint is designed for margin compounding rather than mere volume: India modules lift to 25.7GW by FY27 (with Gujarat retrofit enabling a quick step-up by end-CY25/early-CY26), U.S. modules to 3.2GW, cells to 15.4GW near the Chikhli Giga Campus, and ingot-wafer to 10GW at Butibori, Nagpur (commissioning through FY26–FY27). Forward and lateral integration deepens the moat: junction boxes scale from 5GW to 20GW by FY28 (including more than 50% in the U.S.), aluminium ramps from 10ktpa to 180ktpa, and new lines in glass (~1,250tpd by FY28), encapsulants (25GW) and sealants (30GW) pull critical upstream cost and supply under the Group's umbrella. Adjacencies add operating leverage and strategic relevance: 3GW inverters (FY26), 3.5GWh BESS (FY27) and 300MW electrolysers (FY27; PLI awarded, SECI 90ktpa win) broaden earnings beyond modules and align with grid-stability and green-H_2 demand.

The economic outcome is evident in the business model. DCR share rises from ~6% in FY25 to effectively 100% by FY29e, expanding gross margin by ~800bps to ~37.6% and EBITDA margin by ~500bps to ~24% by FY28 on pricing premia, operating leverage and import substitution. Management guides FY26 EBITDA to Rs55–60bn; our framework implies ~Rs52bn (without other income), over 90% versus FY25, consistent with cell ramp and mix. Cash conversion benefits from advance payments on exports and staggered deliveries, and a deep domestic franchisee network (~388 partners) sustain higher-margin rooftop/C&I flows; the U.S. base anchors multi-year utility volumes.

Premier Energies



Premier Energies is now India's fifth-largest solar module manufacturer, but its value proposition is way more than the ranking, of being one of the few players with a meaningful presence across modules and cells. 5.1GW of module and 3.2GW of cell capacity are operational as of Q1FY26.

On the demand front, Premier's revenue mix is heavily skewed in favour of India (~96% of sales), with EPCs, IPPs, and state-led schemes driving volumes under DCR compliance. Exports still small as the company emphasizes its focus on domestic market primarily. The order book as of Jun'25 stood at Rs86bn (~5.5GW), with modules 60%, cells 39%, and 0.6% EPC contracts. Importantly, the company expects DCR share to rise steadily from 46% of FY25 volumes to nearly 100% by FY28-29, as policy-led domestic demand strengthens while global buyers look for diversification away from China.

The capacity blueprint is built on both downstream expansion and upstream integration. Modules are set to grow from 5.1GW in FY25 to 11.1GW by FY26, supported by new lines at Seetharampur at Telagana. Cell capacity will more than triple to 10GW by FY28, anchored by a 4.8GW TOPCon plant at Naidupeta, Andhra Pradesh (Jun'26 target) and complemented by a 1.2GW U.S. line by FY28 (on hold currently) to capture IRA-led incentives and hedge trade barriers. Upstream, a 2GW wafer JV with SAS (Jun'26) and a wholly owned 10GW ingot–wafer line at Naidupeta (FY28) would structurally reduce Chinese dependence and lock in cost competitiveness. Premier is also diversifying laterally: 12GWh of battery storage (6GWh FY27, 6GWh FY28), 3GW of inverters (JV with Nuevosol, FY28), and 36,000MT of aluminium frame capacity, all designed to pull value chain in-house while adding new earnings levers.

While Premier already holds superior margins, as wafer and cell integration ramps, gross margin is expected to widen from FY25 levels, supported by import substitution and higher DCR mix.

Exhibit 1: Waaree's Scale Leads Growth While Premier Edges Ahead on Margins

Financial Dashboard	Unit	FY23	FY24	FY25	FY26e	FY27e	FY28e
Revenue	Rs bn						
Waaree Energies		67.5	114.0	144.4	222.2	313.6	343.5
Premier Energies		14.3	31.4	65.2	94.7	138.6	173.8
EBITDA (Margin)	%						
Waaree Energies		12.4	13.8	18.8	23.3	23.6	24.0
Premier Energies		5.5	15.2	27.3	27.2	27.6	27.8
PAT (Margin)	%						
Waaree Energies		7.7	8.2	13.4	16.1	17.2	17.5
Premier Energies		(1.0)	7.3	14.4	15.6	15.4	15.4
Net Debt	Rs bn						
Waaree Energies		(14.5)	(33.0)	(66.1)	(28.1)	(18.9)	(52.9)
Premier Energies		5.2	10.0	(8.8)	1.9	22.3	27.1
Capex	Rs bn						
Waaree Energies		8.6	13.4	32.7	83.7	70.9	41.0
Premier Energies		2.7	4.5	6.2	29.0	47.4	44.7
OCF	Rs bn						
Waaree Energies		15.6	23.1	31.6	47.1	63.2	76.5
Premier Energies		0.4	0.9	13.5	20.0	29.9	43.1
FCF	Rs bn						
Waaree Energies		7.0	9.7	(1.1)	(36.6)	(7.7)	35.5
Premier Energies		(2.4)	(3.6)	6.0	(9.0)	(17.5)	(1.7)
Net Debt/Equity	x						
Waaree Energies		(0.8)	(0.8)	(0.7)	(0.2)	(0.1)	(0.2)
Premier Energies		1.6	1.7	0.4	0.2	0.5	0.4
EV/EBITDA	x						
Waaree Energies		-	-	35.4	19.3	13.7	11.8
Premier Energies		-	-	26.9	18.8	12.2	9.8
P/E	x						
Waaree Energies		-	-	53.3	28.8	19.1	17.1
Premier Energies		-	-	50.6	32.1	22.2	17.7

Source: Company, YES Sec

Exhibit 2: Premier Return Ratios Superior, Though Waaree Retains Consistency

Return Ratios	Unit	FY23	FY24	FY25	FY26e	FY27e	FY28e
ROCE	%						
Waaree Energies		26.9	22.0	21.2	29.4	30.1	25.3
Premier Energies		2.3	22.9	31.6	35.2	32.7	29.9
ROE	%						
Waaree Energies		45.3	31.0	28.1	31.3	34.0	27.9
Premier Energies		(3.2)	42.7	53.8	41.5	39.8	34.5
Fixed Asset Turnover	x						
Waaree Energies		7.9	9.0	5.3	2.9	2.2	1.9
Premier Energies		2.7	3.5	6.0	4.5	2.7	2.0
Total Asset Turnover	x						

Return Ratios	Unit	FY23	FY24	FY25	FY26e	FY27e	FY28e
Waaree Energies		1.4	1.2	0.9	1.0	1.1	1.0
Premier Energies		0.8	1.1	1.3	1.2	1.3	1.2
Working Capital days	days						
Waaree Energies		96	80	49	25	25	25
Premier Energies		88	76	78	65	55	40

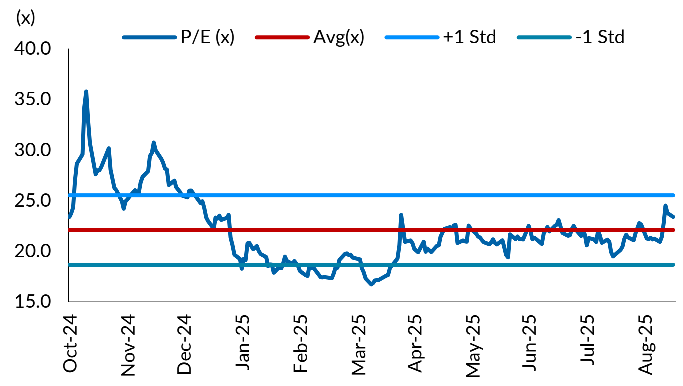
Source: Company, YES Sec

Exhibit 3: Waaree's Aggressive Capacity Push Outpaces Premier's Gradual Scale-Up

Installed Capacity	Unit	FY23	FY24	FY25	FY26e	FY27e	FY28e
Module	GW						
Waaree Energies		9.0	12.0	13.3	16.5	25.7	25.7
Premier Energies		1.4	3.4	4.1	11.1	11.1	11.1
Cell	GW						
Waaree Energies		-	-	5.4	5.4	15.4	15.4
Premier Energies		0.8	2.0	2.0	3.2	8.4	10.0
Ingot-Wafer	GW						
Waaree Energies		-	-	-	-	10.0	14.0
Premier Energies		-	-	-	-	2.0	10.0
US Module	GW						
Waaree Energies		-	-	1.6	1.6	3.2	3.2
Premier Energies		-	-	-	-	-	-
Inverter	GW						
Waaree Energies		-	-	-	3.0	3.0	3.0
Premier Energies		-	-	-	3.0	3.0	3.0
BESS	GWh						
Waaree Energies		-	-	-	-	3.5	3.5
Premier Energies		-	-	-	-	-	12.0
Green H2 Electrolyser	GW						
Waaree Energies		-	-	-	-	0.3	0.3
Premier Energies		-	-	-	-	-	-

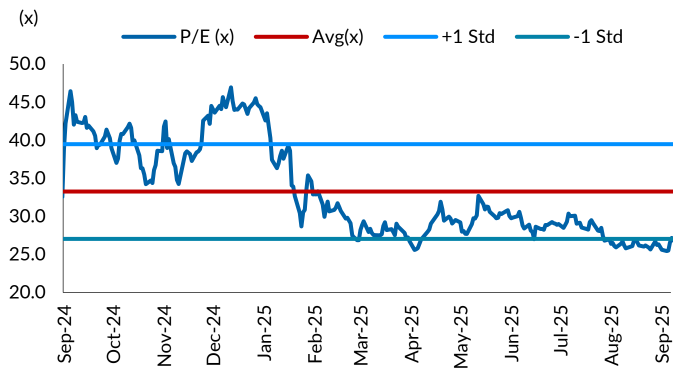
Source: Company, YES Sec

Exhibit 4: PER Trading Bands Waaree Energies



Source: Company, YES Sec

Exhibit 5: PER Trading Bands Premier Energies



Source: Company, YES Sec

GLOBAL ENERGY OUTLOOK

Global Energy Evolution

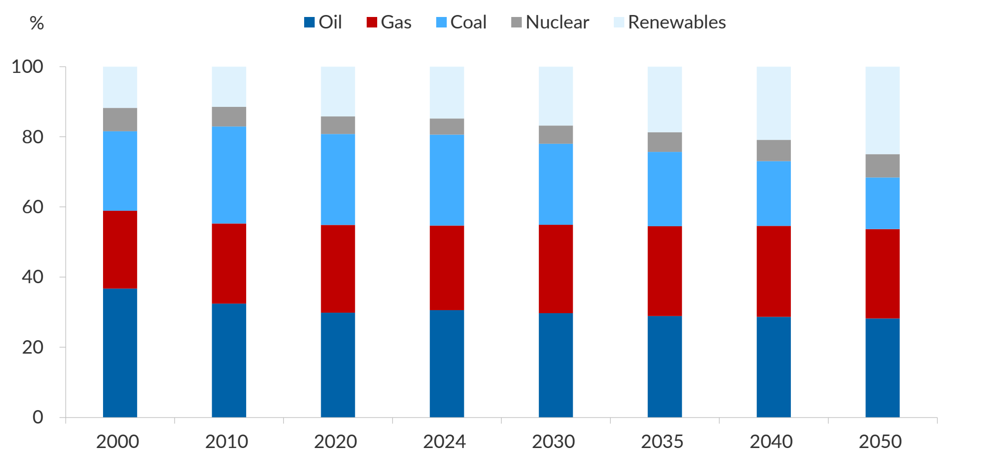
The global energy landscape stands at an inflection point, driven by climate imperatives, energy security concerns, and rapid technological advancements, countries worldwide are shifting their focus from fossil fuel-based systems to more sustainable, diversified energy portfolios. The urgency is clear, fossil fuels still accounted for over 80% of global primary energy supply in 2024, yet their dominance has been gradually receding, down from ~87% a decade ago. While total global energy consumption continues to grow, reaching 620 exajoules (EJ) in 2024, this expansion is increasingly being met through low-carbon alternatives.

India is balancing the twin imperatives of rising power demand and decarbonization. With per-capita electricity consumption, India is still below global averages, demand is growing at over 4.5% CAGR, prompting a capacity of over 780GW by FY31 (would be ~2x of FY22) with a decreasing share of fossil fuel capacity, total including ~500GW of Renewables of which ~346 GW of solar. Falling LCOEs, favorable auction dynamics (50 GW tendering annually), and open access reforms continue to drive momentum, setting the stage for solar and hybrid energy to lead India's power sector transition.

Fossil fuels: Steering development

Historically, fossil fuels have dominated the global energy mix, but their share has declined to near 80% in 2024, despite faster and larger growth in Renewables. In 2024, the global energy consumption with the majority consisting of fossil fuels among which oil products have the highest share in the total consumption basket at ~31% and coal ~26% followed by Natural gas at ~24%. Electricity contributed 21% of total consumption which has increased from 18% in 2022 growing at a CAGR of 2.6% in the same period.

Exhibit 6: Global Energy Consumption



Source: ExxonMobil Global Outlook, Industry, YES Sec

The well-established infrastructure for extraction, transportation, and storage of fossil fuels has further solidified their dominance in the energy sector. Additionally, fossil fuels have been relatively inexpensive to produce and utilize, offering a cost-effective solution for energy needs. These practical advantages have solidified fossil fuels' role as the dominant energy source throughout modern history.

Exhibit 7: Global Energy Consumption by Continent

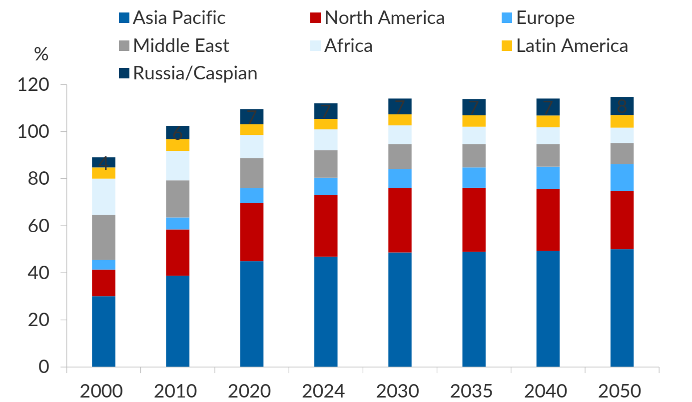
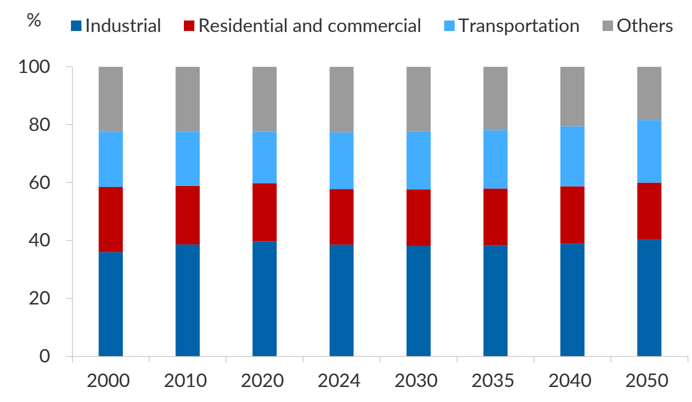


Exhibit 8: Global Energy Consumption by Sector



Source: ExxonMobil Global Outlook, Industry, YES Sec

Need for sustainable sources

Fossil fuels are undeniably excellent fuels, but the negative externalities of their use, their harm to human health, the environment, and society far outweigh any benefit of continuing their use. Global energy-related CO_2 emissions reached a record high in 2023, with coal being the largest contributor, followed by oil and natural gas. However, fossil fuel demand is expected to peak by 2030, signaling a potential turning point in emissions. The rapid adoption of clean energy technologies, especially solar and wind, is already helping to reduce the upward trend in emissions, particularly in power generation, where coal consumption is declining. While coal still plays a significant role in industrial sectors like iron, steel, and cement production, the gradual shift to alternative energy sources such as electricity, bioenergy, and natural gas is expected to reduce coal demand and CO_2 emissions in the coming years.

Exhibit 9: Energy Intensity

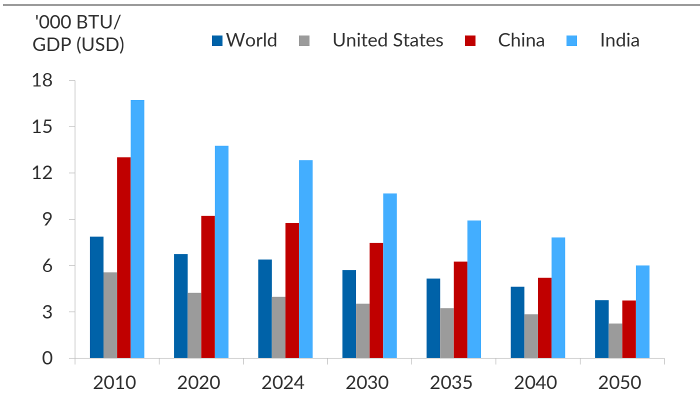
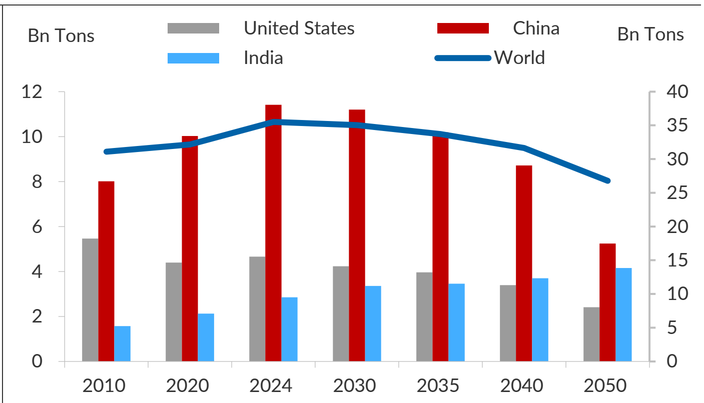


Exhibit 10: Global CO2 emissions



Source: ExxonMobil Global Outlook, Industry, YES Sec

Sustainability in current consumption pattern: Current consumption pattern mostly depends on fossil fuel which is expected to diminish as technology upgrades with time. Certain sources such as ethanol, biodiesel have started to blend and potentially serve as an alternative to fossil fuels such as gasoline and gasoil have created a demand for such technologies. **The leading alternative for such transition is Renewable fuels and Electricity.**

Regional Energy Consumption Trends

Exhibit 11: Asia Pacific – by Energy Type

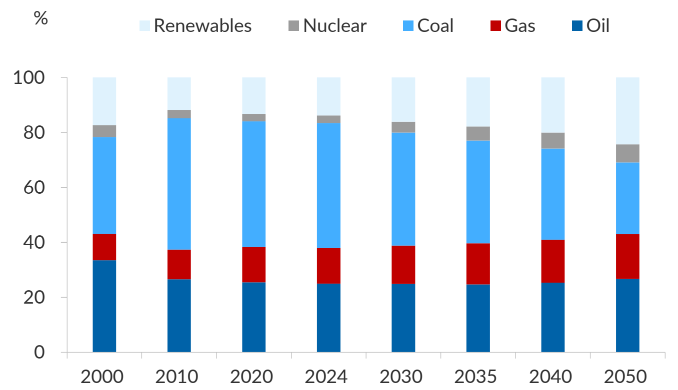
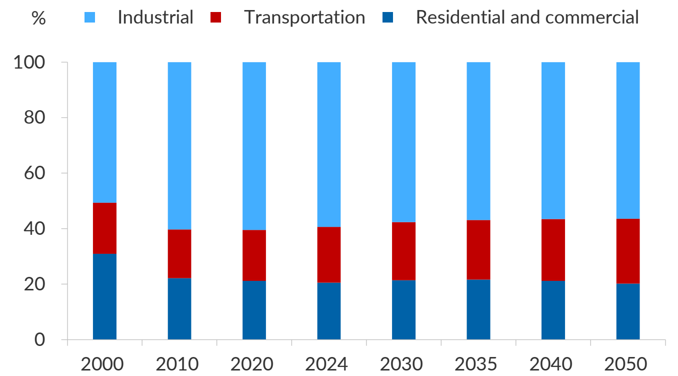


Exhibit 12: Asia Pacific – by Sectors



Source: ExxonMobil Global Outlook, Industry, YES Sec

Exhibit 13: North America - by Energy Type

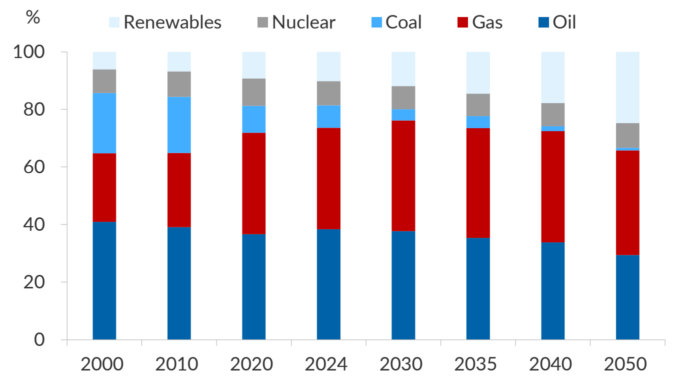
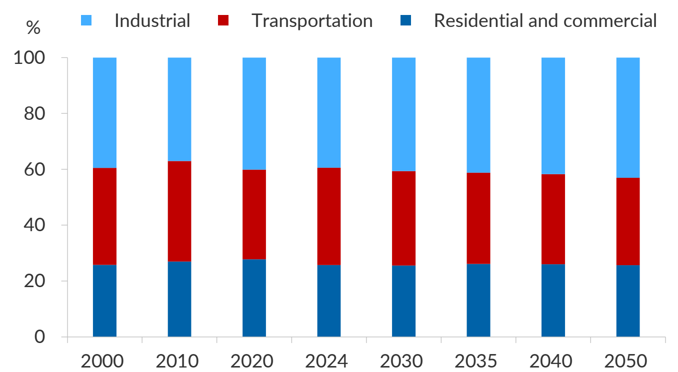


Exhibit 14: North America - by Sectors



Source: ExxonMobil Global Outlook, Industry, YES Sec

Exhibit 15: Europe - by Energy Type

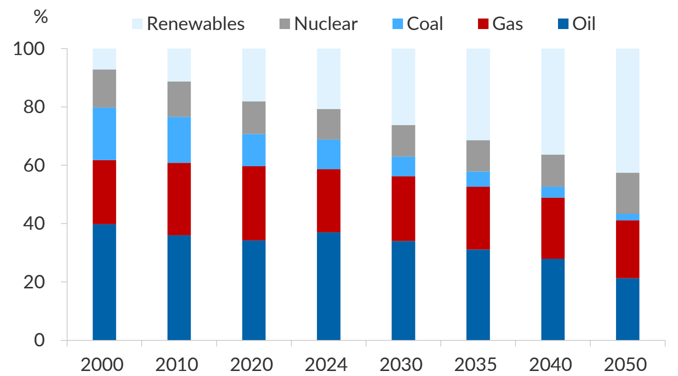
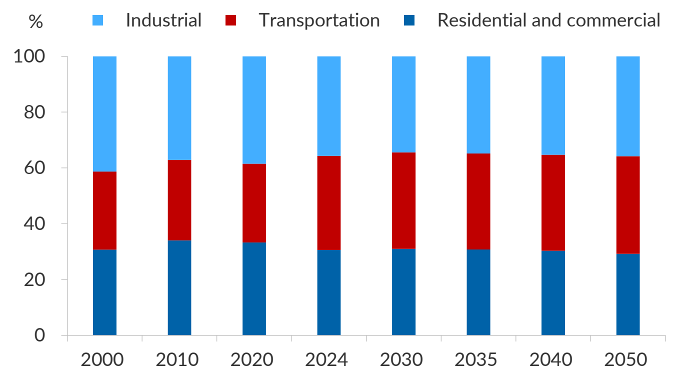


Exhibit 16: Europe - by Sectors



Source: ExxonMobil Global Outlook, Industry, YES Sec

Exhibit 17: Middle East – by Energy Type

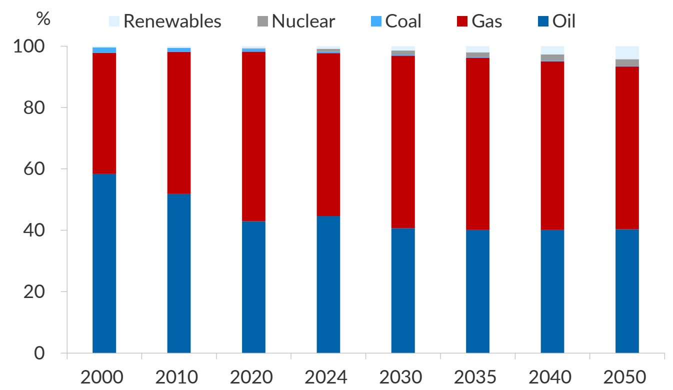
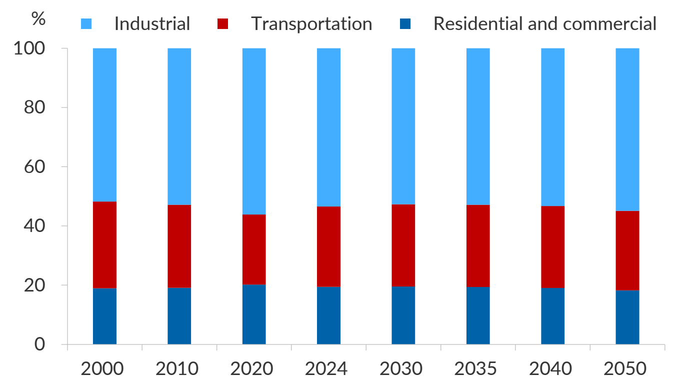


Exhibit 18: Middle East – by Sectors



Source: ExxonMobil Global Outlook, Industry, YES Sec

Exhibit 19: Africa - by Energy Type

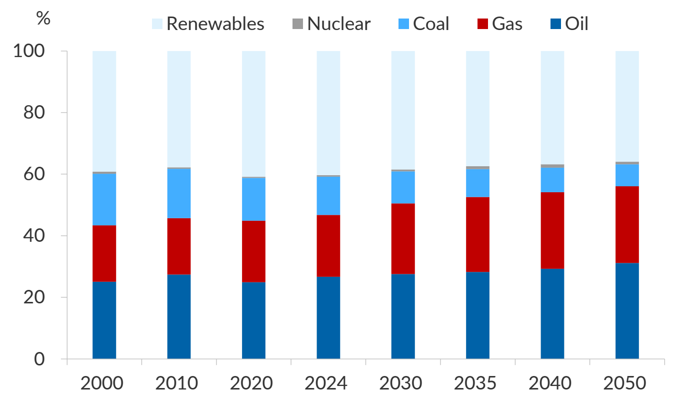
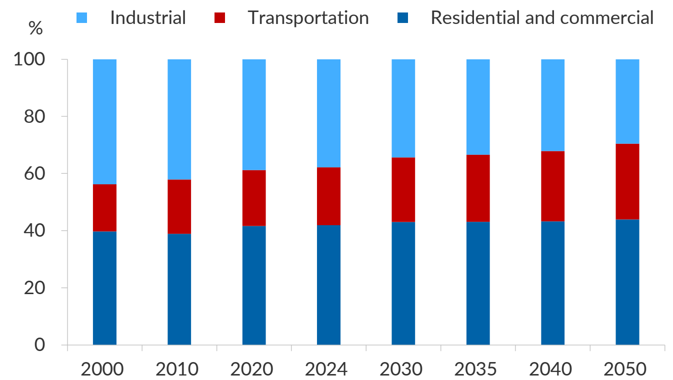


Exhibit 20: Africa - by Sectors



Source: ExxonMobil Global Outlook, Industry, YES Sec

Exhibit 21: Latin America - by Energy Type

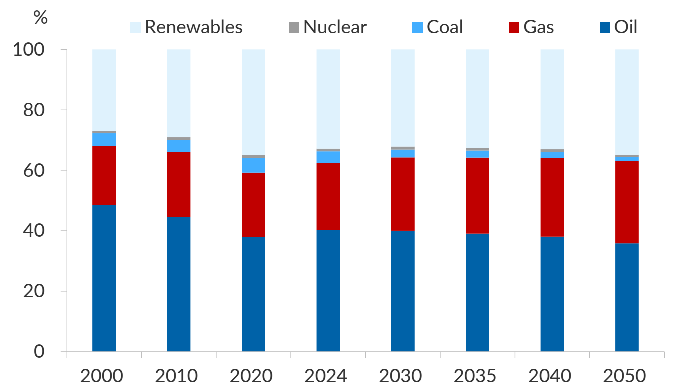
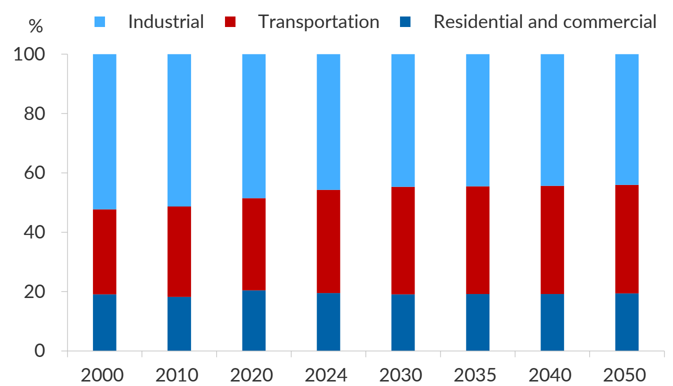


Exhibit 22: Latin America - by Sectors



Source: ExxonMobil Global Outlook, Industry, YES Sec

RENEWABLE FUELS

Renewable fuels encompass a range of renewable energy sources, including solid biomass, liquid biofuels, biogases, renewable hydrogen, and e-fuels, all of which are gaining prominence as sustainable alternatives to fossil fuels. In 2023, the demand for renewable fuels in industry, buildings, and transport sectors reached 22 exajoules (EJ), accounting for 5% of global energy demand in these areas and surpassing the combined output of wind and solar photovoltaic (PV) generation. Modern solid bioenergy constitutes most of this demand (75%), followed by liquid biofuels (20%) in the transport sector and biogases (5%), primarily used in buildings. Renewable hydrogen and e-fuels are currently utilized in smaller quantities, mainly within the transport sector.

Exhibit 23: Renewable fuel demand by countries

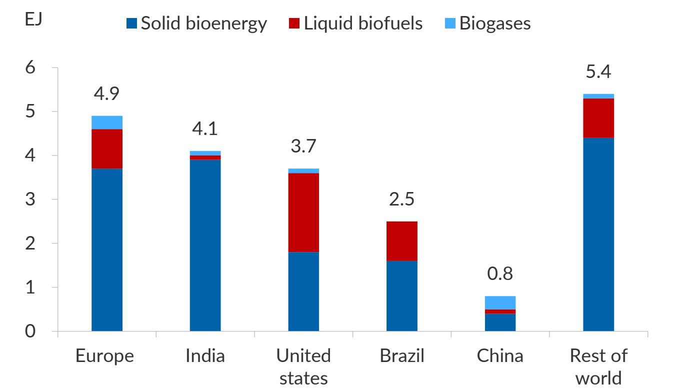
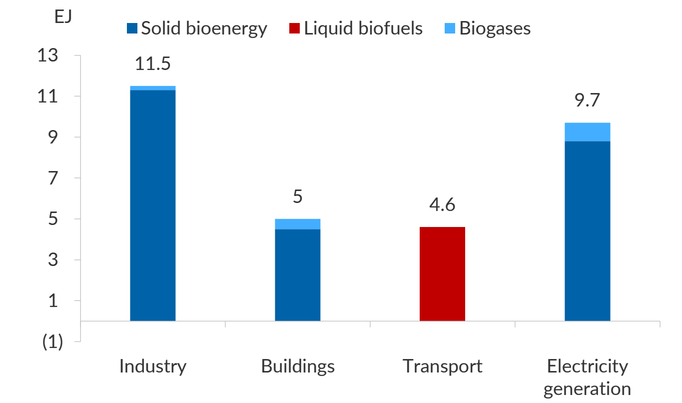


Exhibit 24: Renewable fuel demand by sector



Source: IEA, YES Sec

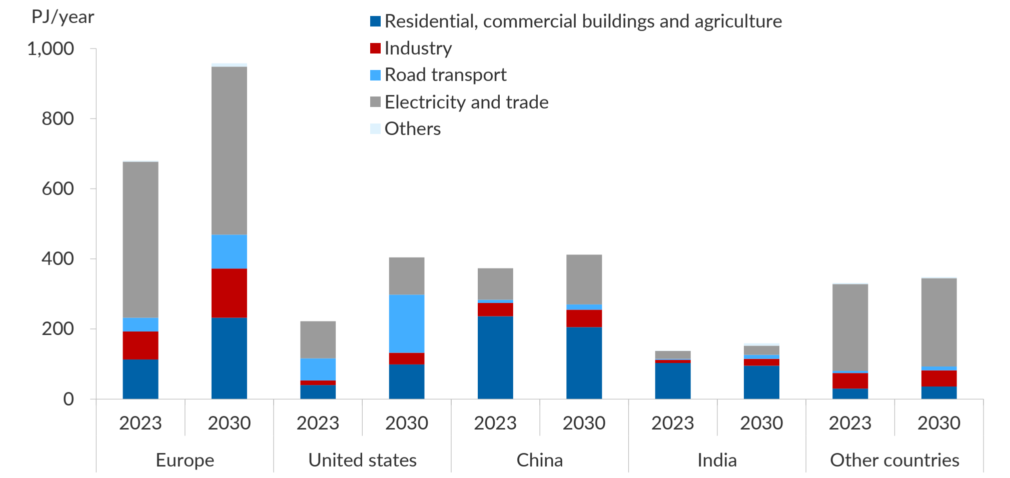
Regionally, India and Europe are the largest consumers of solid bioenergy (3.9 EJ and 3.7 EJ, respectively), highlighting their dependence on biomass for industrial and residential energy needs. In contrast, the United States shows a more balanced reliance between solid bioenergy and liquid biofuels, each at 1.8 EJ. The data also underscores the limited current deployment of renewable hydrogen and e-fuels, which remain niche technologies, primarily in the transport sector. This distribution reflects both regional resource availability and policy orientations toward renewable fuel integration.

Major contributions for growth:

This growth is concentrated in regions such as India, China, Brazil, the United States, and Europe, which collectively support more than two-thirds of this expansion. These regions have implemented dedicated support policies for various renewable fuels, including mandates, greenhouse gas performance criteria, and direct production and capital expenditure investment incentives.

For instance, India provides investment and production incentives for liquid biofuels, biogases, solid biomass, and hydrogen, as well as blending targets for biofuels and biogases, boosting renewable fuel use sharply by 2030.

Exhibit 25: Global demand for Biogas across different geographies

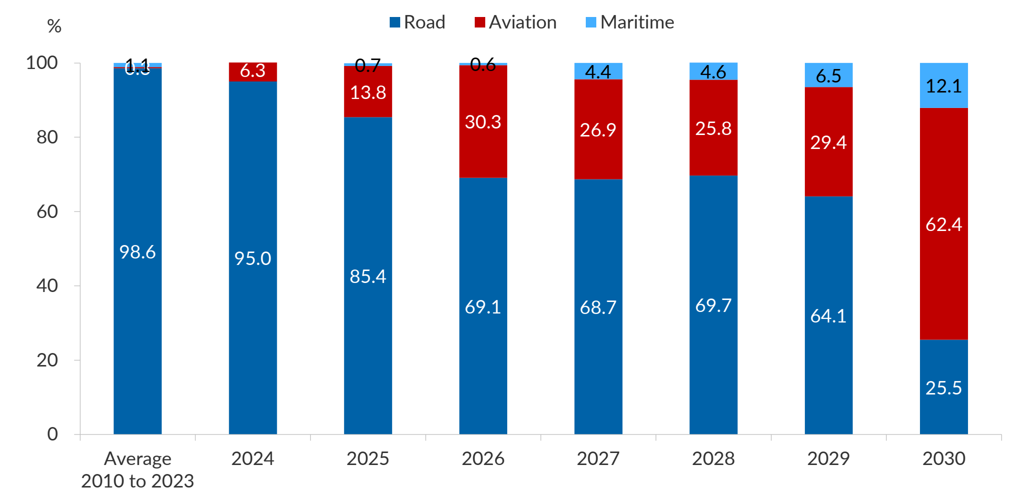


Source: IEA, YES Sec

Between 2024 and 2030, global demand for biogases including both biogas and biomethane is projected to rise by 30%, reaching approximately 2,270 PJ annually by 2030. While electricity production currently dominates biogas use, the sector is shifting as biomethane gains traction in transport and industry due to its lower carbon intensity and capacity to reduce methane emissions from organic waste, such as animal manure. The transport sector is expected to lead this growth, particularly in India, the EU, and the United States, supported by strong policy incentives.

The data shows that biogas use in road transport in the U.S. is set to more than double from 63 PJ in 2023 to 166 PJ in 2030, while Europe's usage will grow from 39 PJ to 97 PJ. Use in industry and buildings is also increasing, fueled by voluntary carbon markets and long-term green gas contracts, especially in Europe and the U.S., where building sector demand is expected to rise from 113 PJ to 232 PJ and 40 PJ to 99 PJ, respectively.

Exhibit 26: Global demand for Biofuel across different sectors

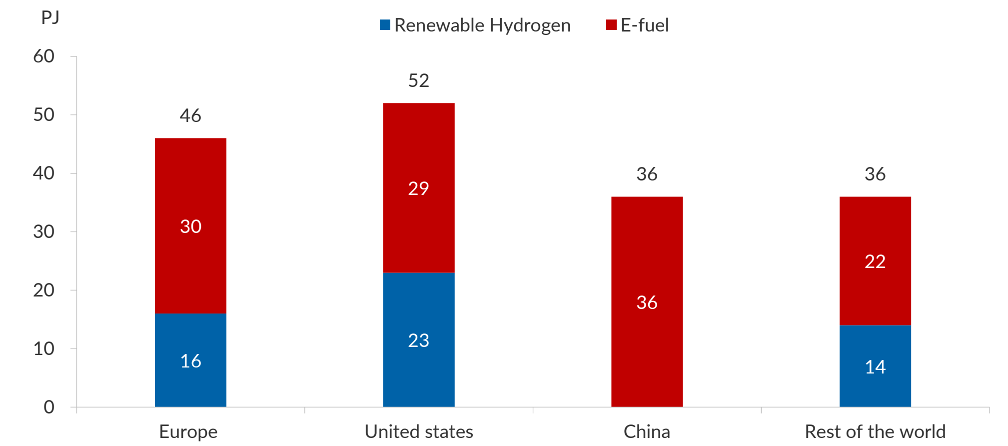


Source: IEA, YES Sec

Biofuels are poised to play an increasingly critical role in decarbonizing transport, with their share in total liquid fuel demand expected to rise modestly from 5.6% in 2023 to 6.4% by 2030—reaching 215bn litres annually. While this represents moderate overall growth, the distribution of demand is shifting dramatically. Between 2023 and 2030, over 75% of new biofuel demand is projected to come from the aviation and maritime sectors, reflecting aggressive decarbonization targets in regions like North America, Europe, and Japan.

Data reveals a stark transformation: the share of road transport in biofuel consumption plummets from nearly 99% (2010–2023 average) to just 25.5% by 2030. Meanwhile, aviation's share soars to 62.4% and maritime climbs to 12.1%, up from near-negligible levels. This pivot is driven by policies prioritizing harder-to-abate sectors, supported by strengthened mandates and financial incentives in key regions including the U.S., Brazil, India, Europe, and Indonesia—accounting for 85% of the growth. However, despite this redirection of demand, total road biofuel consumption still increases by 27bn litres (0.8 EJ), highlighting ongoing relevance even as global focus shifts toward decarbonizing air and sea transport.

Exhibit 27: Renewable Hydrogen and E-fuel consumption (2023)



Source: IEA, YES Sec

Brazil has introduced new demand for liquid biofuels due to planned increases in biofuel blending targets and announced a USD 3.2bn green hydrogen incentive program.

Meanwhile, renewable fuel use expands in all sectors in China, driven by biogas and solid biomass deployment in industry and for building heat; renewed interest in biodiesel blending; and hydrogen use in the transport and industry sectors.

Challenges in expansion:

Biofuels remain more expensive than fossil fuels, with bioenergy being the most competitive, ranging from near parity for ethanol in some regions to more than twice the cost for Bio-Methane and Jet Bio-Fuel. While current bioenergy technologies have limited potential for cost reductions due to their reliance on feedstock prices, hydrogen, e-fuels, and emerging biofuels require a premium of over five times the average cost of fossil fuels.

Expanding biofuel production faces several challenges, including land use competition, food security concerns, feedstock availability and cost, and technical limitations. Additionally, environmental impacts, infrastructure constraints, and policy and regulatory issues pose hurdles to large-scale biofuel adoption.

As per IEA, in 2023, the electrolyzer costs rose nearly 20% from inflation, labor, and material costs, and higher interest rates. However, by 2030, hydrogen and e-fuel production costs could drop nearly 30%, and emerging biofuels by 9%, bringing their lowest-cost options closer to competitiveness with commercial renewable technologies, a consequence of mass production of electrolyzers, falling renewable electricity costs, optimized hydrogen production, and transition to commercial-scale projects. In hydrogen's case, additional infrastructure, storage, and equipment costs also contribute to the price.

There's vast potential for significant growth in renewable fuel usage; the International Energy Agency (IEA) projects deployment to more than double by 2030 from 2023 levels, and then double again by 2050, to align with Net Zero by 2050. However, none of the renewable fuels are currently in line with the projected scenario.

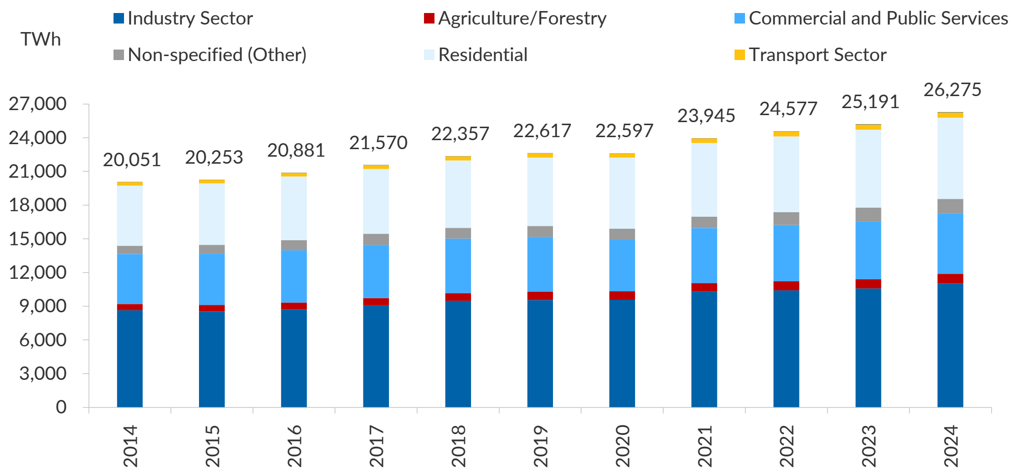
ELECTRICITY

The global energy economy is increasingly electrifying. Since 2010, electricity demand has increased on average by 2.7% per year, while overall energy demand has risen by 1.4% per year. Electricity is increasingly being used in place of fossil fuels to provide heat, mobility and industrial energy demand. Innovations such as smart grids and advances in the efficiency of electric motors and appliances have also boosted the appeal of electricity. The share of electricity in total final consumption risen more rapidly than in the past across almost all regions. This trend is a consequence of increased electrification in households and commercial buildings as well as in transport and industry. Most of this demand growth is from emerging markets and developing economies.

Global electricity landscape

Global electricity consumption in 2024 stood at 26,275 TWh which grew at a CAGR of 2.7% over the last decade. Current consumption is dominated by the industrial sector which accounted for 30% of total electricity consumed driven by growth in Data centers and manufacturing sector, over the last decade industry sector has always been a top electricity consumer growing at a CAGR of 2.5% and expected to stay at the top driven by manufacturing industry in the emerging economies.

Exhibit 28: Global electricity consumption



Source: IEA, YES Sec

In OECD countries, the consumption is evenly split among the three sectors: industry, residential, and commercial/public services, each using roughly 30 to 32% of the electricity. In non-OECD countries, industry accounts for almost half of the total electricity demand. Consumption patterns differ between OECD and non-OECD countries due to variations in economic structures and income levels. Trends also differ at an individual country level.

Global electricity demand rose by more than 2.5% in 2023 a rate similar to average of over the past decade. Two thirds of the increase in demand was driven by China due to increase in electrification of industries and increase in demand of appliances and cooling. Anticipating ahead, global electricity demand is projected to grow at an average annual rate of 3.5% from 2023 to 2050, with emerging economies continuing to drive the bulk of the increase as manufacturing is expected to increase in Asia post China plus one policy.

Electricity Supply

Globally, electricity supply has become more diverse than ever before, driven by rapid technological advancements and a rising global demand for electricity. As of 2024, the global electricity production stands at 31,103 TWh, growing at a CAGR of 2.6% over the last decade. Despite the increasing share of renewables, non-renewable sources still dominate electricity generation, serving as the backbone of industrial growth due to their abundance and cost-effectiveness. Despite this, fossil fuels, particularly coal and gas, still dominate the electricity supply but with a steady rise in low-carbon electricity production globally. Some countries, such as Sweden, Norway, and France, generate nearly all their electricity from low-carbon sources like nuclear and hydropower.

The regions that showed the biggest renewables-driven gains in 2024 include:

Asia, with over two-thirds of the global renewable capacity increase, mostly driven by China. China alone accounted for over ~50% of the global increase in solar generation. India also saw record-breaking growth, adding 24.5GW of solar capacity and 3.4GW of wind capacity, with states like Gujarat, Karnataka, and Tamil Nadu leading the expansions.

Europe, which expanded its renewable capacity significantly by over 70GW in 2024, largely due to strong growth in Germany, Spain, France, and Italy.

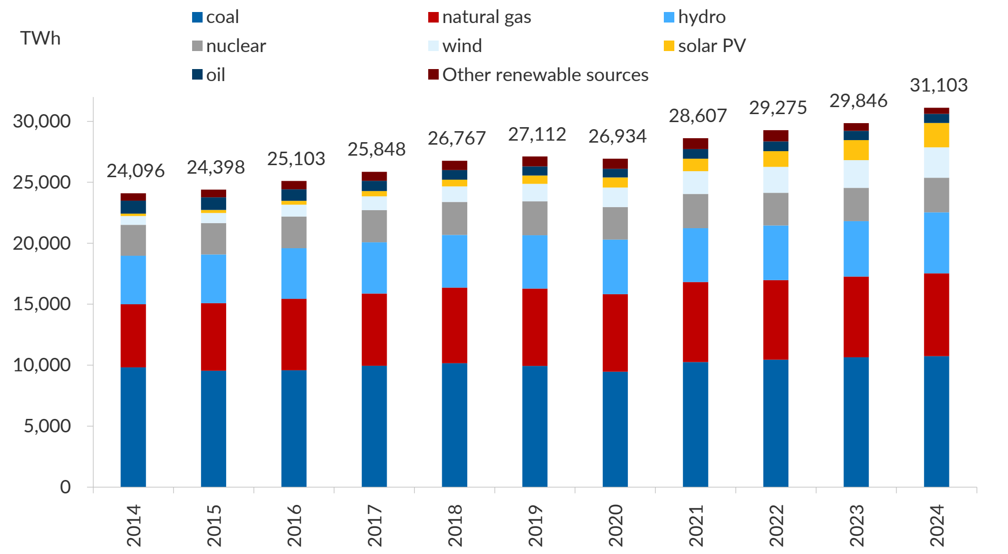
North America, with 45.9GW of new renewable capacity, driven by multiple installations largely in the US and followed by some in Canada.

Latin America and the Caribbean, which had one of the highest regional shares of renewables in their electricity mix, at over ~60% in 2023, and continued growth into 2024.

Other notable countries with strong renewable efforts include Brazil, Ethiopia, Indonesia, Nepal, Pakistan, Tanzania, Viet Nam, and New Zealand.

Solar power was the dominant source responsible for over three-quarters of the new renewable capacity added globally, followed by wind power, primarily in China and the US.

Exhibit 29: Global electricity generation



Source: IEA, YES Sec

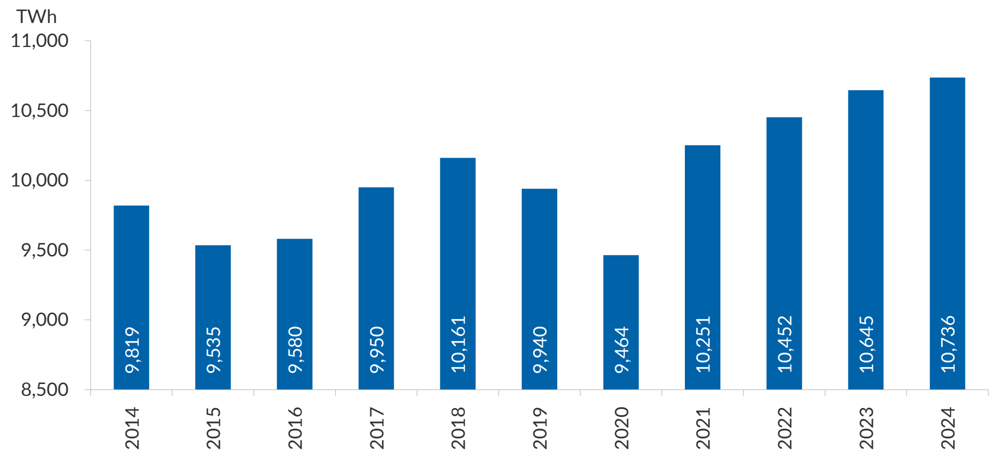
Major Non-Renewable Sources of Electricity Generation

Coal

Formation & Generation Process: Coal is a sedimentary rock formed over millions of years from compressed plant material. It is abundant across the globe and used in its raw form, making it easily transportable. Electricity generation from coal involves: Grinding coal into fine powder, Burning the powder to generate heat, creating steam, Steam spins a turbine, which powers a generator shaft, producing electricity.

Global Usage & Key Statistics: Coal remains the most used electricity source, accounting for 36% of total global electricity generation (10,736 TWh in 2024) which has grown at a CAGR of 0.9% over the last decade. Majority of coal was supplied by China followed by India then united states and Russia. Developed nations like the European Union and the U.S. have been reducing their coal dependency, while emerging nations continue to increase usage.

Exhibit 30: Electricity generation from coal



Source: IEA, YES Sec

Exhibit 31: Coal's advantage and concerns

Why is Coal Still Widely Used?

- **Efficiency:** Ranges between 30-45%, depending on factors like plant age, steam conditions, and coal quality.
- **Reliability in Baseload Power**: Unlike solar and wind, which are intermittent, coal plants provide 24/7 electricity, ensuring grid stability.
- **Transport & Storage Advantages**: Coal is easy to transport and requires no additional processing before use.

Challenges & Environmental Concerns

- **High Electricity Cost per Watt:** While affordable to set up, coal-based electricity has one of the highest generation costs.
- **Major CO2 Contributor:** Accounts for 43% of total CO2 emissions from energy-related activities. Three-quarters of all electricity-related CO2 emissions come from coal.
- **Emission Regulations:** Technologies to reduce pollutants like SO_2, NO_x, and particulate matter exist but are dependent on government regulations rather than technological availability.

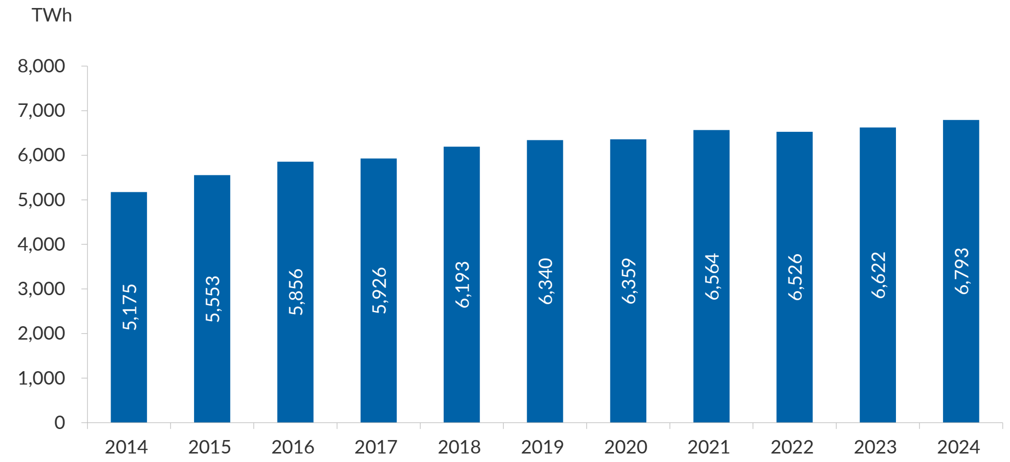
Source: Industry, YES Sec

Natural Gas

Generation Process: Natural gas-fired power plants operate by burning gas to produce heat, which is used to boil water into steam, spinning a turbine and generating electricity. In CCGT (Combined Cycle Gas Turbine) plants, the hot exhaust gases are reused to generate extra steam for a second turbine, increasing efficiency.

Global Usage & Key Statistics: Natural gas is the second most used electricity source after coal, contributing ~22% to global electricity production (6,793 TWh in 2024) growing at a CAGR of 2.8% since the last decade. Currently United States is leading in generating electricity through natural gas followed by Russia. Of the global usage, 1/3rd is US share followed by Russia which is half of US, then China which is 2/3rd of Russia. Electricity generated through natural gas is prominent in regions where natural gas is extracted and can be sourced cheaper than the global prices.

Exhibit 32: Electricity generation from Natural gas



Source: IEA, YES Sec

Exhibit 33: Natural gas advantages and concerns

Why is Natural gas Still preferred?

- **High Efficiency:** Traditional single-cycle plants have ~40% efficiency. However, CCGT plants reach up to 60% efficiency.
- **Lower CO2 Emissions Compared to Coal:** Produces less CO2 and other pollutants than coal (lower by 50%), and emits significantly lower amounts of SO2, NO2, and particulate matter, making it a cleaner fossil fuel option that helps improve air quality and mitigate climate change impacts.
- **Flexibility & Grid Stability**: Can ramp up and down quickly, balancing fluctuations in solar and wind output. Used to supply electricity during peak demand hours.

Challenges & Environmental Concerns

- **Methane Leaks**: Extraction and transportation result in methane emissions, which are highly potent greenhouse gases.
- **Price Volatility:** Natural gas prices fluctuate due to geopolitical tensions, supply-demand changes, and seasonal variations.
- **Energy Security Risks**: Countries without domestic reserves depend on imported LNG, increasing vulnerability to global price shocks.

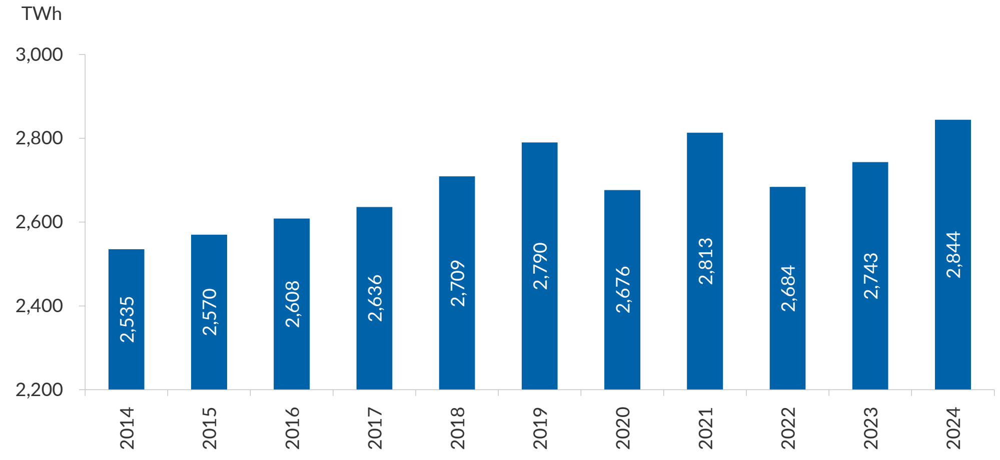
Source: Industry, YES Sec

Nuclear Energy

Generation Process: Nuclear power plants use uranium to generate electricity through nuclear fission. Uranium atoms split inside a reactor, releasing heat. The heat turns water into steam, spinning a turbine that powers a generator. The process has an efficiency of ~35%.

Global Usage & Key Statistics: Nuclear power accounts for ~9.1% of total global electricity production (2,844 TWh in 2024) growing at a CAGR of 1.2% over the last decade. Currently United States has the highest number of reactors (94) generating 96.65 GW of electricity followed by France (56 reactors) generating 61.37 GW of electricity then China (56 reactors) and Russia (36 reactors) generating electricity of 54 GW and 27 GW. South Korea and Japan are increasingly focusing on nuclear energy to reduce their reliance on natural gas.

Exhibit 34: Electricity generation from nuclear energy



Source: IEA, YES Sec

Exhibit 35: Advantages and associated Risks of nuclear energy

What's driving preference for nuclear power?

- **Reliable Baseload Power:** Operates continuously, complementing variable renewable energy sources like wind and solar.
- **Long Operational Lifespan:** Nuclear power plants can function for 50+ years.
- **Energy Security & Low Emissions:** Reduces reliance on imported fossil fuels. Emits zero CO2 during power generation, making it a key player in decarbonization efforts.

Challenges & Environmental Concerns

- **Expensive & Time-Consuming to Build:** High capital costs and long construction timelines (10+ years).
- **Limited Uranium Supply**: While longer lasting than coal and gas, uranium resources are finite.
- **Radioactive Waste Disposal:** Generates radioactive byproducts that are difficult and costly to manage.
- **Perceived Safety Risks:** Nuclear accidents (e.g., Chernobyl, Fukushima) have led to public resistance in many countries.

Source: Industry, YES Sec

Major Renewable Sources of Electricity Generation

Renewable energy is rapidly transforming the way we power our world, driven by the need for sustainable, low-carbon solutions and growing advancements in technology. From harnessing the sun's rays to capturing the power of wind and utilizing bio-based fuels, renewables are steadily reshaping the global energy mix. Global current electricity generation through renewable sources is 8645 TWh which is 29.5% of the global electricity generation. But as the world is increasing their focus towards net zero emissions electricity is expected to play a major role towards achieving that goal, share of renewable electricity in total electricity production is expected to be around 45% of total production by 2030.

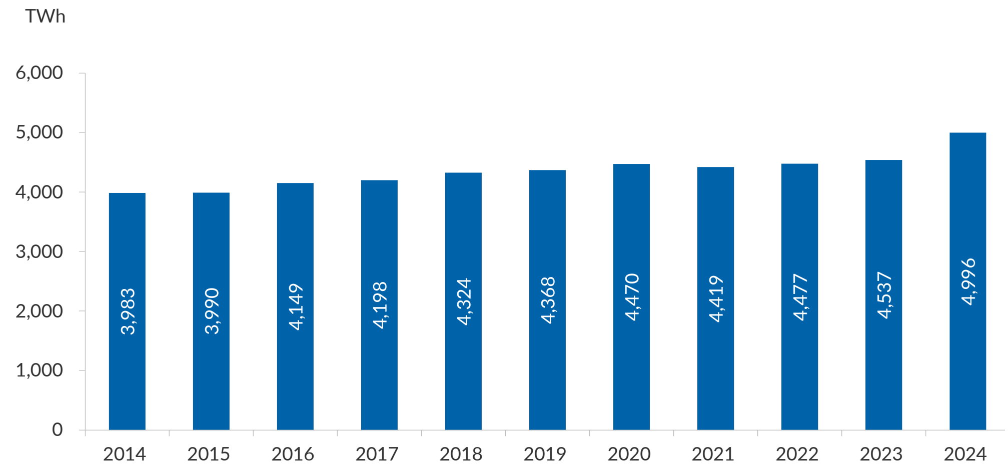
Hydro power

Generation Process: Hydropower is generated by kinetic energy of flowing water which is turned into mechanical energy by turbines then the hydroelectric generator then creates that mechanical energy into electricity, that electricity is then transferred to grids which supplies the electricity ahead. Hydropower is usually generated by creating dams which stores water in a reservoir and then when the water is released electricity is generated. There 3 different ways to generate electricity through hydro power.

- **Run-of-river hydroelectric power station:** This type of power station does not have a reservoir or dam to store large quantities of water before it reaches the turbines. It is the natural flow of the river, stream or any other natural energy source that is used to turn the turbines and produce electricity.
- **Reservoir hydroelectric power plant:** In this type of hydroelectric power plant, water is stored in a reservoir, which may be natural or dammed. It then travels through pipes to drive turbines to generate electricity and then returns to the river.
- **Pumping or reversible plants:** In this case, there are two reservoirs located at different levels. When the demand for energy rises, these two reservoirs operate as we have already seen, with water falling from the upper reservoir turning the turbines, remaining stored in the lower reservoir. When there is less demand, the water returns from the lower reservoir to the upper reservoir and the cycle starts again.

Global Hydropower Trends: Hydro is currently the most used green electricity source worldwide accounting for 50% of electricity generated through renewable sources while it is 16.1% of total electricity generated making it's the third most used source to generate electricity. Globally electricity generated using hydro power is 4.996 TWh in 2024 growing at a CAGR of 2.3% since the last decade. Currently China has the highest capacity to generate electricity through hydro power with capacity of 370.6 GW followed by Brazil with 109.9 GW then USA with 90.3 GW.

Exhibit 36: Electricity generation from Hydro power



Source: IEA, YES Sec

Exhibit 37: Opportunities and Concerns in Hydropower Development

What makes Hydro power attractive choice?

- **Highest Efficiency:** Hydropower is the most efficient renewable energy source, with a conversion efficiency of ~90%.
- **Flexible & Reliable:** Some hydropower plants can quickly ramp up or down, providing backup power during outages.
- **Additional Benefits:** Dams help control floods, support irrigation, and provide clean drinking water.

Challenges & Environmental Concerns

- **Environmental Impact:** While hydropower reduces carbon emissions, building large dams generates greenhouse gases.
- **Climate Sensitivity:** Droughts, low rainfall, and reduced snowfall affect hydro output, making it unreliable in some regions.
- **Land & Cost Challenges:** Finding suitable land for large hydro projects is difficult and expensive.

Source: Industry, YES Sec

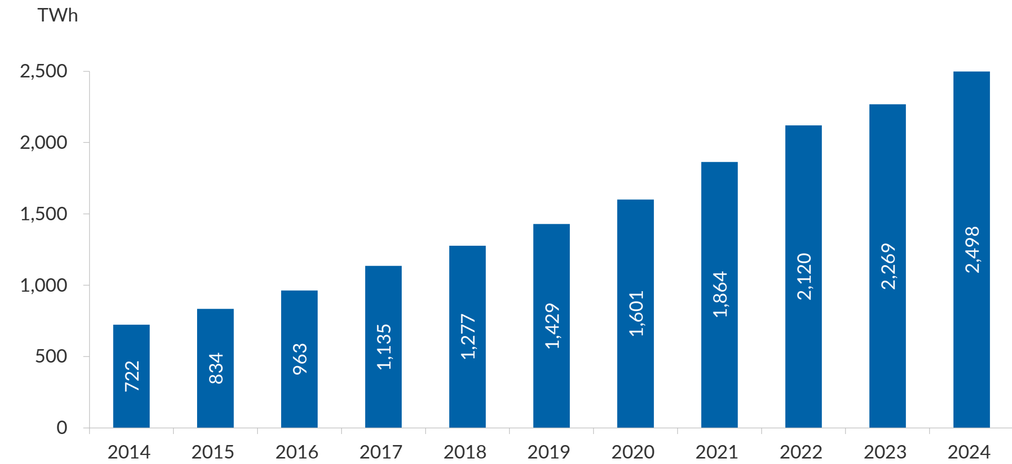
Wind energy:

Generation Process: For generating electricity through wind, a turbine is set in a field where wind blowing across the blades of a wind turbine creates a difference in air pressure on either side of the blade. This difference in air pressure causes the blade to spin, creating lift and drag. The lift is stronger than the drag, which causes the rotor to spin. The rotor is connected to a generator through a shaft and gear, the spinning rotor then spins the generator which generates the electricity. The electricity is sent through a wire to a transformer, which increases the voltage for transmission. The high-voltage electricity is then transferred to power distribution grid which supplies the electricity. while the source is same there are two different wind technology

Offshore wind technology

Offshore wind turbines are installed in seas and oceans, where wind speeds are stronger and more consistent. The Global Offshore Wind Capacity is at ~83GW as of Jun'25 as per the Global Wind Energy Council (GWEC).

Exhibit 38: Electricity generation from Wind



Source: IEA, YES Sec

Exhibit 39: Opportunities and Concerns in Offshore wind technology

Advantages	Challenges
▪ Higher & more stable wind speeds result in higher energy output. ▪ No impact on land usage or residential areas.	▪ High construction costs and complex installation requirements. ▪ Frequent maintenance due to strong ocean winds and waves.

Source: Industry, YES Sec

Onshore wind technology

Onshore wind farms are built on land with minimal obstacles to airflow. The Global Onshore Wind Capacity is over ~1,00GW as of early 2025 as per the Global Wind Energy Council (GWEC).

Exhibit 40: Opportunities and Concerns in Onshore wind technology

Advantages	Challenges
▪ Lower cost to build & maintain compared to offshore turbines. ▪ Can be developed relatively rapidly as they are easier to construct and connect to the grid. Easier access for repairs and maintenance.	▪ Electricity is generated only when wind speeds are sufficient, necessitating to be backed up by alternative sources when wind is not strong enough. ▪ Some communities oppose wind farms due to noise pollution, can be difficult to get approval if residents do not approve of.

Source: Industry, YES Sec

Globally electricity generated through wind is 2498 TWh growing at a CAGR of ~13.2% since the last decade. Currently wind electricity produces about 25% electricity generated from renewables while it stands around 7.2% of electricity generated globally. As per IEA forecast Onshore wind capacity is expected to reach ~1,700GW by 2030 (CAGR of ~14%) from current ~1000GW and Offshore is expected to reach ~220-300GW by 2030 (CAGR of ~27-35%) from current 83GW. The addition from onshore is expected to increase the most from China followed by European union and USA, while the Offshore addition is expected to boost from supply from European union followed by united states and Japan.

Solar Energy

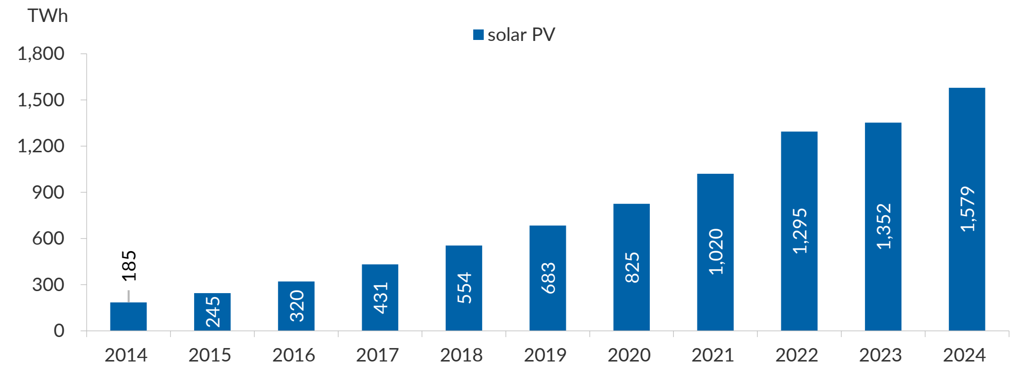
Generation process: Solar photovoltaic (PV) systems generate electricity by converting sunlight directly into electrical energy. When sunlight strikes the PV cells, typically made of semiconductor materials like silicon, it excites electrons, creating an electric current. This current flows through an electrical circuit, producing direct current (DC) electricity, which is then converted to alternating current (AC) using an inverter for use in homes, businesses, and the grid.

Efficiency: The efficiency of solar PV systems, defined as the percentage of sunlight converted into usable electricity, has steadily improved over the years due to advancements in materials and technology. Most commercial solar panels today operate with efficiencies ranging between 15%-22%, with high-performance models reaching up to 26%. However, certain environmental factors, such as temperature, shading, and panel orientation, can influence performance. While sunlight is abundant, the relatively low efficiency of PV systems compared to other energy sources means larger installations are often required to meet significant energy demands. Despite this, ongoing research into technologies like multi-junction cells and perovskite materials holds promise for significantly boosting solar PV efficiency in the near future.

Global Trends

- Currently Solar PV contributes merely 5.1% of the total electricity generation and ~16% among the renewable pack at 1,579 TWh as of 2024. Despite being significantly lower proportionately, it has grown at the highest CAGR of 23.5% over the last decade, making it the most promising source of renewable energy for the future.
- In 2024, Solar experienced third highest absolute generation growth (227 TWh) just falling short behind Wind (270 TWh) and Hydropower (459 TWh) having the highest generation growth.
- In 2024, Solar PV contributed to 77% of global renewable capacity additions.
- Over the next five years, renewable power capacity is expected to grow significantly, with solar PV and wind making up 96% of these additions, driven by their lower generation costs compared to most fossil and non-fossil alternatives and sustained policy support.
- By 2030, Solar PV installations are projected to more than double from 2024 levels, setting new records annually and doubling reaching nearly 4,000 GW as per IEA.
- This growth aligns with the trajectory outlined for 2023-2030 in the Net Zero Emissions by 2050 Scenario.
- Factors such as the improving economic competitiveness of PV systems, substantial advancements in the supply chain, and stronger policy support particularly in China, the United States, the European Union, and India which are anticipated to further drive capacity expansion in the years ahead. While regions of Africa are expected to have increase in supply of electricity as expansion of solar parks in Sahara Desert will be a key factor of expansion in solar PV capacity.

Exhibit 41: Electricity generation from Solar PV



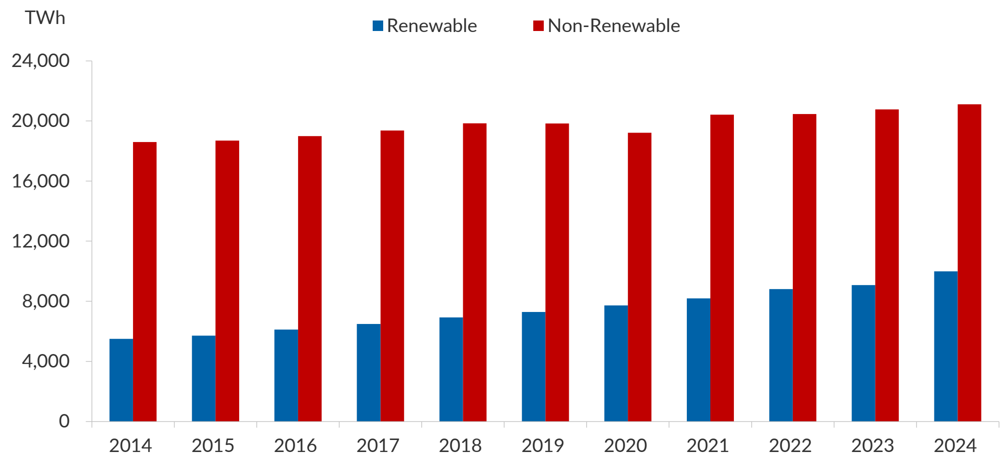
Source: IEA, YES Sec

Electricity generated through non-fossil

Electricity **generated through non-fossil** sources have increased nearly two-fold since the last decade driven by the growth from different sources while the traditional sources stay stable.

Renewables alone supplied over 30% of the global electricity, with solar PV and wind increasing generation. The growth in non-fossil electricity was driven by record expansions in solar PV capacity, wind power, hydropower, and nuclear energy. Around 80% of the growth in global electricity generation in 2024 came from non-fossil sources. This trend is helping to limit the rise in CO2 emissions despite increasing electricity demand globally.

Exhibit 42: Electricity generation over the years



Source: IEA, YES Sec

India's non-fossil fuel power capacity as of FY25 is at 46% share is significantly higher than the global share, which stood at ~32% in 2024. India has achieved this milestone of 46% non-fossil capacity (220 GW out of 475.2 GW total capacity) ahead of its 2030 target, reflecting an accelerated shift toward renewables.

India's share surpasses the global average by about 14 percentage points, showing stronger commitment and progress in expanding clean energy sources. However, coal-based thermal power, which remains significant in India (~45% of capacity), still plays a critical role in balancing the energy mix and meeting demand.

Thus, India is ahead of the global average in non-fossil power capacity, positioning itself as a leader in transitioning toward cleaner power generation.

Solar supersedes other renewable alternatives

Levelized Cost of Electricity (LCOE)

The Levelized Cost of Electricity (LCOE) is a fundamental tool for comparing the economic viability of various power generation technologies over their lifetimes. It represents the per-unit cost (e.g., per megawatt-hour) of building and operating a power plant, averaged across its entire operational life (the lower the better).

Below are the LCOE for various energy sources comparing Indian perspective.
The key assumptions used for this comparison are: A 7% discount rate, representing the cost of capital, a carbon price of USD30/ton, to incorporate the environmental cost of emissions, a heat price of USD37/MWh, representing the cost of fuel for thermal generation, a 100% coal price assumption, reflecting the reliance on coal in India's energy mix.

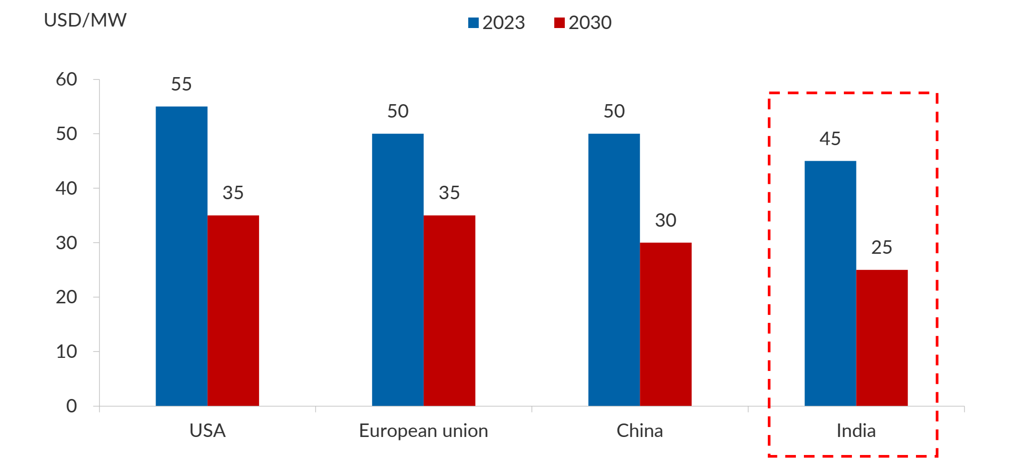
The LCOE values for each plant category are as follows:

Exhibit 43: LCOE factor across key countries

	Capital cost (USD/KW)			Capacity factor (%)			Fuel, CO2, O&M (USD/MW)			LCOE (USD/MWh)		
Year	**2023**	**2030**	**2050**	**2023**	**2030**	**2050**	**2023**	**2030**	**2050**	**2023**	**2030**	**2050**
United States												
Nuclear	5,000	4,800	4,500	90	90	85	30	30	30	110	110	110
Coal	2,100	2,100	2,100	40	20	n.a.	35	35	35	105	165	n.a.
Gas CCGT	1,000	1,000	1,000	55	40	15	35	40	40	60	70	120
Solar PV	1,110	690	480	20	22	23	10	10	10	55	35	25
Wind onshore	1,500	1,430	1,370	42	43	44	10	10	10	40	35	35
Wind offshore	4,060	2,760	1,980	41	46	49	35	25	15	125	80	55
Electricity generation Cost (Weighted Average)										**60**	**70**	**70**
European Union												
Nuclear	6,600	5,100	4,500	70	75	75	35	35	35	170	135	125
Coal	2,000	2,000	2,000	20	n.a.	n.a.	155	170	180	290	n.a.	n.a.
Gas CCGT	1,000	1,000	1,000	20	10	n.a.	130	110	120	205	260	n.a.
Solar PV	750	480	340	14	14	14	10	10	10	50	35	25
Wind onshore	1,630	1,490	1,480	29	30	30	15	15	10	60	55	50
Wind offshore	3,120	2,280	1,660	50	55	56	15	10	10	70	45	35
Electricity generation Cost (Weighted Average)										**130**	**110**	**80**
China												
Nuclear	2,800	2,800	2,500	80	70	70	30	30	30	75	80	75
Coal	800	800	800	55	35	15	55	50	50	70	80	120
Gas CCGT	560	560	560	30	20	15	80	70	75	100	105	115
Solar PV	670	410	280	13	13	13	10	10	10	50	30	25
Wind onshore	990	940	900	24	25	26	10	10	10	45	40	40
Wind offshore	2,380	1,720	1,260	32	37	40	20	15	10	90	60	40
Electricity generation Cost (Weighted Average)										**80**	**80**	**65**
India												
Nuclear	2,800	2,800	2,800	75	85	90	30	30	30	75	70	70
Coal	1,200	1,200	1,200	70	70	65	40	35	35	60	55	55
Gas CCGT	700	700	700	30	35	45	120	85	80	150	110	100
Solar PV	710	450	300	20	21	22	5	5	5	45	25	20
Wind onshore	1,210	1,150	1,090	26	28	30	15	10	10	60	55	45
Wind offshore	2,620	1,960	1,360	33	36	39	25	15	10	115	80	55
Electricity generation Cost (Weighted Average)										**85**	**70**	**55**

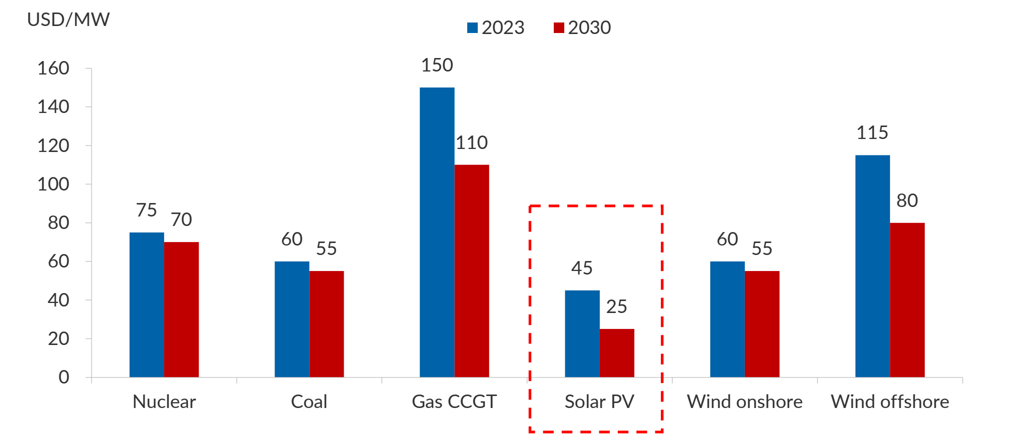
Source: IEA, YES Sec

Exhibit 44: LCOE of solar PV across different markets



Source: IEA, YES Sec

Exhibit 45: LCOE of different segments in India



Source: IEA, YES Sec

India LCOE comparison:

- **Solar and Wind:** solar has the lowest LCOE value of USD45/MWh while Onshore wind generation has one of the lowest LCOE which is USD60/MWh, Offshore wind's LCOE is USD115/MWh respectively for the year 2023, but as the manufacturing is expected to boost the LCOE is for the same in the year 2030 is expected to be USD25/MWh for solar and USD55/MWh for Onshore wind and USD80/MWh for Offshore wind making them the most cost-effective sources of electricity in this comparison. Given their lower LCOE, these sources are likely to play a critical role in India's renewable energy transition, especially with a focus on sustainability and cost containment.
- **Nuclear:** nuclear (USD75/MWh) has moderate LCOE values for the year 2023 but the cost is expected to come down (USD70/MWh) by 2030, suggesting a higher cost compared to solar and wind. However, it could still be viable options, particularly for providing baseload power and stabilizing the grid.
- **Coal (Standard and High):** Coal-based electricity has significantly higher LCOE values, especially under the high coal price scenario, with LCOE of USD60/MWh in 2023 but is expected to stabilize around USD55/MWh by 2030. Given the environmental costs associated with coal, this places it as a less favorable option compared to renewable sources, both in terms of cost and sustainability but will continue to play an important role in India.

- **Natural Gas:** Generating electricity using natural gas remains the most expensive at USD150/MWh in 2023 due to elevated demand from city gas distributers, fertilizers and other industries. Any diversion of supply from these sectors would create an upward pressure on price unless supported by additional supply. The LCOE is expected to moderate to USD110/MWh by 2030 which is still the highest among other alternatives.

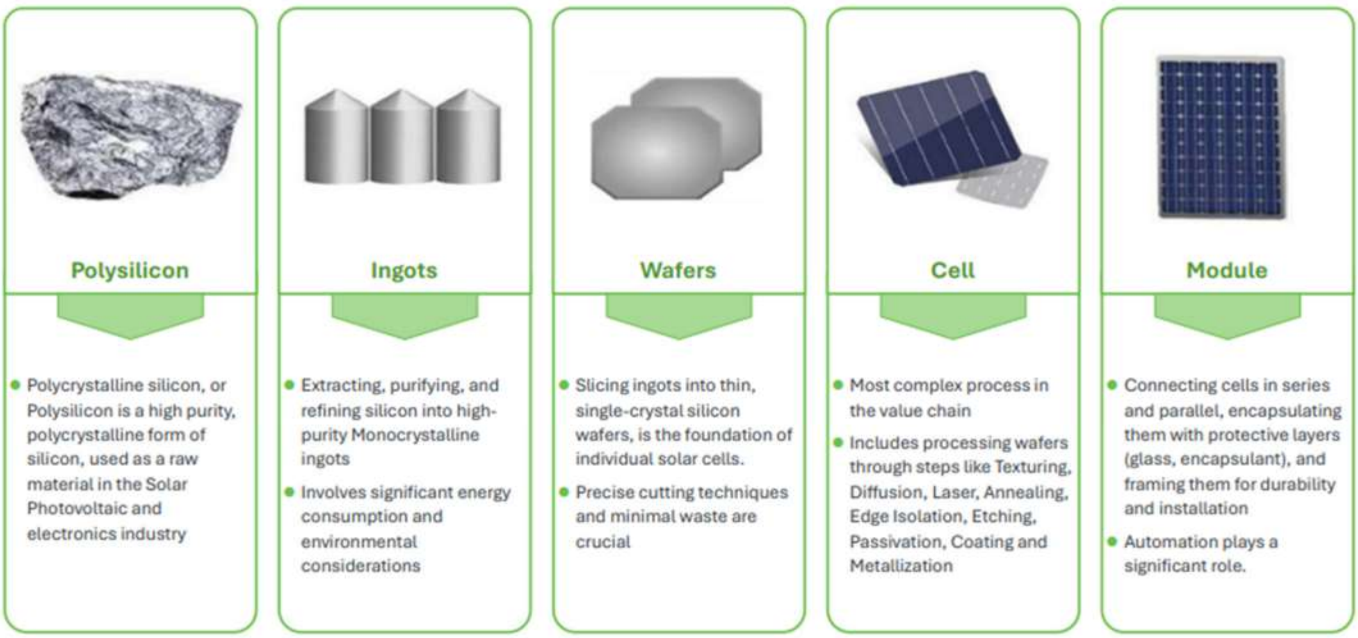
Despite the wide acceptance of LOCE for cost competitiveness, it does not fully capture the broader value provided by power technologies to the electricity system, such as reliability, adequacy, and system services like frequency control.

For instance, adding battery storage to a solar project raises its LCOE due to higher costs and reduced output efficiency, but it enhances the project's overall value by improving grid services and aligning output with system demand. This shows that a technology with a higher LCOE may still be more valuable overall.

With the increasing share of variable renewables like solar and wind, electricity demand patterns are changing, emphasizing the importance of system services beyond just LCOE. As solar power grows, for example, it shifts peak demand hours and calls for greater system flexibility, making it crucial for planners and investors to consider both costs and system value when evaluating energy projects.

Building on this understanding of LCOE and the evolving role of power technologies in the grid, it's essential to delve deeper into the specific characteristics of Solar PV technology. Solar PV not only offers a competitive LCOE but also plays a pivotal role in reshaping energy systems due to its adaptability, scalability, and low operational costs. To fully grasp its potential, we need to explore its value chain; from manufacturing and installation to grid integration and storage solutions. This allows us to understand the broader implications of solar PV's role in meeting future energy demands and its capacity to provide critical grid services, ensuring a reliable, sustainable energy future. Today, electricity-intensive solar PV manufacturing is mostly powered by fossil fuels, but solar panels only need to operate for 4-8 months to offset their manufacturing emissions.

Exhibit 46: Solar Photovoltaic (PV) Technology process

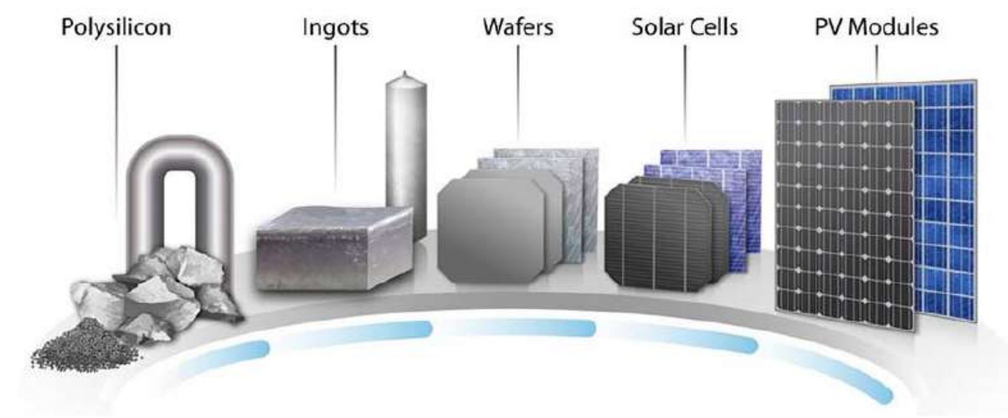


Source: Company, Industry, YES Sec

Solar photovoltaic (PV) technology is the backbone of renewable energy transitions. It transforms sunlight into electricity using semiconductor materials. The PV module, commonly called a solar panel, is the central component of solar power systems.

Solar PV's combination of accessibility, cost-effectiveness, growing efficiency, and environmental sustainability cements it as a foundational technology for the global energy transition toward a low-carbon future.

Exhibit 47: Solar PV process



Source: Industry, YES Sec

Two major types of PV technologies dominate the global market:

- **Crystalline Silicon (c-Si) Modules:** Represent over 95% of production due to their high efficiency and reliability.
- **Thin-Film Modules (e.g., Cadmium Telluride or CdTe):** Known for cost efficiency and ease of large-scale manufacturing, though they hold a smaller market share.

We will focus Crystalline Silicon (c-Si) Module Manufacturing Process

Raw Material Extraction and Purification

The starting material for Crystalline Silicon modules is silicon, which is abundant in sand and quartzite. The process begins with:

- **Quartz Mining:** Quartzite, a high-purity form of silicon dioxide (SiO_2), is extracted through mining. It undergoes initial cleaning to remove impurities.
- **Carbothermic Reduction:** Quartz is heated in a furnace with carbon (in the form of coal or woodchips) at temperatures exceeding 1,900°C to produce metallurgical-grade silicon (MG-Si). This silicon has 98–99% purity.
- **Polysilicon Production:** To achieve the ultra-pure silicon needed for solar cells, MG-Si is further refined into polysilicon. Two main processes are used:
  - **Siemens Process:** MG-Si is converted into trichlorosilane ($HSiCl_3$) gas, which is then decomposed at high temperatures to deposit pure silicon. This method produces high-purity silicon (>99.9999%).
  - **Fluidized Bed Reactor (FBR):** A newer, more energy-efficient process where silicon containing gas is injected together with hydrogen through nozzles at the bottom to form a fluidized bed that carries tiny silicon particles fed above.

Ingot Formation

The purified polysilicon is melted and formed into ingots, the solid blocks of silicon from which wafers are cut. Two methods are employed:

- **Monocrystalline Silicon Ingots:** Created using the Czochralski (CZ) process, where a seed crystal is dipped into molten silicon and slowly pulled upward while rotating. This produces a single-crystal structure with high uniformity, essential for high-efficiency solar cells.
- **Polycrystalline Silicon Ingots:** Formed by melting silicon and allowing it to solidify in a mold. The result is a polycrystalline structure, which is less efficient but cheaper to produce.

Wafer Production

Wafers are thin slices of silicon cut from the ingots. This step involves:

- **Cutting with Diamond Wire Saws:** The ingots are sliced into wafers as thin as 150–200 micrometers (µm). The use of diamond-coated wires minimizes material loss and improves precision.
- **Texturing:** The wafers undergo chemical etching to create a textured surface, which reduces light reflection and enhances light absorption.
- **Cleaning and Inspection:** Wafers are cleaned to remove any contaminants and inspected for thickness, uniformity, and defects.

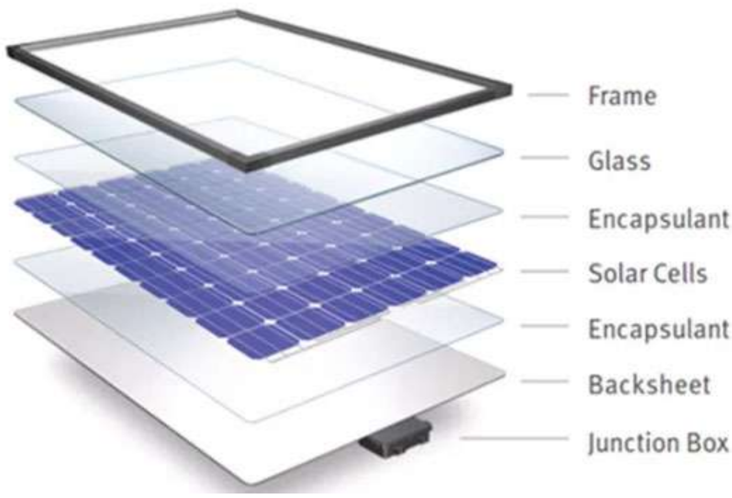
Solar Cell Manufacturing

The wafers are transformed into solar cells through a series of chemical and physical processes:

- **Doping:** Wafers are exposed to gases like phosphorus or boron to create the p-n junction, a critical feature for electricity generation.
- **Anti-Reflective Coating:** A thin layer, typically silicon nitride, is applied to the wafer surface to reduce reflectivity and increase light absorption.
- **Metal Contacts:** Fine lines of conductive silver paste are screen-printed onto the wafer surface to create the grid-like structure that collects and transports electricity.
- **Annealing:** The cells are heated in a furnace to solidify the contacts and improve electrical conductivity.
- **Testing:** Each cell is tested for efficiency, voltage, and current output before assembly.

Module Assembly

Exhibit 48: Module Assembling Process



Source: Industry, YES Sec

The individual solar cells are assembled into modules, a process that ensures their durability and functionality. The key steps are:

- **Stringing and Tabbing:** Solar cells are interconnected using solder-coated copper ribbons to form strings.
- **Encapsulation:** The cell strings are sandwiched between layers of ethylene vinyl acetate (EVA) or polyolefin elastomers (POE), which protect them from environmental factors.
- **Lamination:** The encapsulated cells are laminated with tempered glass on the front and a polymer back sheet on the rear. Lamination ensures structural integrity and weather resistance.
- **Framing:** An aluminum frame is added for additional mechanical support and ease of installation.
- **Junction Box Installation:** A junction box is attached to the back of the module to house electrical connections and diodes, which prevent power loss during shading.

Solar module technology supply chain

Exhibit 49: Solar Cell and Solar Module differentiation

Factors	Solar cells	Solar modules
Raw Materials:	Requires ultra-high-purity silicon, with stringent refining processes to ensure optimal efficiency, along with additional materials like silver and phosphorous.	Uses prefabricated cells, minimizing the need for raw material processing and simplifying material sourcing to focus on integration.
Processing:	Involves advanced steps like crystal growth, doping, and thin-film deposition, requiring high precision and sophisticated machinery.	Primarily involves the assembly of cells, including tasks like interconnection, encapsulation, and lamination, which are less technically demanding than cell fabrication.
Capital Investment:	Significant upfront investment is needed for specialized equipment, cleanroom environments, and advanced technologies in silicon purification and cell fabrication.	Capital investment is lower as the focus is on assembly and integration, requiring less specialized equipment and machinery.
Skilled Labor:	Requires highly trained personnel with expertise in semiconductor fabrication, chemical processing, and precise engineering.	Needs skilled labor for assembly, testing, and quality control but requires less specialized knowledge than solar cell manufacturing.
Production Scale:	Smaller production scale due to the intricate nature of fabrication, which limits throughput and efficiency.	Easier to scale, as the process is focused on assembly and testing, which allows for higher-volume manufacturing.
Technological Advancement:	Rapid pace of technological change, with innovations in materials and manufacturing methods often leading to improvements in efficiency and cost reduction.	Technological advancements are slower and more focused on incremental improvements in design, durability, and efficiency.
Supply Chain Management:	Complex supply chains are needed to handle diverse raw materials and ensure purity, with tightly controlled processes to avoid contamination.	Simplified supply chain focusing mainly on sourcing pre-manufactured cells and other components like glass, frames, and back sheets.
Technological Requirements:	Demands cutting-edge technology to maximize efficiency, such as new cell architectures and improved materials, driving ongoing innovation.	Primarily focused on assembly technology and ensuring long-term performance, with fewer technological breakthroughs compared to cell production.
Quality Control:	Rigorous quality control is essential to ensure the efficiency and longevity of the cells, with extensive testing at each step of production.	While still requiring quality control, the focus is more on module integrity, performance under various conditions, and final product reliability.
Environmental Impact:	Manufacturing processes are energy-intensive and may involve chemicals that require safe disposal, posing environmental concerns that need addressing.	Module production has a relatively lower environmental footprint, as the main focus is on assembling pre-made cells and using materials like aluminum frames that can be recycled.
Market Dynamics:	The market for solar cells is highly competitive, with constant innovation and rapid improvements in technology pushing manufacturers to stay ahead.	The module market is more focused on mass production and cost efficiency, with less frequent changes in design but strong competition for large-scale contracts.
Innovation Pressure:	High pressure to continuously innovate due to the rapid evolution of photovoltaic technologies, making previous methods obsolete.	Less innovation pressure as most improvements are incremental, focusing on optimizing the assembly process and module design.
Product Lifecycle:	Shorter product lifecycles due to the fast pace of technological advancements, with new models replacing older ones more frequently.	Longer product lifecycles since the focus is more on assembly and incremental improvements in module design, meaning older models remain viable longer.

Source: Industry, YES Sec

Over the past decade, the global solar PV manufacturing landscape has undergone a major geographical shift, with China solidifying its dominance across all production stages. Between 2010 and 2021, China significantly expanded its manufacturing capabilities in wafers, cells, and modules, increasing its share in global polysilicon production capacity nearly threefold. As of currently in 2025, China accounts for over 80% of global solar PV manufacturing, a share that is more than double.

Key reasons for China's dominance include a) low-cost electricity for industrial use; b) strong government policies supporting solar manufacturing; c) Economies of scale in the solar PV supply chain; d) availability of key raw materials; e) particularly silicon and polysilicon.

Silicon has many other uses like manufacturing of semi-conductors, used for making alloys like aluminum, glass, Portland cement, etc.

Although stationary storage applications for silicon remain limited due to lower energy density requirements, the industry continues to respond dynamically to demand shifts.

Global Polysilicon Capacity & Production

Global polysilicon capacity in 2024 was 3.25mmt, out of which China's share is 93.5%. In terms of solar-grade polysilicon, it accounted for ~79% of the total global polysilicon market, this means around 2.57mmt of the total capacity was solar-grade polysilicon. China accounts for a dominant share of this capacity, producing ~95% of the world's solar-grade polysilicon.

Exhibit 50: Polysilicon production cost

Cost component	% share
Raw materials	38%
Other materials	28%
Energy and depreciation	10% each
Labour, Maintenance and Other expenses	14%

Source: Industry, YES Sec

Since 2015, the market has fluctuated between oversupply and supply tightness for polysilicon:

- **2015-2020:** Oversupply led to falling prices.
- **2021:** Supply tightened, causing a price surge.
- **2023:** A new oversupply situation emerged, leading to a 74% price drop to around USD 8/kg.
- **2025 -current:** The prices have seen some fluctuations but remain relatively stable around USD 6.2/kg due to production adjustments and supply-demand balance efforts, particularly by Chinese manufacturers.

China's Dominance in Polysilicon Production

In 2024, global polysilicon production stood at ~1.8mt, with China accounting for over 93%. For 14 consecutive years, China has been the world's largest polysilicon producer, holding over 50% of global production for the past 8 years. Beyond polysilicon, China dominates the entire solar supply chain, including raw material mining & refining, manufacturing of critical inputs like ingots & wafers (over 90% share).

Given its strategic importance, polysilicon manufacturing needs diversification to ensure security of supply in case of geopolitical tensions or trade restrictions, reduced market concentration, preventing over-reliance on a single country, increased competition, leading to better pricing and innovation.

In H12025, the Chinese production has dropped and 2025 will end lower. The Chinese government is pushing for industry reforms to reduce overcapacity and improve quality, including a plan to acquire and shut down around one-third of production capacity to curb the ongoing oversupply and price pressures.

China's dominance in polysilicon production forms the backbone of the global solar PV manufacturing industry, underpinning the world's rapid expansion of solar power capacity.

Electricity is the Key Factor for Competitive Solar PV Manufacturing

- Low-cost electricity is critical for maintaining competitiveness in polysilicon and wafer production.
- Electricity accounts for 40% of production costs for polysilicon.
- It makes up ~20% of costs for ingots and wafers.

Around 80% of electricity used in polysilicon production is consumed in China, where the average industrial electricity price is USD 75/MWh, 30% lower than the global industrial price average.

Cost Competitiveness: Why China Leads the Solar Supply Chain

Maintaining competitiveness in these segments requires that manufacturers have access to comparable or lower electricity costs. China is the most cost-competitive location to manufacture all components of the solar PV supply chain. Costs in China are 10% lower than in India, 20% lower than in the United States, and 35% lower than in Europe.

Exhibit 51: China's Cost competitiveness

Key reasons for China's lower costs	Challenges in Breaking China's Dominance
▪ Lower electricity prices (30% below global average). ▪ Lower labor costs & manufacturing scale efficiencies. ▪ Government incentives & tax policies supporting solar manufacturing. ▪ Well-integrated supply chain with domestic production of key raw materials.	▪ High energy costs in other countries make large-scale polysilicon and ingot production less competitive. ▪ Lack of financial support and investment incentives outside of China slows diversification efforts. ▪ Few countries in Southeast Asia have emerged as alternatives, but their capacity remains limited.

Source: Industry, YES Sec

Potential Solutions for Diversification: Government-led financial incentives to support local PV manufacturing outside China and strategic partnerships between solar manufacturers in the US, Europe, and India to create alternative supply chains.

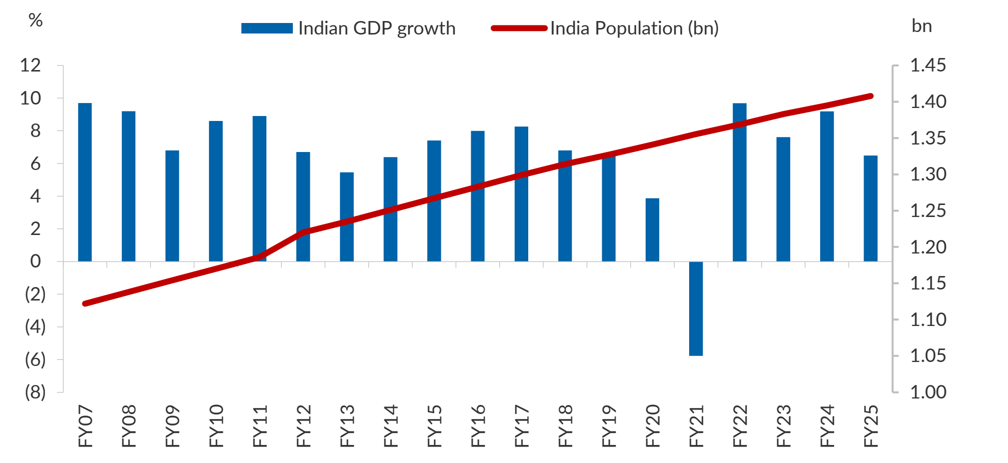
We believe anyone backward integrating towards Ingot/wafers can achieve good economies of sales in longer term as experienced by LONGI solar and Jinko solar which have achieved consistent returns compared to their peers.

INDIA STORY

India's GDP: 20-Year Overview

India's GDP has shown robust growth over the past 20 years, marked by significant economic expansion, and increasing global prominence.

Exhibit 52: India's Historical GDP trend



Source: CEIC, YES Sec

Over the past two decades, India has emerged as one of the fastest-growing major economies, experiencing fivefold GDP growth from USD 710bn in 2004 to USD3.57trn in FY23 (at constant 2012 prices) and today stands at USD3.8trn. This remarkable expansion has been fueled by rapid industrialization, technological advancements, increased foreign investments, and a growing services sector.

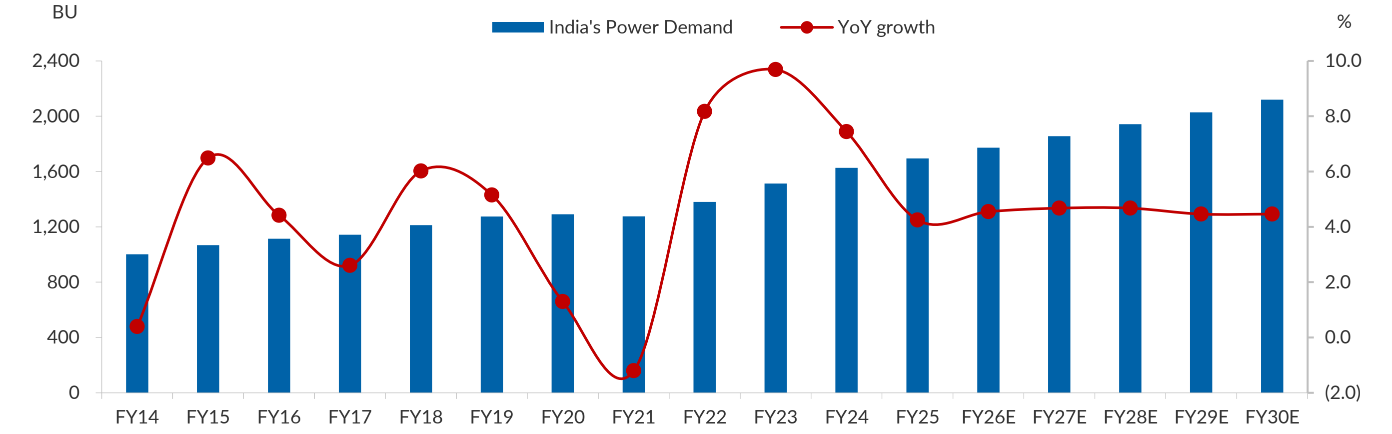
The Indian economy showed resilience despite global downturns, including the 2008 financial crisis and the COVID-19 pandemic in 2020, where GDP contracted by 5.8%, however, it rebounded swiftly, and has averaged 6.1% in the last decade. The structural reforms introduced under initiatives like Make in India, Digital India, and Aatmanirbhar Bharat have further strengthened the economy.

India's energy consumption has surged due to industrialization, urbanization, and increasing per capita electricity use. From 2002 to 2024, India's primary energy consumption more than doubled, with a sharp rise in electricity demand across residential, industrial, and commercial sectors.

Electricity Consumption Trends in India

Electricity consumption in India has nearly tripled since 2000, reflecting rapid industrialization, urbanization, and expanding electrification. From around 400 kWh per capita in 2000, consumption rose to ~1,400 kWh per capita in 2024, signaling a growing energy demand across all sectors. The trend has been shaped by economic growth, increased household electrification, and policy-driven subsidies for various consumer categories.

Exhibit 53: India's Power Demand to grow at a CAGR of 4.6% for FY26-30



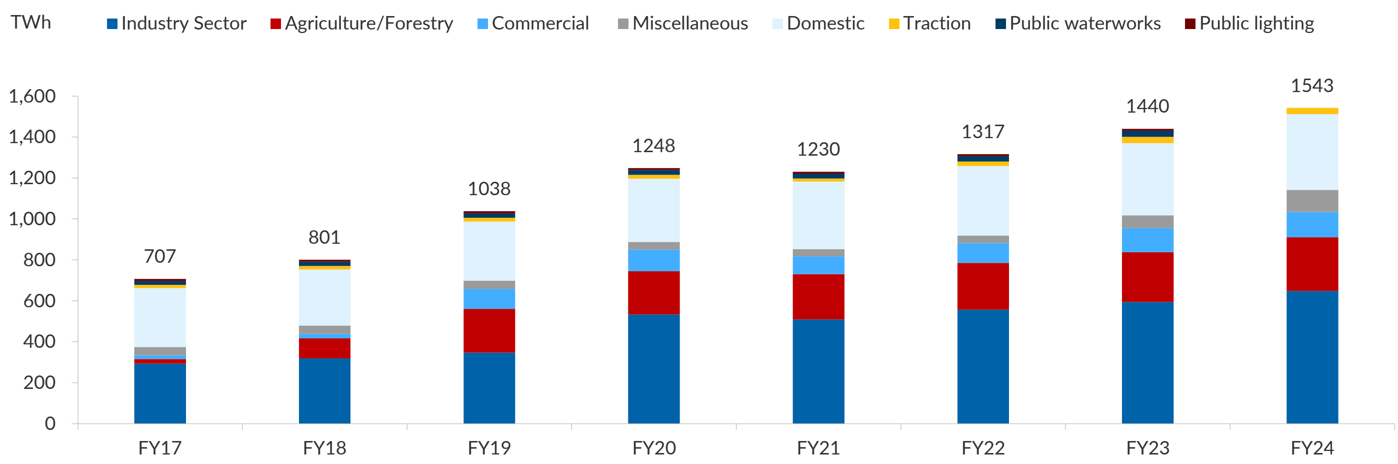
Source: CEA, YES Sec

India's electricity demand has steadily increased from 1,002BUs (billion units) in FY14 to 1,695 BUs in FY25. Over the last decade (FY15–FY25), demand grew at a CAGR of ~4.9%. In the more recent five-year period (FY20–FY25), growth has accelerated, with demand rising at a ~5.6% CAGR, underpinned by rapid economic recovery post-pandemic, increased manufacturing activity, and higher electrification of both rural and urban areas. This acceleration highlights a clear upward shift in India's power consumption trajectory, indicating growing energy intensity of the economy.

This was led by Industrial sector which consumed the largest share of electricity, followed by domestic, agriculture, and commercial sectors. This shift was primarily boosted by the additions in renewable energy capacity which has been growing significantly, making up a substantial portion of installed capacity, aiding the transition toward sustainable energy sources and alternative power source to the increasing demand. Power outages have drastically reduced in recent years, supporting uninterrupted demand growth.

As per our projections, we foresee power demand growth at a CAGR of ~4.6% (adding 424BUs) for period FY26-30 and a capacity addition of over 250GW for the same period.

Exhibit 54: India's Electricity Consumption pattern

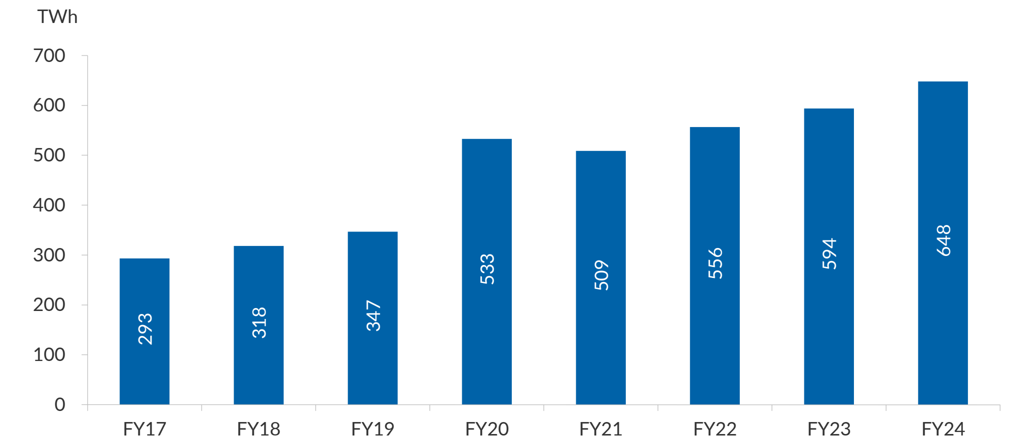


Source: CEA, MOSPI, YES Sec

Industrial Sector – The Largest Consumer of Electricity

The industrial sector has consistently accounted for the largest share of electricity consumption in India, contributing around 42% of total demand. This dominance stems from the energy-intensive nature of industries such as steel, cement, chemicals, textiles, and manufacturing.

Exhibit 55: India's Industrial sector electricity consumption pattern



Source: CEA, MOSPI, YES Sec

Exhibit 56: Industrial sector electricity consumption key trends

2000-2010
- Industrial consumption grew steadily as India's economy expanded, driven by infrastructure projects and an increasing focus on exports.

2010-2020
- Rapid urbanization and the Make in India initiative pushed industrial energy demand further. Large manufacturing hubs, industrial corridors, and Special Economic Zones (SEZs) increased electricity consumption.

Post-2020
- Growth in heavy industries slowed due to decarbonization policies, efficiency improvements, and a gradual shift towards electrified and automated industrial processes.

Source: Industry, YES Sec

Outlook:

Energy Efficiency: Government-led programs like Perform, Achieve, and Trade (PAT) under the National Mission on Enhanced Energy Efficiency (NMEEE) are encouraging industries to optimize energy use.

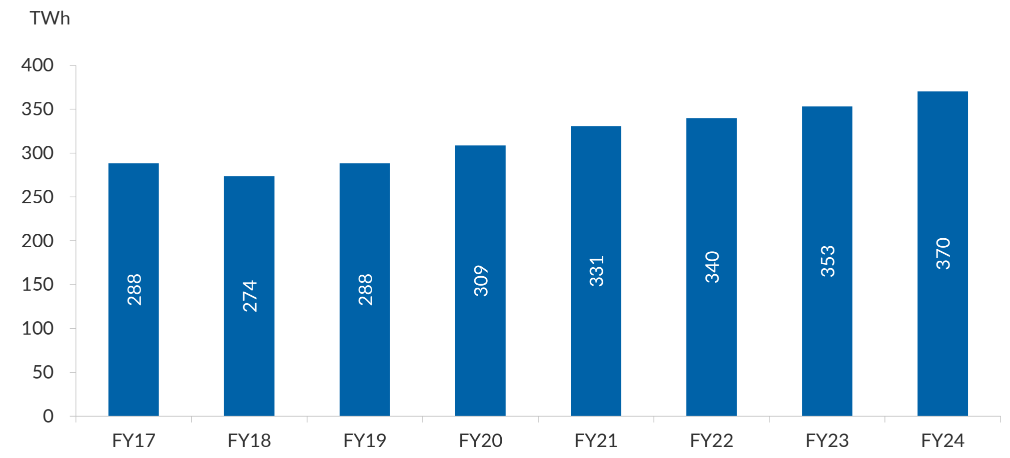
Renewable Energy Adoption: More industries are shifting towards captive renewable power, reducing reliance on the grid while lowering costs.

Electrification of Industrial Processes: The push for electric furnaces, hydrogen-based steelmaking, and battery storage integration will reshape industrial electricity demand in the future.

Residential Sector – Fastest Growing Segment

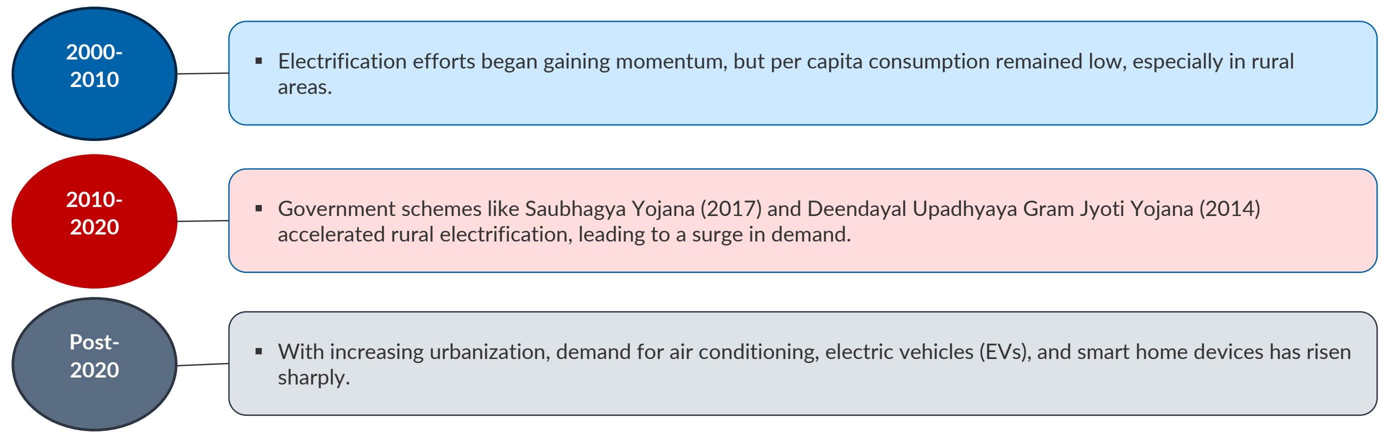
The residential sector has seen a significant rise in electricity consumption, with its share growing from ~15% in FY00 to over 24% by FY24. This increase is attributed to the expansion of household electrification, rising disposable incomes, and the adoption of electric appliances, air conditioning, and electric cooking solutions.

Exhibit 57: India's Residential sector electricity consumption pattern



Source: CEA, MOSPI, YES Sec

Exhibit 58: Residential sector electricity consumption key trends



Source: Industry, YES Sec

Outlook:

Energy Efficiency: Adoption of LED lighting, energy-efficient appliances, and solar rooftop installations is helping manage growing demand.

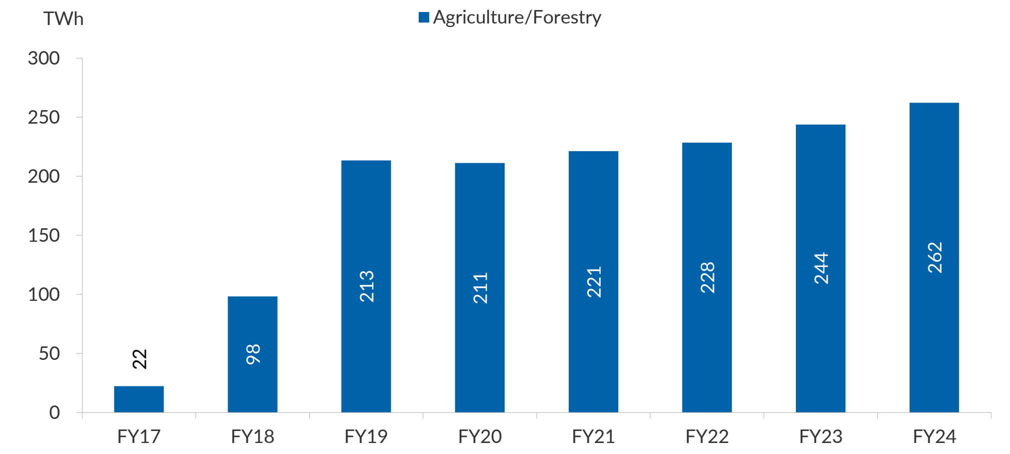
Urban Load Growth: Metropolitan areas are experiencing rapid increases in residential electricity use, requiring better grid management.

Electrification of Cooking & Heating: The shift from LPG to electric induction stoves and heat pumps could further increase household electricity consumption.

Agricultural Sector – High Demand Due to Irrigation Needs

The agricultural sector accounts for ~17% of total electricity consumption, largely due to the extensive use of electric pumps for irrigation. India provides highly subsidized electricity to farmers, leading to high power usage in rural areas.

Exhibit 59: India's Agricultural sector electricity consumption pattern



Source: CEA, MOSPI, YES Sec

Exhibit 60: Agricultural sector electricity consumption key trends

2000-2010
- Electricity demand in agriculture grew steadily, fueled by government incentives for groundwater irrigation.

2010-2020
- Rising diesel prices led to higher reliance on electric pump sets, further increasing demand. However, issues like power theft and inefficiency remained a challenge.

Post-2020
- Increased adoption of solar-powered irrigation pumps (KUSUM scheme) is helping reduce the agricultural sector's dependence on the main grid.

Source: Industry, YES Sec

Outlook:

Subsidy Burden: The high cost of power subsidies places financial pressure on State Electricity Boards (SEBs).

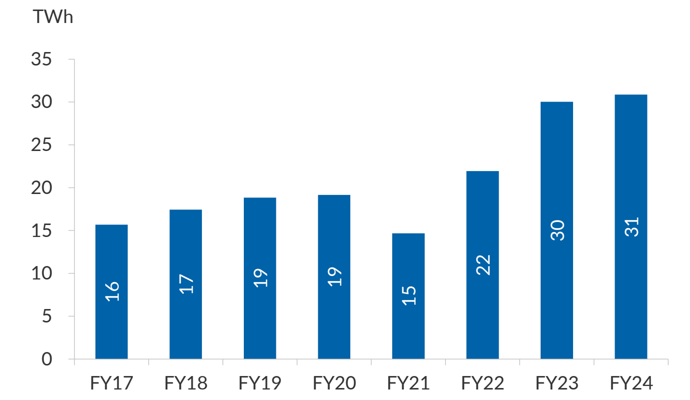
Energy Efficiency Measures: Deployment of efficient pump sets and solar-powered systems will play a key role in managing consumption.

Decentralized Power Solutions: Distributed generation through microgrids and solar pumps will reduce reliance on conventional power.

Commercial & Transport Sectors – Emerging Electricity Consumers

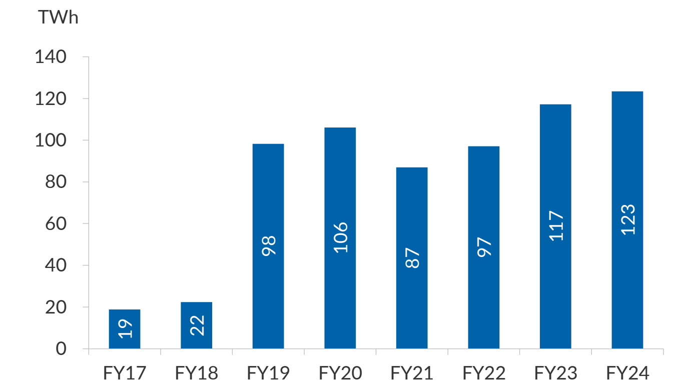
Electricity consumption in the commercial and transport sectors has grown steadily, reaching ~10% of total demand. This segment includes offices, malls, data centers, metro rail networks, and EV charging infrastructure.

Exhibit 61: India's transport sector demand



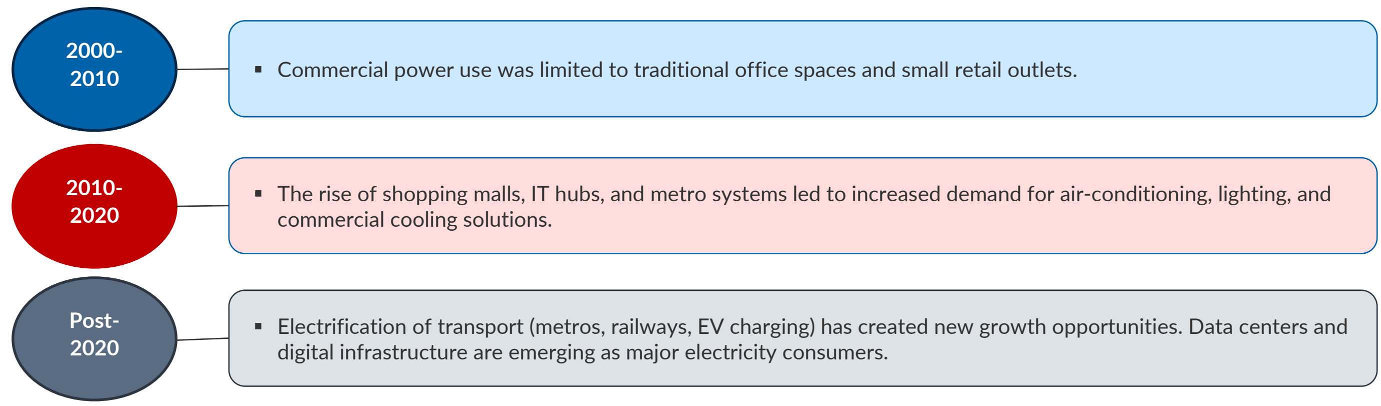
Source: CEA, MOSPI, YES Sec

Exhibit 62: India's commercial sector demand



Source: CEA, MOSPI, YES Sec

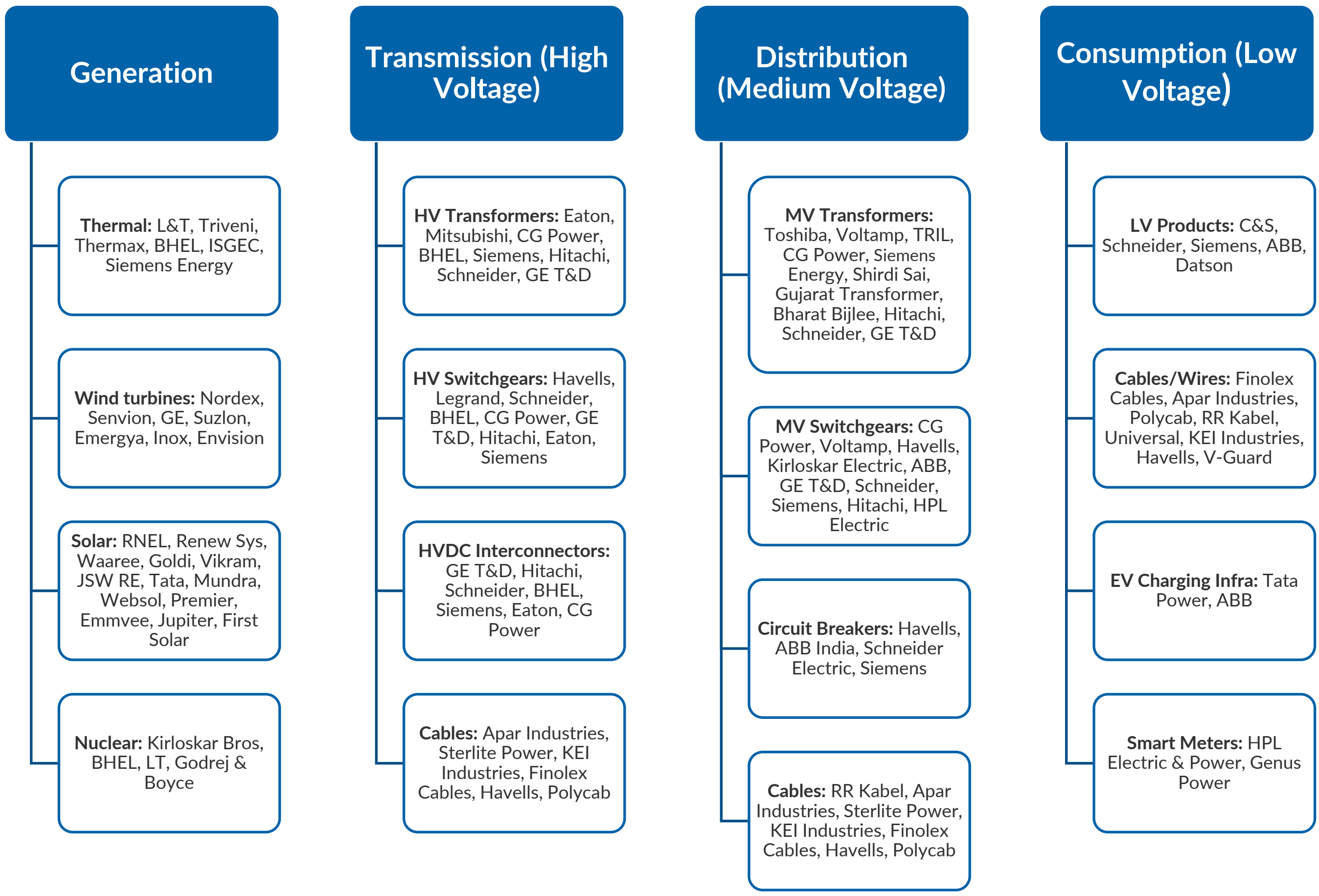
Exhibit 63: Commercial and transport sector electricity consumption key trends



Source: Industry, YES Sec

India's electricity consumption patterns have evolved significantly over the past two decades. While industrial demand continues to dominate, residential, agricultural, and commercial demand is growing rapidly. The future of electricity consumption in India will be shaped by Electrification of Transportation & Industry, Decentralized Renewable Power, Demand-Side Management & Smart Grids, and Energy Efficiency Regulations.

Exhibit 64: Electricity Value Chain



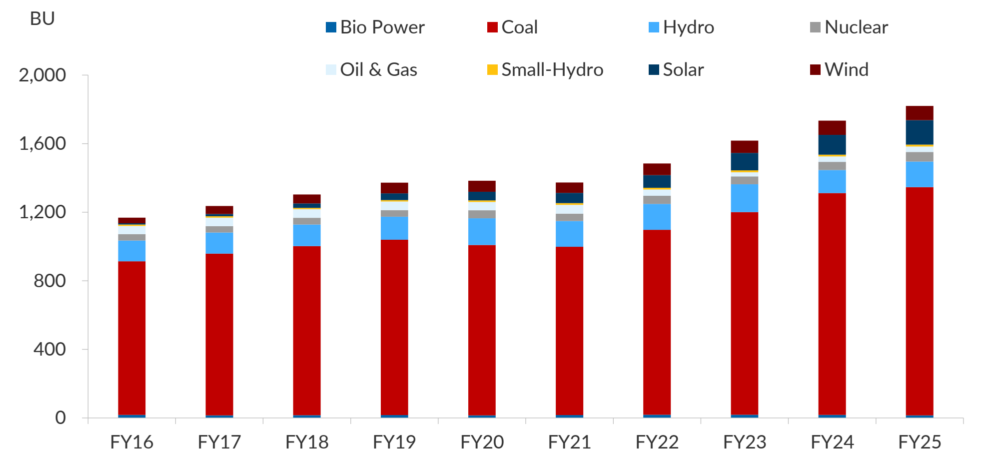
Source: Industry, YES Sec

Electricity Generation Trends in India

India's electricity generation has more than doubled since 2000, growing from below ~600 TWh to over 1,600 TWh in 2025. The country has undergone a structural shift in its power generation mix, transitioning from a coal-dominated system to a more diversified energy portfolio that includes renewables, nuclear, and natural gas. This shift has been driven by rising energy demand, environmental policies, falling renewable costs, and technological advancements. Below is a detailed breakdown of how electricity generation has evolved across different sources.

Coal has remained the dominant source, accounting for ~71% of generation in FY25, although its share in new electricity demand growth has declined in recent years. Renewable energy, including solar, wind, biomass, and small hydro, has expanded rapidly, with more than 22% of total generation in FY25, making India the third-largest global generator of wind and solar power. Large hydro contributes around 8%, and nuclear power generation has also increased modestly.

Exhibit 65: India's electricity generation trend



Source: CEA, YES Sec

Coal-Based Generation – The Backbone of India's Power Sector

Coal has been the primary source of electricity in India, accounting for over 70% of generation in 2000. Despite efforts to diversify the energy mix, coal still contributes over 50% of total generation in 2024, making it the dominant fuel for power production.

Exhibit 66: Coal based electricity generation key trends

2000-2010

- Coal-based generation increased sharply, driven by economic growth and industrialization. The government prioritized coal-fired power plants due to their reliability and scalability.

2010-2020

- Coal capacity additions peaked as demand surged, but environmental concerns and policy shifts started slowing expansion.

Post-2020

- The share of coal in total generation has declined, mainly due to increased renewable energy adoption, stricter emissions norms, and lower utilization rates for aging plants.

Source: Industry, YES Sec

Outlook

Stranded Assets: Many coal plants are underutilized due to lower demand and higher competition from renewables.

Carbon Pricing Impact: With a USD30/ton carbon price assumption, coal's cost competitiveness is declining.

Efficiency Improvements: Supercritical and ultra-supercritical coal technologies are being deployed to improve efficiency and reduce emissions.

Policy Shift: The government is now focusing on flexible coal plants that can ramp up/down quickly to complement renewable energy sources.

Renewable Energy – The Fastest Growing Segment

India's renewable energy generation has grown exponentially over the past two decades, rising from nearly zero in FY00 to ~22% of total electricity generation in FY25.

Solar Power – From Marginal to Mainstream

Solar energy has seen the most dramatic growth, going from a negligible share in FY10 to over 8% share of generation in FY25.

Exhibit 67: Solar power generation key trends

2000-2010	Solar PV was expensive and remained a niche technology.
2010-2020	Solar PV was expensive and remained a niche technology.
Post-2020	Large-scale solar parks and rooftop solar installations have made solar one of the cheapest electricity sources in India.

Source: Industry, YES Sec

Wind Power – A Consistent Contributor

Wind energy has steadily grown, contributing over 5% share of generation in FY25, making India the fourth-largest wind energy producer globally.

Exhibit 68: Wind power electricity generation key trends

2000-2010	Initial wind farms were set up in Tamil Nadu, Gujarat, and Maharashtra.
2010-2020	Capacity expanded significantly, aided by tax incentives and feed-in tariffs.
Post-2020	Offshore wind and hybrid solar-wind projects are being explored.

Source: Industry, YES Sec

Hydropower – A Stable But Declining Share

Hydropower has historically played a major role in India's power sector, but its share has declined due to seasonal variations, environmental concerns, and fewer new projects and contribute ~9%.

Exhibit 69: Hydro power electricity generation key trends

2000-2010	▪ Hydro projects grew steadily, contributing to baseload power.
2010-2020	▪ Growth stagnated due to land acquisition and ecological issues.
Post-2020	▪ Small hydro and pumped storage projects are being developed for better grid balancing.

Source: Industry, YES Sec

Outlook for Renewables

Intermittency: Solar and wind are variable sources, requiring storage and grid flexibility. RTC issues are expected to be resolved by integrating BESS in current standalone solar projects while certain hybrid FDRE projects are also issued by the SECI.

Grid Integration: Investments in Green Energy Corridors are helping integrate more renewables. Grid capacity additions have been associated with upcoming projects while the past projects are also expected to connect to the grid.

Battery Storage Growth: Hybrid solar + battery projects are emerging as solutions for reliability issues. While the pattern of solar only projects is expected to change to solar + storage projects coping the RTC issues.

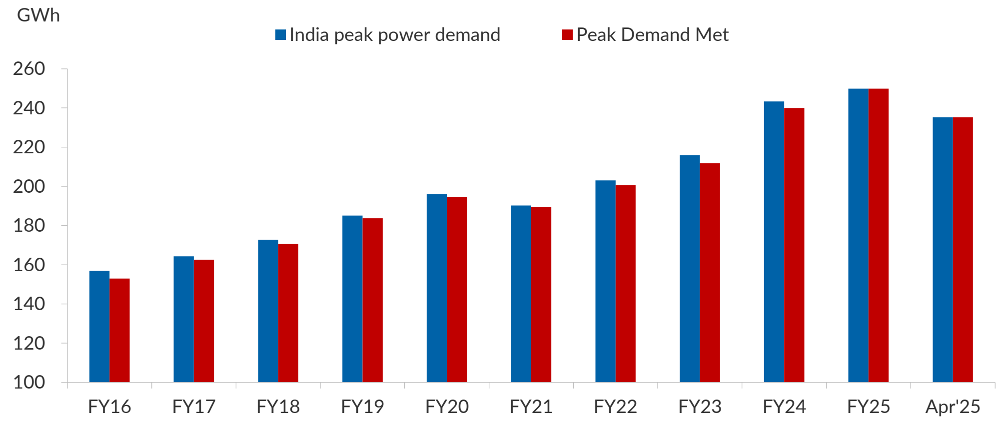
Future Targets: India aims to reach 500GW of non-fossil fuel capacity by 2030, making renewables the dominant source of electricity. India's electricity generation trends indicate a clear transition from coal dependence to renewable energy dominance. While coal remains the largest contributor, its share is declining, with solar, wind, and hydro filling the gap. Decrease in prices due peak solar hours in the spot market as well as FDRE and RTC + BESS contracts given out by government gives an edge to supply power even during non-solar hours.

Key Drivers for Future Growth: The government's focus on achieving 500 GW of non-fossil capacity by 2030 will drive solar and wind growth. Investments in battery storage, pumped hydro, and smart grids will improve reliability. Increased electricity demand from electric vehicles (EVs) and green hydrogen production will influence future generation trends. Coal is not disappearing but will operate flexibly to complement renewables rather than dominate.

The Growing Role of Round-the-Clock (RTC) Renewable Energy in India's Power Sector

As India transitions towards a low-carbon energy future, ensuring a reliable, 24x7 electricity supply remains a key challenge, especially with the increasing share of intermittent renewables like solar and wind. This is where Round-the-Clock (RTC) renewable energy is emerging as a game-changer. RTC projects integrate solar, wind, energy storage (batteries or pumped hydro), and in some cases, thermal power, to provide continuous and stable power output, reducing dependence on fossil fuels while improving grid reliability.

Exhibit 70: India's peak power demand



Source: NITI Aayog, YES Sec

Why RTC Energy is Crucial for India's Power Sector?

- **Managing Renewable Intermittency:** Solar power is available only during the day, and wind energy generation fluctuates seasonally. RTC projects help bridge this gap by integrating storage and complementary energy sources, ensuring a steady power supply even during non-solar hours.
- **Meeting Peak Demand:** India's power demand peaks in the evenings (7–10 PM) and during summers when air conditioning loads surge. RTC projects, with battery storage or wind-solar hybrid models, can supply energy exactly when needed, reducing reliance on coal-fired plants. During the peak solar hours, the prices of solar power in the spot market have reached near to Rs 0/KWh making a need to push towards saving the excess electricity to meet the peak demand during the night. Government have stopped approving standalone Solar projects to Solar + Storage saving the excess electricity to meet the peak demand.
- **Grid Stability & Reduced Curtailment:** A high share of standalone solar and wind often leads to curtailment (i.e., surplus energy wasted due to grid congestion). RTC solutions optimize generation and align supply with demand, minimizing these losses. Renewable energy contracts have been handed to the successful bidders in competitive bidding processes who then signs the PPA to sell the generated power to the buyer.
- **Competitive Tariffs & Cost Reduction:** Initially, RTC power was expensive, with tariffs between Rs 4–6/unit, but declining battery costs and hybrid power models are making RTC tariffs more competitive (Rs 3.5–5/unit). With further advancements in storage technologies and domestic manufacturing, RTC tariffs are expected to decline.
- **Government Push & Policy Incentives:** The Indian government has aggressively promoted RTC projects through SECI's RTC tenders and policy incentives like the Viability Gap Funding (VGF) for energy storage which is a scheme that has provision to extent capital cost for Battery storage system solutions (BESS) upto 40% of the total cost. Further, Ministry of Heavy Industries (MHI), in Jun'21 has launched a Production-Linked Incentive (PLI) scheme for the manufacturing of ACC Battery Storage scheme, launched with a Rs181bn outlay, aims to boost domestic battery manufacturing for electric mobility. Firms must invest Rs2.25 bn/GWh and achieve 60% local value addition in 5 years. It includes a 2-year gestation period

(2023–24) and a 5-year performance period (2025–29). Of the 50GWh target, 30GWh has been allocated, with 20GWh open for fresh bids. In 2020, SECI awarded India's first 400 MW RTC tender, with a blended tariff of Rs 3.6/unit, significantly lower than coal-based alternatives.

- **Decreasing cost of batteries:** Global Lithium-ion-phosphate (LFP) Battery cost have been down by 84% in the last 10 years from USD 715/KWh in 2014 to USD 115/KWh in 2024 to even further down to USD 55/KWh in May 2025. Battery prices have seen a huge drop due to optimization in supply chain management driven by China where battery prices are at historical low as they have built a ecosystem for batteries driven by boost in EV sales and renewable energy push.
- **Boost to Industrial & Commercial Consumers:** Many industries and large commercial entities are shifting towards RTC renewable contracts to ensure reliable power supply while meeting sustainability targets. This reduces their dependence on grid electricity, which is often more expensive and carbon intensive.

Demand-Supply Outlook

India's electricity demand is projected to grow at a CAGR of 4.1% for FY25-30, driven by multiple factors, including urbanization, industrial expansion, and the electrification of transportation and household appliances. With India's population and economy expanding, per capita electricity consumption is set to increase from 1,255 kWh in FY23 to ~1,550 kWh by FY27 as per CRISIL.

To meet this growing demand, India is ramping up capacity additions, particularly in renewable energy and battery storage infrastructure. The integration of real-time power markets, energy storage solutions, and grid modernization efforts will play a critical role in ensuring that demand growth does not outpace supply. However, key challenges remain, including grid congestion, transmission bottlenecks, and the need for efficient load balancing mechanisms.

Open access a push towards integrating industrial customers towards clean electricity

Open access (OA) is a network (similar as grid) which provides electricity to bulk electricity users for where 1 MW or more must be demanded to have access to OA. OA acts as a grid operator transporting electricity from the IPP to the contracted party via the state or central transmission companies and any excess can be sold through IEX in spot markets.

How it works: PPA is signed between the supplier (IPP) and the industrial customer (for X MW) the IPP is then connected to the nearest substation which is connected to the grid and then the grid (central/state) transport the electricity to the customer, any fluctuation in demand is usually from the customer is usually informed to the IPP let's say usual demand 20 MW and now only 15 MW is required the IPP can then sell the rest to the spot market.

Approvals: There are 3 different types of contracts,

- **Captive**: where the customer will have more than 26% equity in the IPP and will consume more than 51% of the plant's electricity.
- **Group captive**: where 2 customers own stake in the IPP (>26% combined) and use the power (>51%).
- **Third party sale**: Where both IPP and customer have only contractual relationship between them.

Charges Incurred by Industrial Consumers under Open Access (Third-Party Model):

- **Wheeling Charges**: These are fees paid to use the distribution network (like poles and wires) to carry electricity from the grid to the consumer. If your solar plant is in a different location than the consumer, this charge applies for using local electricity distribution lines.
- **Transmission Charges:** These are paid to use the high-voltage transmission network — for moving electricity over long distances (like state-to-state or large cities). Charged by state or central transmission utilities depending on the network used.
- **Cross-Subsidy Surcharge (CSS):** DISCOMs (distribution companies) lose their best-paying customers (like industries) when those customers shift to Open Access. To compensate for

this loss, CSS is levied on Open Access consumers — it's a kind of penalty for not buying from the local DISCOM.

- **Additional Surcharge (AS):** This is to cover the fixed costs of power that the DISCOM had already committed to buy (in long-term contracts) for you. When you switch to Open Access, DISCOMs might still be paying generators for power you're no longer using — AS recovers those costs.
- **SLDC / Scheduling Charges:** SLDCs (State Load Dispatch Centers) manage the electricity flow within the grid. They charge small fees for approving, monitoring, and managing your electricity schedule usually per kWh or monthly.
- **Banking Charges:** If you generate more electricity than needed (say, solar over-generates during daytime), you can "bank" that extra power for later use (like at night). States charge either a percentage of energy banked or a fixed rate per unit as a banking fee.

Revenue generation

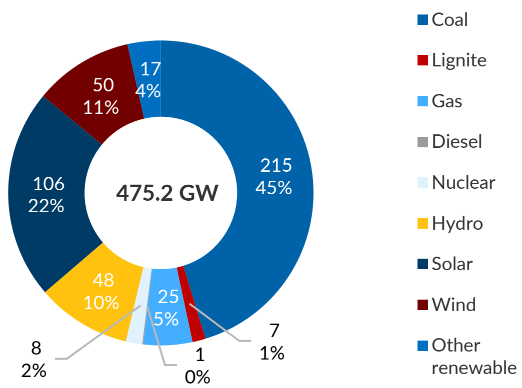
IPP generates revenue through the sale of electricity, where tariffs are decided before signing the PPA, and realization for excess electricity on the spot market. The realization is higher in open access compared to discom which have lower tariffs as it is safer option compared to OA. OA generally have stricter legal compliances and requires better project management, metering. In some cases, IPP chooses both (depending on the capacity of the plant) Discom and OA to sell electricity as discom provide bankable long term annuity income and OA provides higher margins.

Green Open Access:

- **Faster Approvals**: Before 2022, Open Access (OA) applications took anywhere from 30 to 90 days for approval, depending on the state. Under the Green OA Rules, this has been streamlined to a maximum of 15 days, enabling quicker access to renewable energy.
- **Lower Minimum Load Requirement**: The earlier minimum load requirement of 1 MW limited participation to large consumers. The new rules reduce this threshold to 100 kW, allowing small and medium enterprises to also benefit from green Open Access.
- **Banking Provisions:** Banking of surplus renewable energy (e.g., solar generation during the day) was previously state-dependent and often restricted. The 2022 rules encourage and support banking, making it more accessible across different states.
- **Surcharge Relief (CSS & AS):** Renewable energy consumers often faced higher cross-subsidy surcharge (CSS) and additional surcharge (AS) under the old regime. The Green OA Rules provide for waivers or reductions, especially for captive users, making green energy more cost-effective.
- **Improved Access to Energy Markets:** Access to platforms like the Indian Energy Exchange (IEX) was previously limited for RE players. The new rules have eased market participation, helping developers and consumers tap into real-time power trading opportunities.

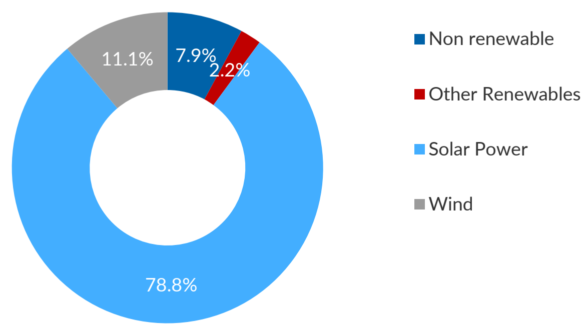
Electricity Capacity Trends in India

Exhibit 71: India's Installed Capacity Mar'25



Source: Niti Aayog, YES Sec

Exhibit 72: Estimated Capacity Additions (FY26-30E)



Source: YES Sec

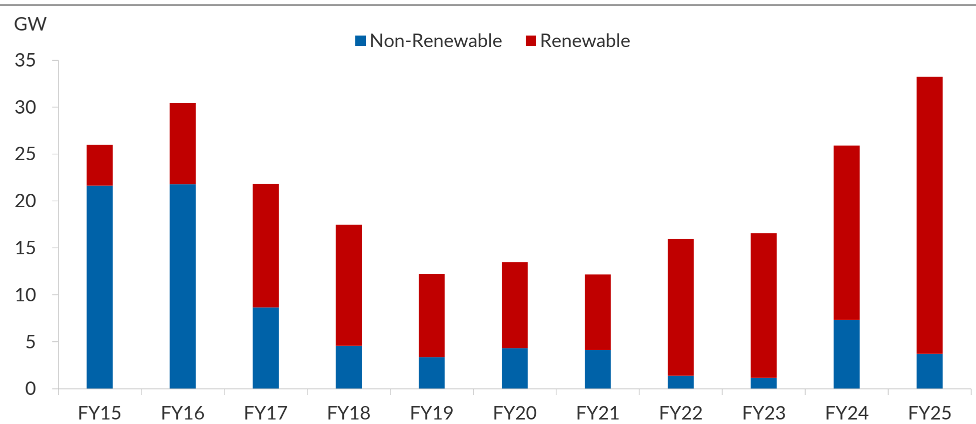
India's installed power generation capacity has grown almost fourfold from 105 GW in 2002 to over 400 GW in 2023. This expansion has been driven by rising electricity demand, industrialization, and policy support for renewable energy. Over the years, India's energy mix has evolved, transitioning from a coal-dominated system to an increasingly diversified capacity portfolio, with solar, wind, and hydro playing an expanding role.

As of FY25, India's thermal power capacity stands at around 215 GW, with planned net additions of 20.5 GW by FY30, bringing the total to approximately 235.7 GW and growing at a modest CAGR of 2%. Wind power is set to expand from 50 GW to 78 GW over the same period, driven by 28 GW of new capacity, while solar is expected to see a significant surge from 106 GW to 305 GW, supported by nearly 199 GW of additions and a robust CAGR of 24%.

Other renewable sources, excluding hydro, will experience gradual growth from 64 GW to 70 GW, alongside hydro projects, which will add 3.2 GW to their existing 53 GW share. Nuclear power will contribute incrementally, rising from 8.2 GW to 8.5 GW by FY30. Overall, thermal and renewable sources will together shape the energy mix, with nuclear providing a steady, though modest, contribution as per our expectations.

Post the Modi government country's focus on electricity generation has substantially increased due to boost in manufacturing as well as growing environmental concern necessitating reliance on alternative sources and reducing import dependence. Such factor steered focus towards additions in solar PV more than traditional non-renewable sources. Country saw a significant increase in solar additions post 2017 where government brought certain policies which aided developers helping them achieve competitive pricing.

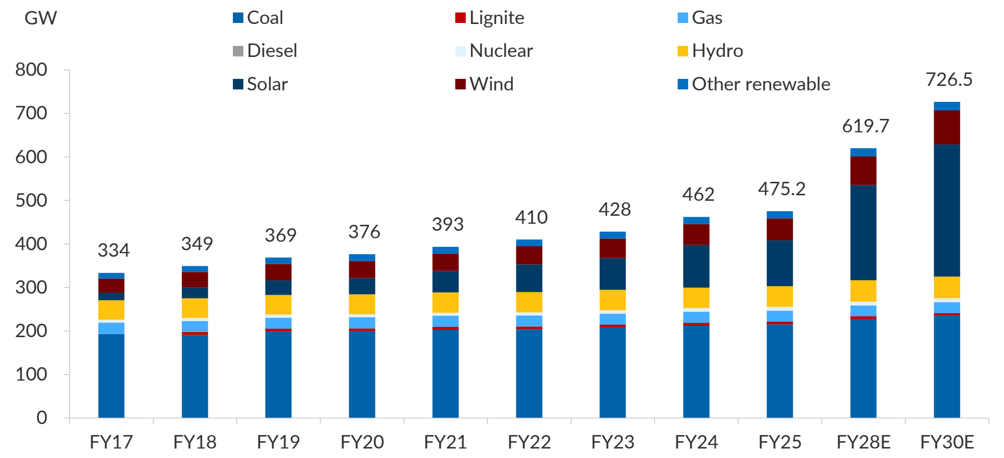
Exhibit 73: India Renewable and Non-Renewable capacity additions



Source: MNRE, CEA, NITI Aayog YES Sec

Capacity growth is crucial as it determines how much electricity the country can generate, shaping energy security, economic growth, and sustainability efforts. Below is an in-depth analysis of how installed capacity has developed across different power sources.

Exhibit 74: India's electricity generation capacity across different sources

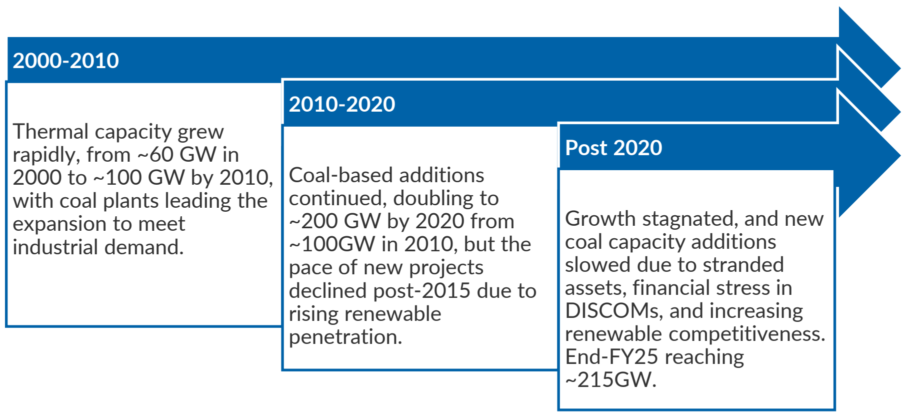


Source: CEA, YES Sec

Thermal Power Capacity – From Growth to Stagnation

Thermal power comprising coal, gas, and oil-based plants has traditionally been the largest contributor to India's installed capacity, making up ~70% of total capacity in 2000. However, in recent years, its growth has slowed due to environmental concerns, policy shifts, and the declining cost of renewables and Thermal power capacity is down to ~48%.

Exhibit 75: Thermal Power Capacity key trends



Source: Industry, YES Sec

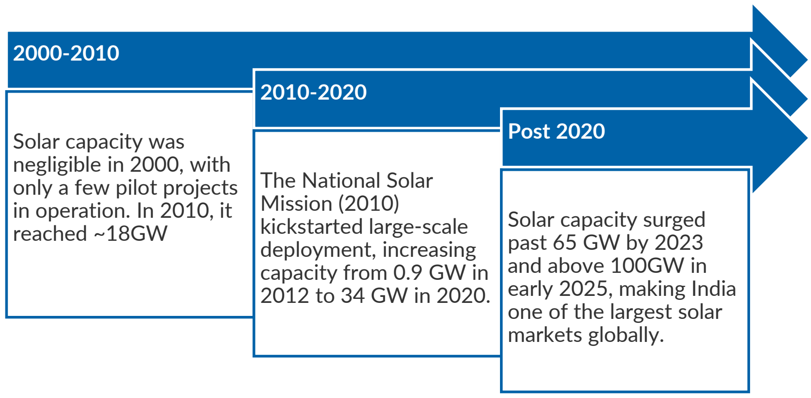
Outlook for Thermal:

- **High stranded assets:** Many coal plants are operating at low plant load factors (PLFs) due to overcapacity and lower-than-expected demand.
- **Environmental regulations:** Stricter emission norms are increasing the cost of running coal plants.
- **Shift to flexible operation:** Future coal plants will likely act as peaking power sources, balancing renewables rather than providing baseload power.

Renewable Energy Capacity – The Fastest Growing Segment

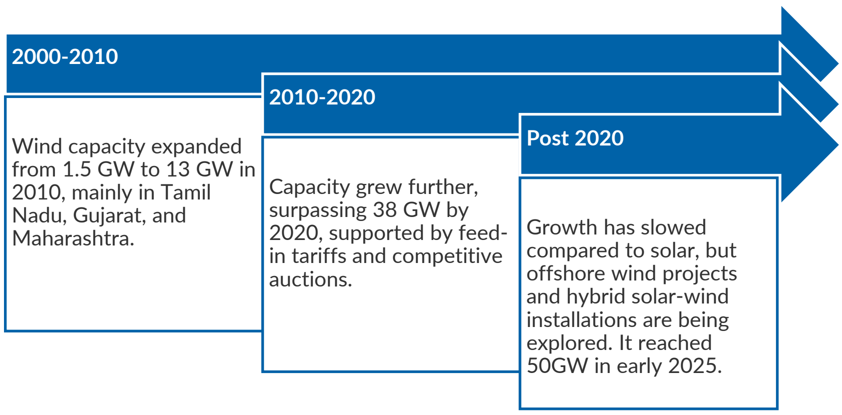
India's renewable energy installed capacity has surged from less than ~3GW in 2000 to over 200 GW in 2024, making it the fastest-growing segment in the power sector. The government's aggressive renewable energy targets and declining costs have made renewables an attractive alternative to fossil fuels.

Exhibit 76: Solar Power – From Near Zero to a Key Player



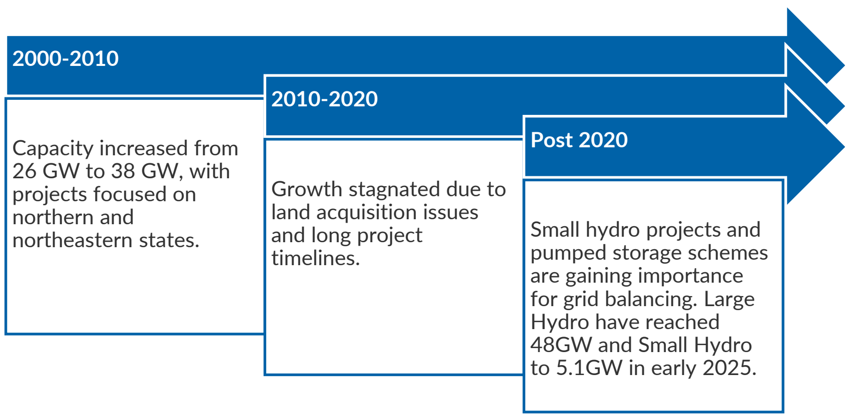
Source: Industry, YES Sec

Exhibit 77: Wind Power – A Consistent Contributor



Source: Industry, YES Sec

Exhibit 78: Hydropower – A Declining Share in Capacity Mix



Source: Industry, YES Sec

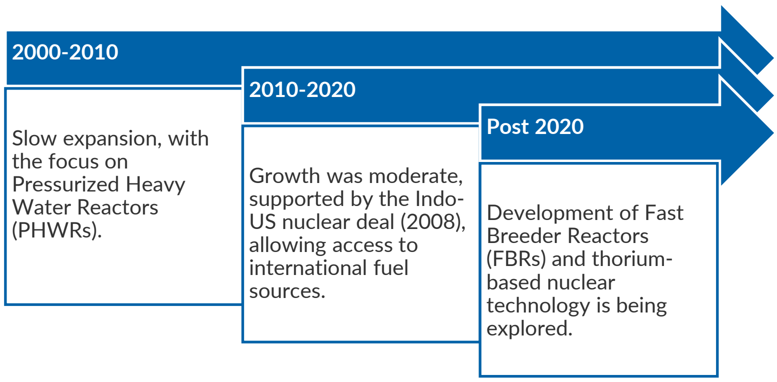
Outlook for Renewables:

- **Intermittency Issues:** Solar and wind generation is variable, requiring storage and grid balancing solutions.
- **Land Acquisition Challenges:** Large solar and wind farms require significant land resources, leading to delays in execution.
- **Hybrid Energy Projects:** The focus is shifting to hybrid solar-wind projects with battery storage to improve reliability.

Nuclear Power Capacity – Small but Strategic Growth

Nuclear power has remained a small but steady contributor to India's energy mix, growing from 2.7 GW in 2000 to ~7 GW in 2023. While it offers high reliability and low emissions, growth has been limited due to high capital costs and regulatory constraints. In Union Budget 2025, FM announced a Nuclear Energy Mission targeting 100GW nuclear capacity by 2047. Atomic Energy Act and Civil Liability for Nuclear Damage Act to be amended for private sector participation. Rs200bn allocated for Small Module Reactors (SMRs) R&D, with at least 5 indigenous SMRs expected by 2033.

Exhibit 79: Nuclear Power Key trends



Source: Industry, YES Sec

Outlook for Nuclear:

- **High capital costs:** Nuclear plants require large upfront investments, making financing difficult.
- **Public perception & safety concerns:** Resistance to new plants remains a major hurdle.
- **Limited expansion potential:** Nuclear will likely remain a niche contributor, with renewables taking the lead in future capacity additions.

Transmission & Grid Infrastructure Expansion

Installed capacity growth alone does not guarantee energy availability—expanding the transmission network is equally important. India's power transmission and distribution (T&D) network has expanded from ~6mn circuit km in 2000 to over 15mn circuit km in 2023.

Key Developments: Interregional transmission capacity expansion has enabled better power distribution across states. Green Energy Corridors (GECs) are being developed to integrate renewables into the grid. Smart grids & automation are improving power reliability and reducing losses.

AT&C remain high (~18-25%), compared to global benchmarks of 6-8% due to high technical loss (8-15%) in the country vs the global average (8%) and commercial loss of 5-10% causing financial stress in DISCOMs as they get lesser power than they paid. Technical losses in India's power system occur at both the transmission and distribution levels. Transmission losses, typically seen at 400kV–132kV levels, result from long-distance power flow where energy is lost as heat due to resistance in the lines (I^2R losses), amounting to ~2–4%. Distribution losses, which occur at lower voltages like 33kV, 11kV, or 415V, are higher — ranging from 6–12% or more — especially in rural areas due to poor infrastructure. Together, technical losses can account for 8–15% of total energy loss, depending on the state.

These losses are primarily driven by several systemic issues: overloaded transformers and conductors are run beyond capacity, leading to overheating; outdated infrastructure like old or undersized wires is common, especially in rural feeders; and long, unbalanced feeder lines result in higher resistive losses. Additionally, low power factor from industrial loads and unplanned grid expansions without adequate reinforcement further worsen technical inefficiencies. Cost of building new transmission lines can be high and obtaining necessary permits can further increase the time and cost to complete the projects.

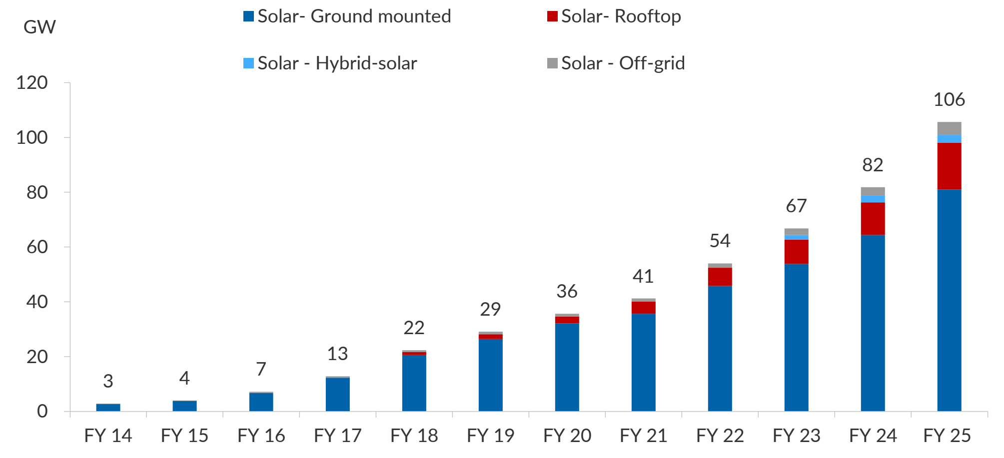
Battery storage & grid modernization will be critical for handling high renewable energy penetration, as renewable electricity sources are subject to fluctuations depending on the weather. Contracts like RTC+BESS and FDRE will help to integrate consistency in the renewable sources. India's installed capacity trends indicate a clear transition from coal dominance to renewable leadership. While thermal power remains the largest segment, its share is shrinking as solar, wind, and hydro gain ground.

Key Drivers for Future Capacity Growth: India aims to reach 500 GW of non-fossil fuel capacity by 2030, making solar and wind the dominant sources. Investment in battery storage, pumped hydro, and flexible coal plants will improve energy reliability. Growth in EVs, green hydrogen, and industrial electrification will drive new capacity additions. The future power grid will require smart demand response systems and dynamic load management to balance variable generation sources.

Solar Power

Capacity: Solar power generation capacity has increased in India over the past decade showing exponential growth across the country since the country has suitable and cos advantage. In 2017 of the total solar stood at 5% of the mix with capacity of 17 GW but in 3M2025 solar was 22% of the total mix having capacity of over 106 GW and growing at a CAGR of 26%. The government has kept target of 280 GW (As per IBEF) for solar capacity by 2030 which is poised to grow at a CAGR of 22%.

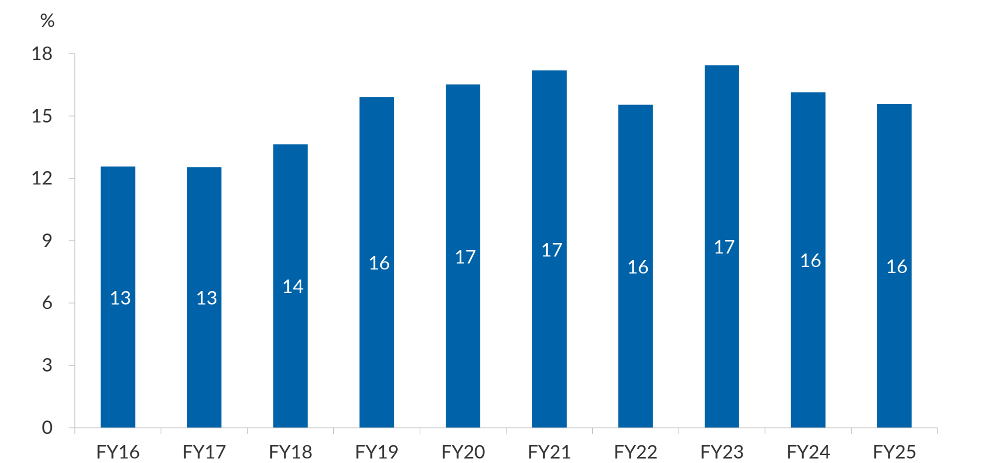
Exhibit 80: Solar capacity breakup



Source: NITI Aayog, YES Sec

Generation: Current solar power generation stands at 144.2bn units (BU) for FY25 which was 7.45 BUs in FY16 growing at a CAGR of 40%. Solar electricity generation is currently 8% of the total electricity generated in the country since reliance on coal was the did not significantly reduce while the technology was solar was not feasible. In FY16 the average PLF factor for solar stood around 13% while the PLF for other renewable sources were far better but as technology improved, while hybrid solar and wind projects delivered PLF of >35%.

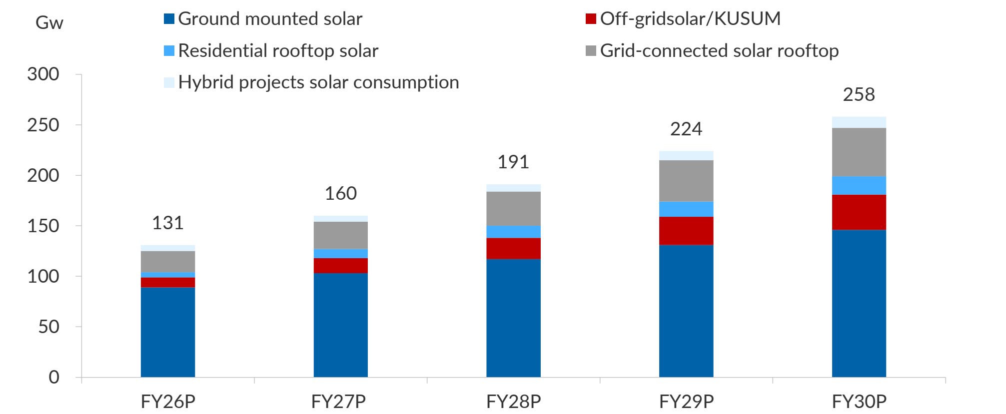
Exhibit 81: Solar PV PLF over the years



Source: NITI Aayog, YES Sec

Solar Powerplants: Government of India has set a target of achieving 50 GW of incremental capacity generation from renewable sources in the country to achieve its target of 500 GW renewable energy by 2030. As of Mar'25 India's generation capacity 81 GW from ground mounted solar, 17 GW from rooftop solar, 2.9 GW Hybrid solar, 4.7 GW from Off grid solar. To achieve the target set by the government of India solar PV is expected to play the major role to boost the capacity generation, incentives from the government as well as certain government policy like PM KUSUM for farmers, PM Muft Ghar Surya Bijli yojana for roof top solar is expected to boost the demand for solar PV while new technology cells like TOPCON will improve the PLF factor coupled with Hybrid plants with battery storage.

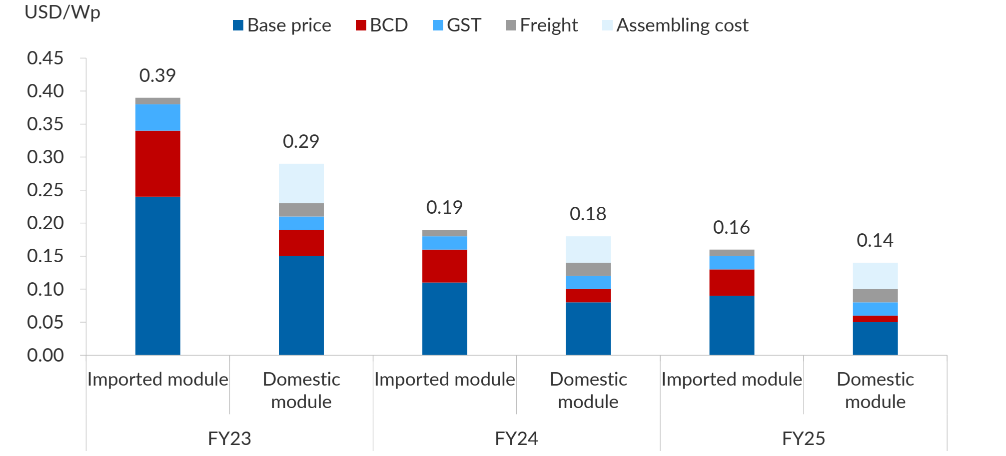
Exhibit 82: Expected Solar Installation



Source: Company, YES Sec

- **Heavy Reliance on Chinese Imports:** India remains heavily dependent on Chinese imports for solar modules, cells, wafers, and polysilicon. While modules and cells are primarily sourced from China, wafers and polysilicon are fully imported, as India currently lacks domestic production capacity for these key raw materials. India currently imports USD 1.64bn of cells and USD 1.61bn of modules.
- **Growth in Domestic Module Manufacturing:** India's solar module manufacturing industry saw significant growth following the introduction of ALMM List-I by the government. In 2017, India's module manufacturing capacity stood at just 4.2 GW, but by FY25, it has expanded to 74 GW. This momentum is expected to continue, with an additional ~90 GW of capacity projected by 2028, bringing India's total module manufacturing capacity to ~160-170GW. This rapid expansion is expected to strengthen the domestic module market and reduce import dependency. Companies like Reliance Industries, Waaree Energies, Premier Energies, Vikram Solar, Mundra Solar (Adani Group) and Renew Power are expected to be key players by 2027.
- **Solar Cell Manufacturing and Dependence on China**: Despite progress in module manufacturing, India remains highly dependent on China for solar cells. Indian manufacturers struggle to compete with China's low production costs, making imported cells more financially viable. The primary reason behind India's high reliance on imported solar cells is the lack of large-scale domestic manufacturing capacity. Unlike modules, which require assembly and finishing, solar cells need complex fabrication processes, including wafer processing, doping, and metallization, which require significant capital investment and technological expertise. To level the playing field, the Indian government has imposed a 25% duty on Chinese solar cells. Currently, only a few companies, such as Waaree Energies, Premier Energies, Reliance Industries, Mundra Solar (Adani Group), Tata Power, and Jupiter Solar, manufacture solar cells domestically, indicating a shift toward self-reliance.
- **Imports still a viable option**: India currently has almost no large-scale solar cell production, while China dominates the global market with massive economies of scale. Domestic cell production is 1.5-2x costlier than importing from China due to smaller production volumes and expensive raw materials but as per IBEF Indian solar cell imports declined by 20% and module imports have declined by 57% in FY25. India still imports wafers (the base material for solar cells), making local cell production dependent on foreign suppliers. Chinese manufacturers benefit from large-scale production, government subsidies, and lower raw material costs, allowing them to undercut Indian manufacturers on price. But push of backward integration from companies like Waaree Energies, Premier Energies have stated their plans to start ingot-wafer facility while Mundra solar (Adani Group) have already started their ingot-wafer facility.

Exhibit 83: Cost structure of Imported vs Domestic module using imported cells



Source: Vikram Solar DRHP, YES Sec

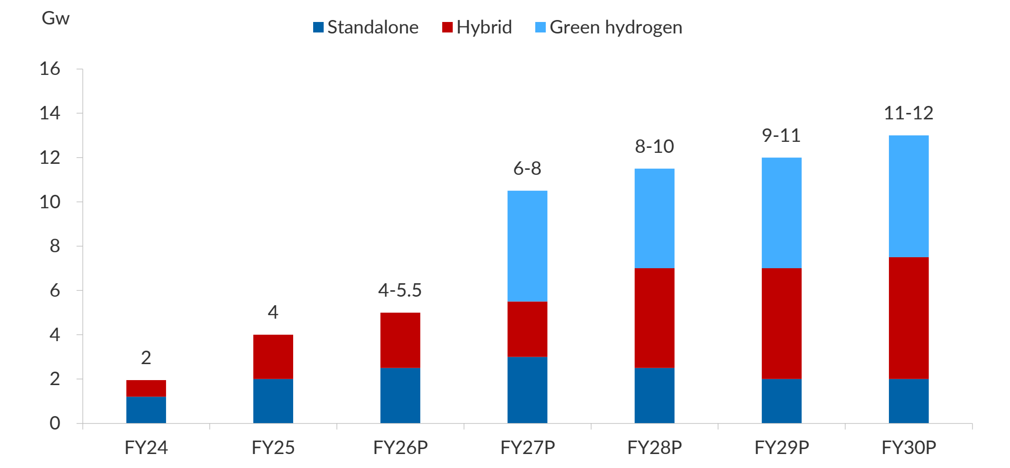
- **Projected Growth in Solar Cell Manufacturing**: Driven by technological advancements and the government's ALMM List-II policy, India's solar cell manufacturing capacity is expected to increase to 93 GW by 2027. ALMM List-II provides incentives and market advantages to manufacturers producing solar cells domestically, further supporting the sector's expansion.
- **Government Initiatives and Incentives**: To accelerate domestic solar manufacturing, the Indian government has introduced the Production Linked Incentive (PLI) scheme, aimed at boosting local solar PV manufacturing. The scheme provides financial support to manufacturers across various stages of the solar supply chain, encouraging investment in polysilicon, wafer, cell, and module production. With these policies and incentives in place, India is poised to significantly reduce its reliance on Chinese imports and emerge as a global hub for solar module and cell manufacturing over the next few years.

Wind Energy

Capacity: In 2017 wind generation capacity stood at 33 GW which increase to 50 GW by Mar'25 growing at a CAGR of ~4.8%. the expansion has mostly taken place in western, southern, and north-western states. Wind generation capacity is expected to grow in India as Hybrid plants including solar and wind which have superior PLF factor compared to standalone wind and solar plants. Wind capacity is expected to reach 140 GW by 2030 growing at a CAGR of 23% as per government's plans.

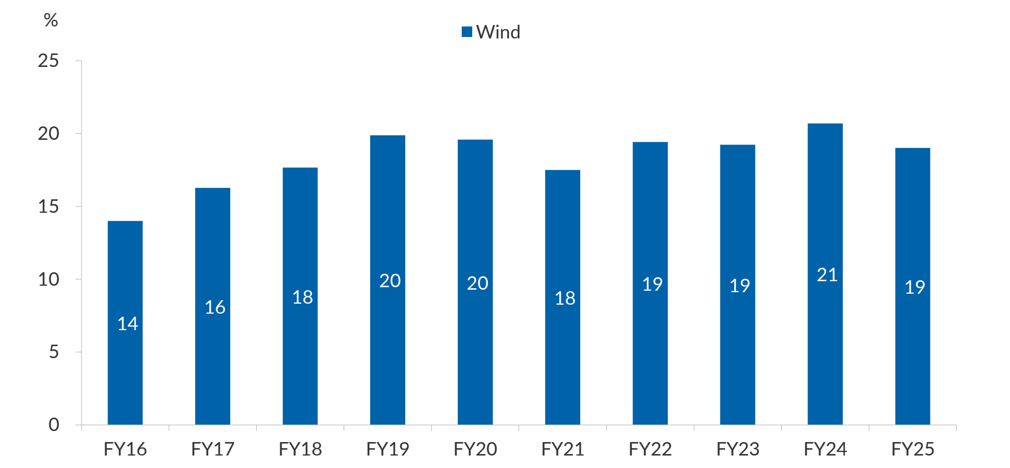
Generation: In 2016 wind generation stood at 33 BU which currently stands at 83 BU in FY25 growing at a CAGR of ~9.3%. Wind generation in India is mostly on shore which is over 42.6GW as on Jan'25 while rest is Hybrid. Currently offshore technology is still developing in India, but government has set target of 30 GW by 2030 given country's long coastline of 7600 km. PLF factor for wind turbines is ~20%, currently Gujarat is biggest wind energy producer (12.4 GW) followed by Tamil Nadu (11.3 GW), Karnataka (6.7 GW), Maharashtra (5.2 GW), Rajasthan (5.2 GW).

Exhibit 84: Wind power capacity additions



Source: CRISIL intelligence, YES Sec

Exhibit 85: Wind PLF factor over the years



Source: NITI Aayog, YES Sec

- Wind turbines manufacturing: Wind generation requires heavy CAPEX as the size of a single wind turbines is extremely big. India currently manufactures 70-80% of its wind turbines while the rest is imported from countries like China, Germany, Denmark, Spain. The Government of India has provided policies like RLMM (revised list of model and manufacturers) and CCDCs (concessional custom duty certificates) to incentivize its domestic manufacturers and domestic demand to achieve its targets.
- Cost and companies: cost of manufacturing wind turbines is expensive as the parts are manufactured separately while its assembling requires heavy machinery. Generally, on shore wind parks are less expensive compared to offshore due to its complexities. Currently Indian companies like Suzlon energy, Inox wind, Adani Wind have advantage in India due to their design, testing and implementation.

Exhibit 86: List of Wind Solar Hybrid tenders concluded between April 2021 – June 2025

Bidding scheme	Result month	Winning tariffs discovered (Rs/unit)		Capacity (MW)		Winners
		Lowest	Highest	Tendered	Allotted	
MSEDCL Pan India	Jul-21	2.62	2.62	500	500	Tata Power, Azure Power
SECI Pan India Tranche IV	Aug-21	2.34	2.35	1,200	1,200	NTPC Ltd. NLC India Ltd. Project Ten Renewable Power (Ayana Renewable Power), Azure Power India
SECI Pan India Tranche V	May-22	2.53	2.53	1,200	1,170	TO Surya (Tata Power), Amp Energy Green, NTPC REL
TPDDL Pan India	Dec-22	3	3	255	510	Tata Power REL
CESC Pan India	May-23	3.07	3.07	150	150	AMP Energy India
TPC-D Pan India	Sep-23	3.27	3.28	225	225	Juniper Green Energy Ltd., Tata Power REL
NTPC Pan India	Dec-23	3.35	3.37	1,500	1,104	O2 Power, Sprng Energy, ACME Cleantech Solutions, Juniper Green Energy Ltd., Avaada Energy
SECI Multiple States WSH Tranche-VI	Jan-24	3.15	3.21	2,000	900	NTPC REL, Juniper Green Energy Ltd., Green Infra Wind Energy
GUVNL Tranche I	Jan-24	2.99	3.04	500	200	KPI Green Energy, Juniper Green Energy Ltd.
SJVN Pan India WSH Tranche I	Feb-24	3.43	3.49	1,500	1,500	Juniper Green Energy Ltd., Datta Power Infra, Green Infra Wind Energy (Sembcorp), Energizent Power (O2 power), Green Prairie Energy (EverGreen Power), Avaada Energy
NTPC Pan India WSH Tranche II	Mar-24	3.27	3.32	1,500	1,500	ABC Cleantech (Axis Energy), Juniper Green Energy Ltd., ACME Cleantech Solutions, ReNew Solar Power
NTPC Pan India - Tranche V	Apr-24	3.41	3.47	1,000	1,000	Sprng Energy, Ampin Energy Transition, Juniper Green Energy Ltd., Renew Power, Avaada Energy
GUVNL Pan India - Tranche I	Jun-24	3.33	3,39	500	560	KPI Green Energy, Juniper Green Energy Ltd., JSW Neo, Hinduja Renewables
SJVN Pan India - Tranche II	Jun-24	3.41	3.42	1500	1500	Ampin Energy Transition, Ganeko Solar (Solarpack), Juniper Green Energy Ltd., Datta power Infra, Inaayu Renewables (Evergreen) , JSW Neo , Avaada Energy
SECI Pan India - Tranche VIII	Jun-24	3.43	3.46	1200	1200	Juniper Green Energy Ltd., UPC Renewables, JSW Energy, Ampin Energy, Adyant Enersol (Datta power Infra), Avaada Energy
MSEDCL Pan India - Tranche III	Jul-24	3.6	3.69	500	426	JSW Energy, Juniper Green Energy Ltd., BN Peak Power (BrightNight), Avaada Energy
SECI Pan India - Tranche VII	Jul-24	3.41	3.42	1,200	1,200	Pace Digitek, JSW Neo Energy, Hero Solar Energy, ACME Solar Holdings
NTPC Pan India - Tranche VI	Jul-24	3.43	3.46	1000	1000	Juniper Green Energy Ltd., JSW Neo, TEQ Green power (O2 power), Adyant Enersol (Datta Infra) , Avaada Energy
MSEDCL Pan India	Aug-24	3.6	3.6	1,650	488	JSW Neo, Juniper Green Energy Ltd., Tata Power REL
SECI Pan India – Tranche IX	Oct-24	3.25	3.26	600	600	Juniper Green Energy Ltd., ACME Solar Holdings, Sembcorp Green Infra
NTPC - Tranche VII	Oct-24	3.28	3.29	1,200	1,200	Green Prairie Energy (Evergreen), Adyant Enersol (Datta Power Infra), Sembcorp Green Infra, Adani Renewable, ReNew Solar Power
SJVN Pan India – Tranche III	Nov-24	3.19	3.19	1,200	1,200	Adyant Enersol (Datta Infra), Gentari Renewables India, Juniper Green Energy Ltd., Enfinity Global, Sunsure Solarpark RJ 1
NTPC Pan India – Tranche VIII	Dec-24	3.38	3.44	1,200	1,200	JSP Green (Jindal Renewables), Adyant Enersol (Datta Infra), Green Prairie Energy IV (Evergreen), Ampin Eenrgy Utility, Adani Green Energy
NTPC Hybrid 02	Jan-25	3.38	3.44	1,200	1,200	JSP Green/Jindal Renewables, Adyant Enersol, Green Prairie, AMPIN Energy, Adani Green
NTPC Solar ISTS Jan2025	Jan-25	2.55	2.7	916	916	BPCL, Onward Solar, ReNew Solar Power, Illuminate Hybren, Adyant Enersol, DCR Agrawal
SECI ISTS-XVIII Solar	Jan-25	3.04	3.1	1,000	800	ACME Solar, ReNew Solar Power, Adani Renewable, Avaada
SECI Tranche VIII	Feb-25	3.43	3.46	1,200	1,200	Juniper Green, Asurari/UPC, AMPIN Energy, Adyant Enersol, JSW Neo Energy, Avaada Energy
NHPC Tranche X	Mar-25	3.41	3.42	1,200	1,200	Adani Renewable, Illuminate/Mahindra Susten, Sprng Energy, Avaada Energy
NTPC Hybrid 03	Mar-25	3.35	3.36	1,200	1,200	EG Solwin/Enfinity, Welspun Renewable, NLC India, Adani Renewable
SECI Tranche IX	Jun-25	3.25	3.26	600	600	ACME Solar, Juniper Green, Sembcorp Green
SECI Tranche XVIII Wind	Jun-25	3.82	3.98	600	400	Torrent Green, Powerica Ltd, Adyant Enersol

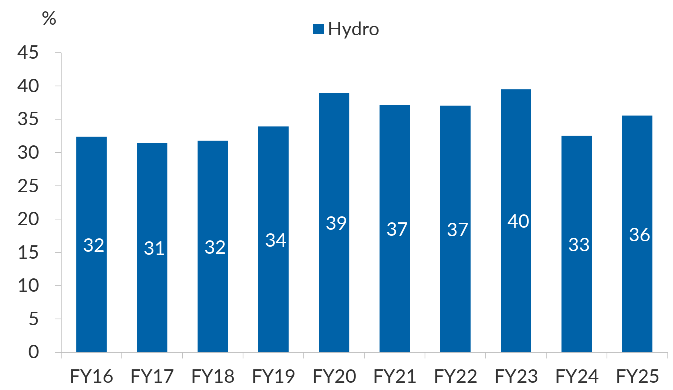
Source: Industry, CRISIL intelligence, YES Sec

Hydro Power

Capacity: In 2016 total Hydro power capacity stood at 41.3 GW which currently is 47.7GW till Mar'25 growing at a CAGR of ~1.5%. Whereas small hydro which was 4.04 GW in 2016 is currently 5.1 GW growing at a CAGR of ~2.6%. Government has plans to achieve 70 GW of hydro power capacity in the country which will be driven by both large and small hydro power plants which is expected to grow at a CAGR of 6.1%.

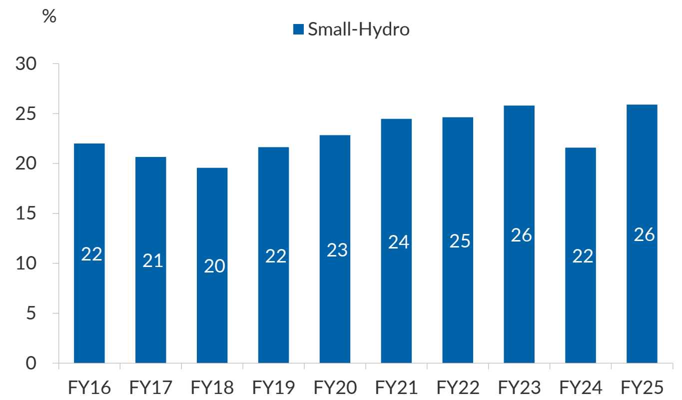
Generation: Hydro power (large and small), in FY16 hydro was the biggest source of renewable energy to generate electricity in the country at 130BU which peaked in FY23 with 173BU and in FY25 stood at 160BU, is still the biggest renewable source to generate electricity which is ~9% of the total electricity generated including small hydro power plants in FY25. The PLF factor of large hydro power plants is ~37% while for small hydro power plants its ~24%.

Exhibit 87: Hydro power PLF factor



Source: : NITI Aayog, YES Sec

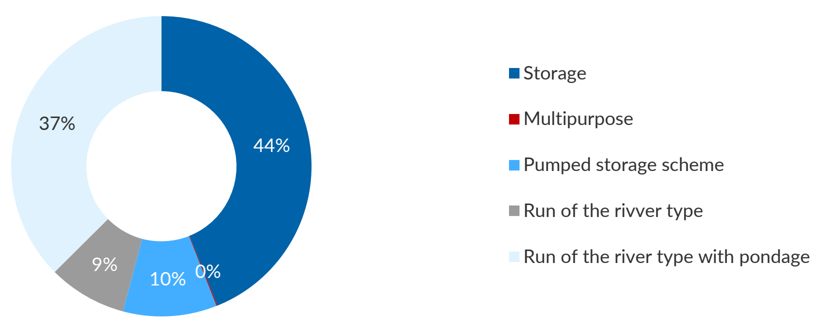
Exhibit 88: Small Hydro power PLF factor



Source: : NITI Aayog, YES Sec

Pumped storage: Pumped storage is a technology which has picked up globally as the technology is environment friendly as well as increases electricity generation, its PLF factor ranges from 25% to 41% based on the hours the technology is used to generate electricity. Currently India has 4.7 GW of Pumped storage project (PSP) while countries like China, Japan and USA have capitalized on the technology showing potential. The Indian government has set target to achieve 19 GW of Pumped storage capacity by 2030.

Exhibit 89: Hydro power capacity share in % (FY25)



Source: NITI Aayog, YES Sec

Cost: To set up hydro power plant it is relatively more expensive in union territories, North Eastern states and certain Northern states like Himachal Pradesh, Uttarakhand and Jammu & Kashmir compared to other states here it requires around Rs120mn/MW to set up the plant while for the rest of the states the cost Rs96mn/MW, while the operational cost in the same split is averaged at Rs4.5mn/MW and Rs3.4mn/MW respectively. Hydro power is mostly operated by government companies like NHPC, NEEPCO, THDC and Satluj Jal Vidyut Nigam but there are some private players like Tata power, Jaypee group and JSW energy are biggest private player in the segment.

Comparing two major storage systems for Renewables

PSP utilizes large reservoirs at different elevations to store energy by pumping water uphill and generating electricity by releasing it downhill. **BESS** uses large batteries, mainly lithium-ion, to store electrical energy that can be rapidly charged and discharged.

Exhibit 90: Comparison of PSP and BESS

Parameters	PSP (Hydro Pumped Storage)	BESS (Solar Battery Energy Storage System)
Capital cost	Total capital cost for a closed loop PSP ranges around ~Rs 50-60 Mn/ MW	Lithium-ion battery storage can range from USD 550-700/kW (for a four-hour storage solution)
Efficiency	75-80%	80-85%
Land requirement	~2,000 m2 /MW	~100 m2 /MW
Ideal storage duration	6–12 hours	Upto 4 hours
Response time	30-90 seconds	In milliseconds
Project life	40–50 years (life of dam/reservoir is over 80 years)	12-15 years
Construction period	4–5 years, it also depends upon other external and socio-political factors	1 year
Operating cost	Lower	Higher since batteries need to be replaced after certain period
Estimated levelized tariff	Rs 4–6/kWh	Rs 5–7/ kWh
Environmental impact	Need substantial reservoirs which may cause environmental consequences, such as habitat destruction and changes in water flow downstream	Disposal of batteries is a major concern. If not taken care properly, may end up in landfills, posing risks of corrosion, flammability, and environmental contamination
Execution and operational risk	• Long approval process for land, environmental and forest clearances • Rehabilitation and resettlement issues • Limited naturally suitable sites • Long gestation period with high construction risk • Managing water requirement, especially in case of any adverse events	• Shortage of rare minerals and metals • Limited manufacturing capacity • Cost volatility • Performance deterioration and fire risk in extreme ambient conditions • Constant degradation and self-discharge

Source: CRISIL intelligence, YES Sec

Exhibit 91: Key Policy Trends for Battery Energy Storage Systems

2021	In June 2021, ISTS charge waiver fcr ESS proects ccnmissioned on or before June 30. 2025 In June 2021, PLI scheme for manufacturing Of ACC batteries was launched
2022	CERC issual Ancillary Services Regulations. Storage projects allowed to participate in secondary and tertiary ancillary markets. In March 2022, govt formulated Guidelines for Procurement and Utilization BESS as part of GTD assets. CEA issued National transmission systen plan 2030 in Which district-wise BESS capacity that needs to be set up by 2030 is specified. In April 2023, Mop issued guideline for PSP Which provides framewcyk for bidding and allotment of PSP sites to developer
2023	In June 2023. Electricity (amendment) Rules, 2023, MOP allowed the energy stored in BESS to be considered for captive status. In June 2023, Mop issued bdding guidelines for FORE based tenders which reuire mandatory ESS deployment. In August 2023, Mop issued National Framework Promoting ESS. In septernber 2023, the govt approved VGF scheme to develop 4 GWh BESS capacity by 2030
2024	In May 2024, India's first cornmercial utility scale battery energy stcgage system project receives approval from Delhi Electricity Regulatory Commission
2025	In February 2025. MOP mandated to include ESS in all future solar tenders with a minimum two-hour storage, equivalent to 10% of installed solar capacity. In June 2025 BESS target under VGF scheme increased to 13.5 GWh further from 4 GWh; further increased to 30 GWh with Rs. 54bn VGF

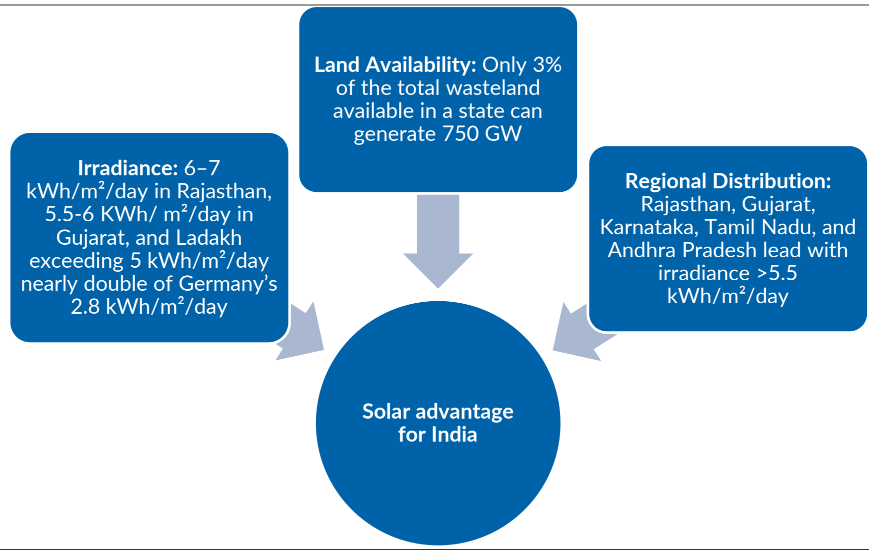
Source: Industry, YES Sec

Why Solar Energy is India's Preferred Renewable Energy Source

Solar Resource Potential: A Geographic Advantage

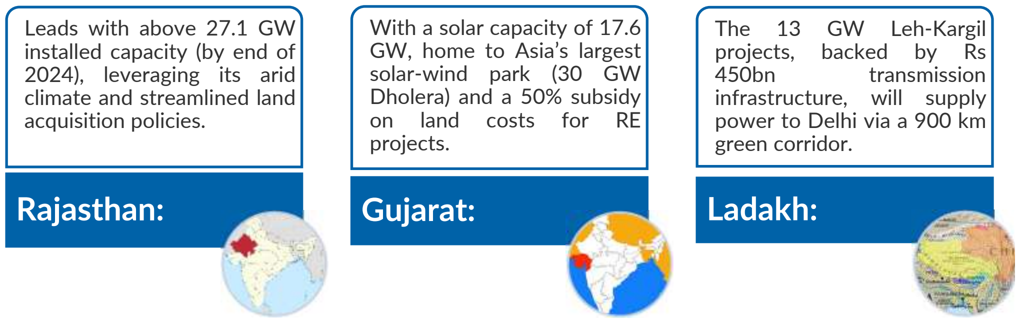
India receives 5,000tn kWh of solar radiation annually equivalent to 1.5–2x the energy generated by all fossil fuels combined, with 300+ sunny days in most regions.

Exhibit 92: India's Solar Resource Potential



Source: Industry, YES Sec

Exhibit 93: Regional Hotspots



Source: Industry, YES Sec

Exhibit 94: Comparison with Other Renewables

Wind: Limited to 8 states with >6 m/s wind speed; capacity factor ~20–25% vs. Solar's ~18–22%, are marginally higher than solar, but land disputes and noise pollution hinder scalability.

Hydro: Only ~45 GW of India's 145 GW potential has been tapped due to ecological concerns (e.g., Subansiri Dam delays) and 5–7year project timelines. Seasonal variability, land acquisition hurdles, and ecological concerns (e.g., Uttarakhand floods).

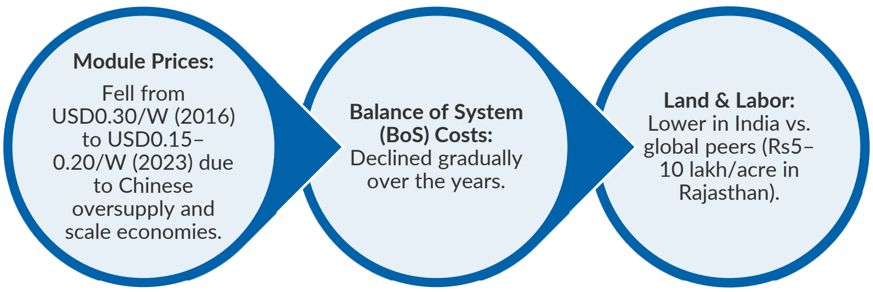
Biomass: Struggles with inconsistent feedstock supply and low efficiency (15–20%), with tariffs 25% costlier than solar at Rs 5–6/kWh.

Source: Industry, YES Sec

Cost Competitiveness: Solar Tariffs at Record Lows

Solar has achieved grid parity, tariffs have plummeted from Rs 12.16/kWh in 2010 to Rs 2.53–2.60/kWh in 2023 auctions (SECI), 30–40% cheaper than coal (Rs 4.5–5/kWh).

Exhibit 95: Key Cost Drivers



Source: Industry, YES Sec

Indian Solar Manufacturing Environment

Rising Demand and the Role of DC Overloading

India's solar energy sector is experiencing a surge in demand, with the need for solar modules far exceeding capacity additions due to the widespread industry practice of Direct Current (DC) overloading. This technique involves pairing inverters with oversized DC module capacity to optimize generation during non-peak hours, ensuring better efficiency despite modules operating at peak output only for a limited time. Consequently, actual solar module requirements surpass targeted capacity additions, intensifying the demand for domestic manufacturing.

Exhibit 96: India Module Sales in Q4FY25

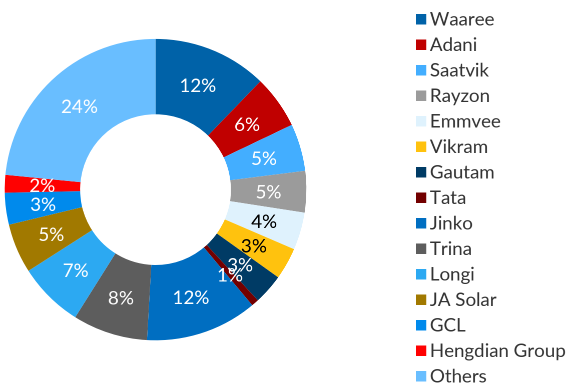
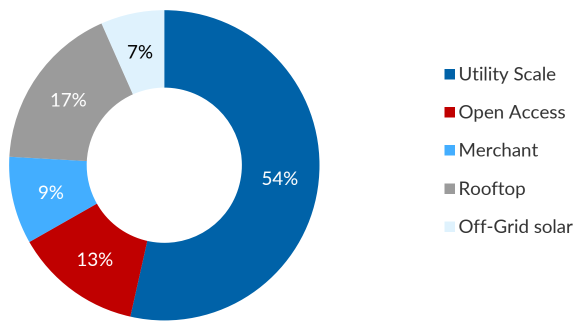


Exhibit 97: India Module Demand in Q4FY25



Source: CRISIL Bridge to India, YES Sec

In Q4FY25, total solar module sales in India stood at 15,395 MW. Of this, Indian companies supplied 5,991 MW (38.9%), while international players accounted for 9,404 MW (61.1%), reflecting the continued reliance on imports despite growing local capacity.

Among Indian suppliers, Waaree Energies led with 1,885 MW (12.2% of total market), followed by Adani (876 MW, 5.7%), Saatvik (781 MW, 5.1%), Rayzon (683 MW, 4.4%), and Emmvee (620 MW, 4.0%). Other domestic players included Vikram Solar (526 MW, 3.4%), Gautam Solar (500 MW, 3.2%), and Tata (120 MW, 0.8%).

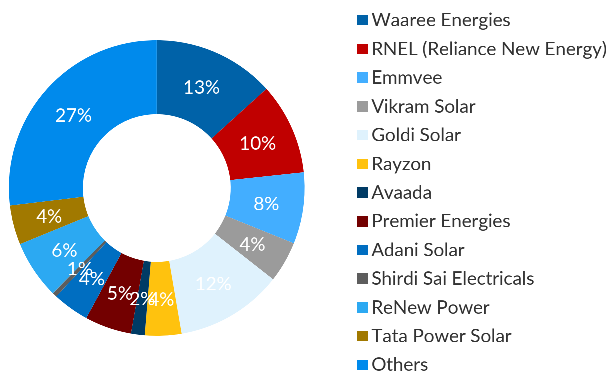
On the international side, Jinko Solar was the largest with 1,845 MW (12.0%), followed by Trina Solar (1,238 MW, 8.0%), Longi (1,078 MW, 7.0%), and JA Solar (819 MW, 5.3%). Smaller contributors included GCL (526 MW, 3.4%) and Hengdian (292 MW, 1.9%). The "Others" category (3,606 MW, 23.4%) reflects a highly fragmented base of foreign suppliers that collectively form the largest single block.

Waaree clearly dominates among Indian manufacturers with a market share comparable to global giant Jinko, but the overall market remains import-heavy, with Chinese suppliers like Jinko, Trina, and Longi holding a combined 27% share of total sales/shipments, underlining India's dependence on foreign modules despite a fast-expanding domestic industry.

Growth of Domestic Manufacturing: A Global Contender

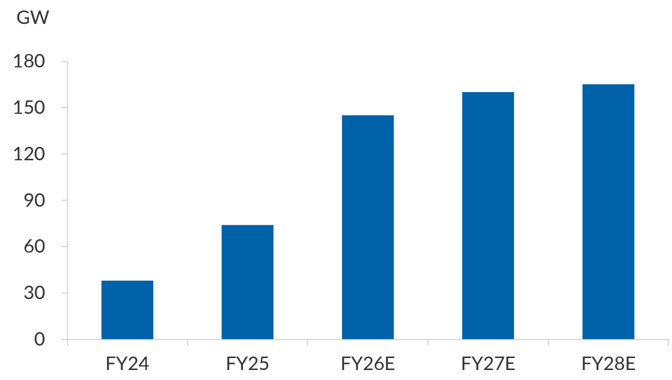
India's solar module manufacturing capacity skyrocketed from 4.2 GW in FY2017 to ~74 GW by FY25, growing at an astonishing 50.6% CAGR. As a result, India has emerged as the third-largest solar module manufacturer globally (~3% share), following China (~90% share) and Vietnam (~5% share). The Indian government's supply-side initiatives, including Basic Customs Duty (BCD), the Approved List of Models and Manufacturers (ALMM), and the Production Linked Incentive (PLI) scheme, have played a crucial role in this rapid expansion.

Exhibit 98: Solar module manufacturing capacity % share (Jun'25)



Source: Company, Industry, YES Sec

Exhibit 99: Solar module manufacturing capacity trend



Source: PIB, Vikram Solar RHP, Crisil Intelligence, YES Sec

Currently, there are over 100 solar module manufacturers in India, with the top 10 companies accounting for over 70 GW of cumulative capacity. Leading manufacturers include Reliance New Energy, Waaree Energies, Renew Power, Tata Power Solar, Premier Energies, Mundra Solar, Rayzon Solar, Vikram Solar, Goldi Solar, First Solar, and Emmvee Group. Given the rapid expansion, India's module manufacturing capacity is projected to reach 160-170 GW by FY28.

Exhibit 100: Indian Solar Module Manufacturing Capacity across Key Players (in GW)

Company	Existing Capacity (Jun'25)	Upcoming Capacity (GW)	Future Capacity	Timeline
Waaree Energies	13.3	12.4	25.7	FY27
RNEL (Reliance New Energy)	10.0	10.0	20.0	FY27
Emmvee	7.8	8.5	16.3	FY28
Vikram Solar	4.5	11.0	15.5	FY27
Goldi Solar	11.7	3.0	14.7	FY26
Rayzon	4.0	8.0	12.0	FY26
Avaada	1.5	10.5	12.0	FY27
Premier Energies	5.1	6.0	11.1	FY26
Adani Solar	4.0	6.0	10.0	FY27
Shirdi Sai Electricals	0.5	9.5	10.0	FY26
ReNew Power	6.4	-	6.4	Already achieved
Tata Power Solar	4.3	-	4.3	Maintaining current

Source: Company, YES Sec

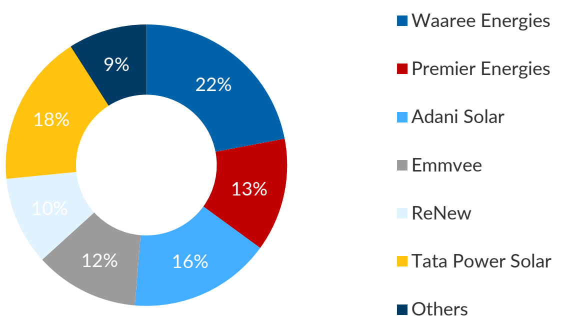
The PLI scheme has been instrumental in expanding domestic solar manufacturing capacity, with Rs240bn allocated across two tranches; Tranche I (November–December 2021): 8.7 GW allocated, Tranche II (April 2023): 39.6 GW allocated.

This initiative is driving a shift from mere module assembly to fully integrated solar manufacturing, enabling domestic manufacturers to compete with global players by producing solar cells and modules at scale.

India's Solar Cell Manufacturing Capacity: A Critical Gap

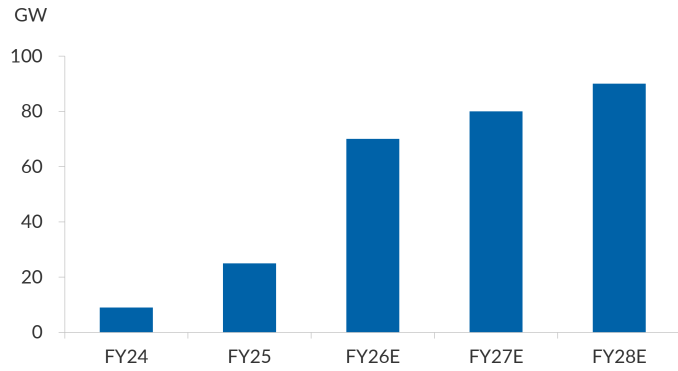
While India has achieved remarkable growth in module manufacturing, solar cell production lags significantly. As of FY24, India's solar cell manufacturing capacity stood at just 9 GW, creating a major dependence on imported cells—primarily from China. Within a year the capacity almost tripled to 25GW by FY25. Waaree Energies, Mundra Solar and Premier Energies dominate domestic cell manufacturing.

Exhibit 101: Solar cell manufacturing capacity % share (Jun'25)



Source: Company, Industry, YES Sec

Exhibit 102: Solar cell manufacturing capacity



Source: PIB, Vikram Solar RHP, Crisil Intelligence, YES Sec

Recognizing this gap, more than 15 companies have announced plans to set up integrated solar manufacturing plants, many of which will commence operations by FY28, pushing India's solar cell manufacturing capacity beyond 60 GW. This shift is expected to reduce import reliance and improve energy security, but challenges remain in achieving economies of scale comparable to China.

The Role of Integrated Manufacturing in India's Solar Industry

The number of fully integrated solar cell and module manufacturers in India remains limited due to the complexity and capital-intensive nature of solar cell production. Among the top 5 module manufacturers, only Waaree, Adani Mundra Solar, Premier Energies, Tata Power Solar and Emmvee have integrated manufacturing facilities. Unlike module production, which primarily involves assembly, solar cell manufacturing is technology-intensive and requires extensive utility management.

Backward integration allows companies to reduce dependence on imports, gain access to DCR module markets, lower production costs, and expand exports to premium markets like the U.S.

Exhibit 103: Indian Solar Cell Manufacturing Capacity across Key Players (in GW)

Company	Existing Capacity (Jun'25)	Upcoming Capacity	Future Capacity	Timeline
RNEL (Reliance New Energy)	-	20.0	20.0	FY28
Waaree Energies	5.4	10.0	15.4	FY27
Vikram Solar	-	12.0	12.0	FY27
Avaada	-	12.0	12.0	FY27
Premier Energies	3.2	6.8	10.0	FY28
Adani Solar	4.0	6.0	10.0	FY27
Shirdi Sai Electricals	-	10.0	10.0	FY27
Emmvee	2.9	6.0	8.9	FY28
ReNew	2.5	3.9	6.4	FY27
Tata Power Solar	4.3	-	4.3	Maintaining current
Goldi Solar	-	4.0	4.0	FY27
Rayzon	-	3.5	3.5	FY27

Source: Company, YES Sec

Domestic and Export Market Trends

As per Premier Energies DRHP, the Indian solar module consumption market has grown at 35% CAGR, with annual consumption rising from 21 GW in FY23 to 28.3 GW in FY24. Projections indicate solar module consumption will surge to 58 GW by FY28, driven by aggressive solar capacity expansion efforts aimed at achieving 280 GW installed solar capacity by CY30.

Explosive Growth in Solar Module Exports

Exhibit 104: Indian Solar module export value

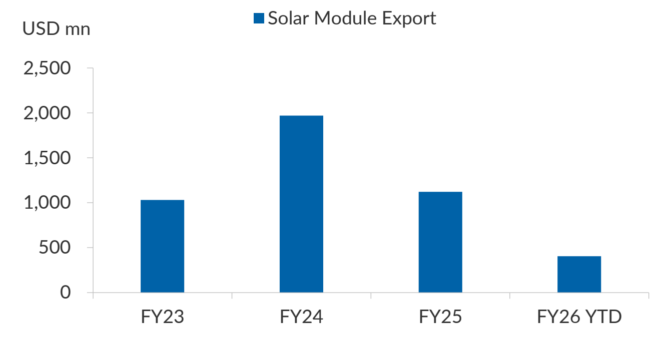
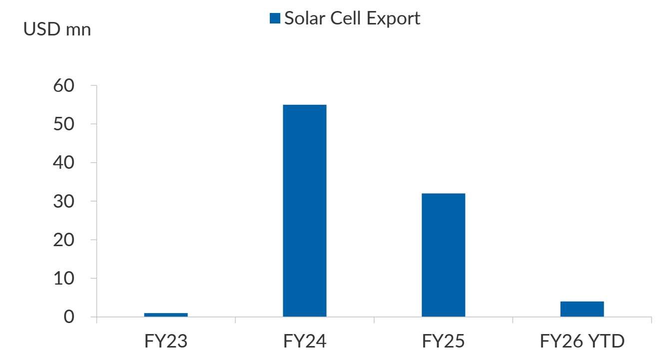


Exhibit 105: Indian Solar cell export value



Source: Ministry of commerce, YES Sec
Note: FY26 YTD as of Jun'25

India's solar module exports surged from USD 112mn in FY22 to USD 1.03bn in FY23, led by a 16x increase in exports to the U.S. By FY24, the exports nearly doubled to USD 1.97bn. While overall exports dipped in FY25 to USD 1.12bn, FY26 YTD exports have crossed USD400bn by Jun'25.

- Exports to the US are expected to remain speculative in FY26 due to tariffs and are expected to stay uncertain but post 2032 due to reduction in domestic solar incentives under the Inflation Reduction Act (IRA) there could be some opportunities for companies having lower prices compared to global peers.
- The EU market could become more accessible following the Carbon Border Adjustment Mechanism (CBAM) in 2025.
- India's export share is expected to reach 26% of total module production in India by FY26, stabilizing at that level despite reduced U.S. demand.
- India's domestic production of cells, as well as increased module production will bring domestic prices closer to Chinese prices which can become competitive at the global level considering China plus one policy will play out in India's benefit.
- USA has imposed 50% import tariffs on Chinese solar modules, cells, polysilicon, wafers, such barriers on trade for China has opened opportunity for southeast Asian countries to increase their exports to US.

Declining Import Dependence and the Rise of Domestic Solar Cells

Exhibit 106: Solar Modules Import

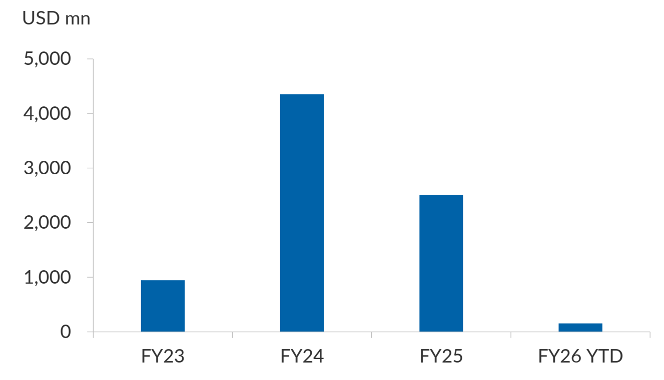
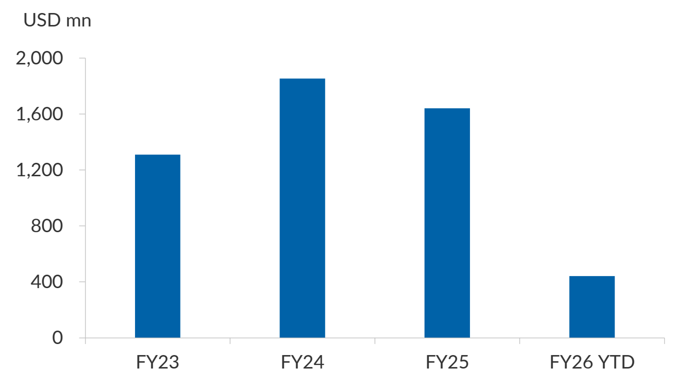


Exhibit 107: Solar Cells imports



Source: Ministry of commerce, YES Sec
Note: FY26 YTD as of Jun'25

Indian solar module and cell imports peaked in FY24 after which they have witnessed decline on increasing domestic production lead by self-sustaining policies and national push towards integrated production lines. This trend is expected to continue in the future with the visibility of upcoming capacity announcements by major companies.

Exhibit 108: India's Top Destination for Module Imports (FY25)

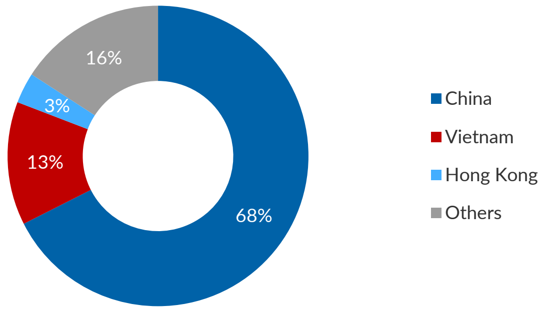
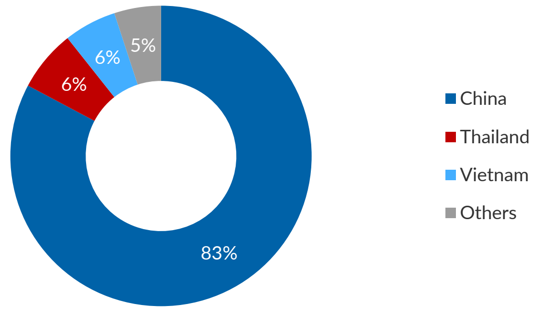


Exhibit 109: India's Top Destination for Cell Imports (FY25)



Source: Ministry of Commerce, YES Sec

Key government policies such as PM Surya Ghar Yojana, CPSU Scheme, and PM-KUSUM are boosting demand for DCR modules, which require domestically manufactured cells. However, even with significant cell capacity additions, India's module manufacturers will continue relying on imports to some extent especially further back in value chain.

India's Growing Solar Cell Export Market

Solar cell exports from India remain relatively small compared to modules but have grown exponentially from USD 1.1mn FY23 to USD 54.7mn in FY24, of which 57% account for US market. This growth is largely due to the China Plus-One strategy, as U.S. companies seek to reduce dependence on Chinese imports, benefiting Indian manufacturers. However, the long-term demand for Indian solar cells in the U.S. and EU markets will depend on evolving trade policies, tariffs, and local manufacturing incentives in these regions.

Challenges for India's Solar Manufacturing Sector

Despite the impressive growth, India's solar manufacturing sector faces several challenges, including:

- **High Capital Requirements**: Setting up integrated solar manufacturing plants requires substantial capital investment and long lead times (15–18 months to establish a plant and then another 6–9 months for stabilization).
- **Technological Catch-up:** China leads in solar cell efficiency and cost-effectiveness, making it difficult for Indian manufacturers to match global price and performance benchmarks.
- **Raw Material Dependence:** India still imports key raw materials like polysilicon, wafers, and specialized equipment, leading to supply chain vulnerabilities.
- **U.S. & EU Trade Barriers:** While the China Plus-One strategy favors India, shifting trade policies, such as the U.S. anti-circumvention investigations and EU's Green Deal could impact future export opportunities.

Key risks for India's Solar PV manufacturing

India's module and cell capacity has scaled aggressively (module capacity ~100 GW, cell capacity rising rapidly crossed 25GW), driven by policy (PLI, BCD, ALMM) and furious capex announcements, but scale alone doesn't eliminate risk. The sector now sits at an inflection point where policy, input markets, demand signals, trade flows and technology shifts will determine which players survive and who gets squeezed.

Demand/off-take mismatch and oversupply risk: India's nameplate module capacity rose from the high-teens to ~100 GW within a short period; announced additions could push nameplate capacity far beyond domestic demand (estimates of 160–170GW by 2028 in industry roadmaps). If domestic tenders, export windows (US/EU) or rooftop uptake slow, utilization will fall and margins will compress. Oversupply is not hypothetical, inventory/price pain already visible in China and globally.

Input concentration: polysilicon, wafers and cells dominated by China: China still controls the bulk of upstream inputs (polysilicon → wafers → cells → modules), with >80% share across stages per IEA meaning India's module makers are exposed to raw material bottlenecks, price shocks and diplomatic/trade disruption. Polysilicon prices recently swung dramatically (sharp falls in 2024 but volatility remains), a structural advantage for Chinese incumbents.

Policy and rule risk (BCD / ALMM / DCR / PLI execution): Government protection (20% BCD on modules; 20% on cells) and ALMM/DCR have driven investment but raise two risks: (a) policy reversal, grandfathering or legal challenge could destabilize planned demand; (b) ALMM List II / cell rules (implementation timelines and list composition) can create winners/losers and sudden local price power for approved cell makers. PLI allocations reduce project economics uncertainty for winners but increase the stakes and competition for capital.

Export market volatility and trade friction: Indian Solar Modules exports have surged in recent years (notably to the US), but export demand depends on external trade rules (IRA, US anti-circumvention, CVD/AD actions in SE Asia) and on buyers' preference for local content. Sudden duties or anti-dumping findings can close export windows quickly, leaving Indian makers with surplus capacity and weaker domestic realizations.

Technology and product evolution risk: Rapid transition from p-type multi to mono PERC → TOPCon → HJT means capital deployed for older tech depreciates faster. Winners will be those who upgrade to high-efficiency cell lines and secure supply of higher-value wafers/ingots. Smaller players who cannot finance upgrades face margin erosion and loss of ALMM listing competitiveness.

Financing, working capital and margin pressure: Module manufacturing is capex-intensive and working-capital heavy (prepayment for wafers/cells, inventory). With potential oversupply and falling module prices globally, lenders may tighten project financing terms; higher interest rates or refinancing risk will pressure ROEs.

Execution and timeline risk: Building integrated wafer → cell → module lines take 12-30 months as per articles (ingot wafer: 6-18months, Cell-Module: 6-12 months); delays, capex overruns or supply chain misalignment can push commissioning and eligibility for PLI, ALMM, or tender deadlines, eroding projected returns.

Solar Module & Cell Price Trends: Global vs. India (2020–2025)

Exhibit 110: Global Solar module price trend

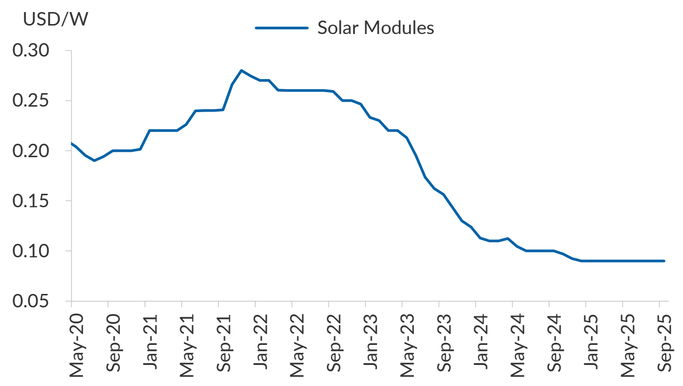
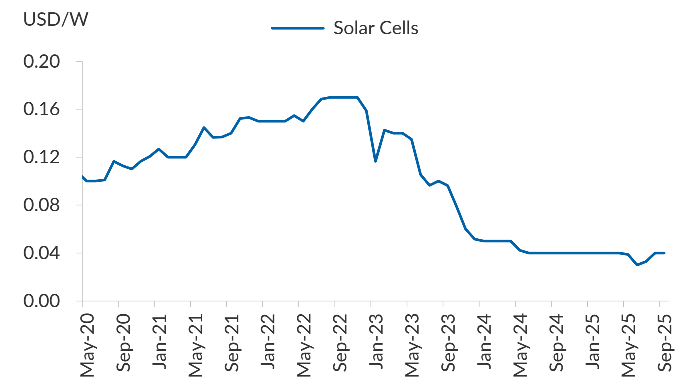
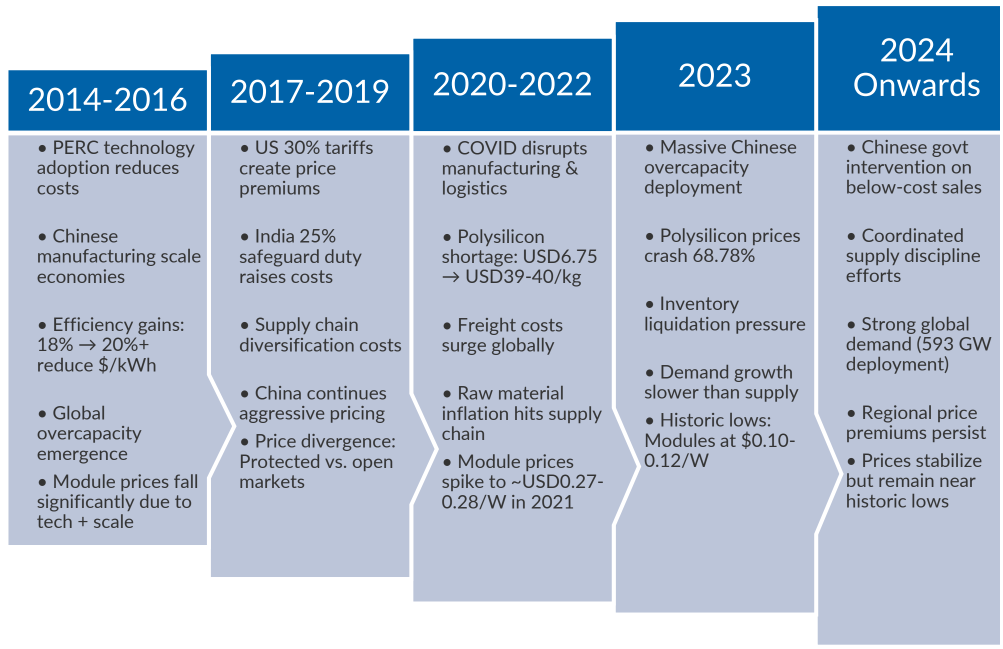


Exhibit 111: Global Solar cell price trend



Source: Industry, Bloomberg, YES Sec

Exhibit 112: Global Solar price trend



Source: Industry, YES Sec

US Inflation Reduction Act

Benefits earned during the bill's tenure: The Inflation Reduction Act (IRA) 2022, allocated USD 370bn in support of clean energy sectors including solar, wind, battery storage, and electric vehicles with the goal of accelerating the country's transition to renewable energy. This amount was distributed through a mix of tax credits, grants, and loans. Within the solar and wind sectors, the policy was designed to support the entire value chain, offering targeted incentives to manufacturers, utility-scale power producers, and residential rooftop solar adopters.

Benefits to Solar Module Manufacturers: Under the IRA, manufacturers producing solar modules within the United States were eligible for direct cash incentives based on the volume and type of components produced and sold. These incentives, provided under Section 45X of the act, were structured as per-unit production tax credits that could be monetized as cash refunds. The benefit structure was as follows:

Exhibit 113: Benefits under IRA

Type	Benefit	Unit
Solar cells	4 USD cents	per WDC capacity
Solar wafers	12 USD	per square meter
Solar grade silicon	3 USD	per kilogram
Polymeric backsheet	40 USD cent	per square meter
Solar modules	7 USD cent	per WDC capacity

Source: Industry, YES Sec

The policy was structured to incentivize domestic solar manufacturing by offering direct financial benefits across the value chain. Module manufacturers that also produced key components such as solar cells within the United States were eligible to receive a refund of USD 0.11/watt for every watt of modules sold. This effectively provided a margin cushion, enabling U.S.-based manufacturers to better compete with lower-cost imports from China and other South Asian countries.

For the solar rooftop, under IRA homeowners installing rooftop solar systems in the U.S. are eligible for a 30% federal Investment Tax Credit (ITC) on the total cost of the system. This includes expenses related to solar panels, inverters, cabling, mounting hardware, and even battery storage (whether installed with the solar system or added later). The credit directly reduces the homeowner's federal income tax liability and applies in the year the system is installed and becomes operational. If the full credit cannot be used in one year due to low tax liability, the unused portion can be carried forward to future years.

Cuts after new bill passed

With the credit scheduled to reduce beginning in 2030 and expire fully after 2032 in a phased manner (25% reduction each year), the solar industry faces both opportunities and challenges.

Short-Term Acceleration (2025–2029): The next four years represent the most favorable environment for solar manufacturers. With the full credit in place, companies can significantly reduce effective production costs, strengthen margins, and improve the economics of U.S.-based factories. This has already spurred a wave of new facility announcements and expansions, with global players including those from India prioritizing U.S. entry.

Investment Urgency: Because the credit begins to step down in 2030, solar manufacturers will face mounting pressure to front-load investments and capacity build-outs. Facilities commissioned before 2030 will enjoy the strongest return profiles, while delayed entrants may struggle to justify economics as the incentive declines.

Long-Term Cost Competitiveness: As the 45X benefit diminishes, the U.S. solar industry will need to transition from being policy-driven to being cost-competitive on a global scale. Without full credit support, manufacturers must rely on economies of scale, supply chain integration, and technological efficiencies (e.g., higher-efficiency modules, automation, localized raw material sourcing) to remain viable.

Impact on Supply Chains: The phasedown raises questions about the durability of supply chain reshoring efforts. Some suppliers may accelerate U.S. commitments through 2029, but with the credits fading, there is risk of underutilization or stalled expansion after 2030 unless demand pull and other supportive policies remain strong.

Implications for Indian Manufacturers: For Indian solar companies evaluating U.S. manufacturing, the phase-down creates a time-sensitive opportunity. Entering the market before 2030 ensures access to the maximum incentive window, enhancing project bankability and investor interest. However, the declining benefits post-2030 mean strategic planning must weigh the sustainability of operations once subsidies taper off.

Exhibit 114: Indian Leading Module manufacturers with plans to start manufacturing in United States

Company	Planned/ Operational Capacity	Location	Product Type	Timeline	Notes
Waaree Energies	1.6 GW FY25 → 3.2 GW	Brookshire, Texas	Modules	FY26 End	Further expansion contingent on Macro environment
Premier Energies	1.2 GW N-type Cells planned	-	Solar Cells	FY27	Evaluating clarity on US policies and tariffs
Vikram Solar	3 GW planned	-	Modules	FY27	USD1.5bn, currently in planning stage only
Navitas Solar	1.2GW planned	-	Modules	-	On Hold
Saatvik Solar	1.5GW planned	-	Modules	-	On Hold

Source: Industry, YES Sec

With the recent repeal and phase-out of key incentives under the Inflation Reduction Act (IRA), companies that were planning to open solar manufacturing plants in the U.S. now face significant uncertainty and potential economic headwinds.

Delayed or Cancelled Projects: Many companies especially foreign players like Indian, Korean, or European module makers had planned U.S. capacity expansions based entirely on the 45X economics. Without that support, several projects may be put on hold, downsized, or scrapped entirely. The loss of this margin support makes it harder to compete with lower-cost Asian imports unless the U.S. introduces other forms of trade protection (e.g., tariffs).

Shift Back to Import-Based Models: Without financial incentives for domestic production, companies may prefer to import cells or modules from their existing Asian facilities and rely on assembly-only operations or exit the U.S. manufacturing market altogether if policy stability is lacking.

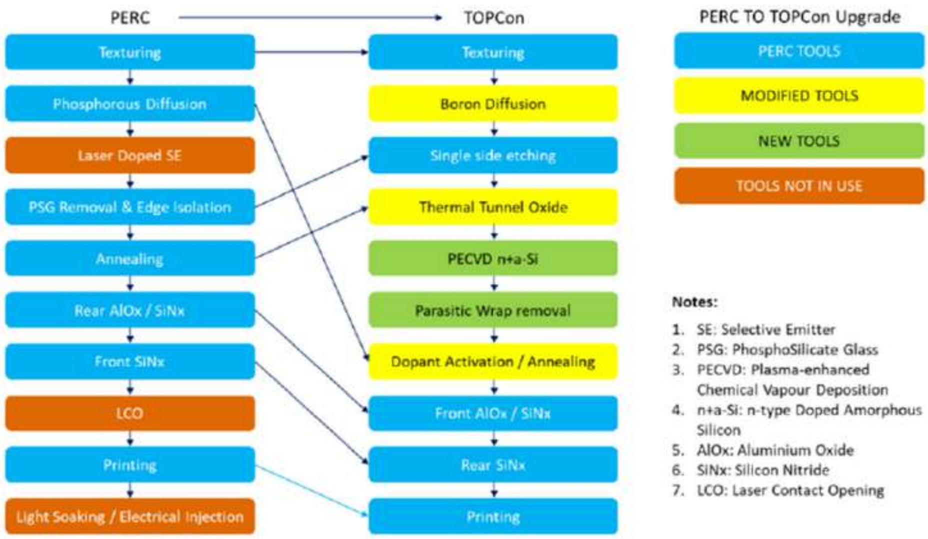
Exhibit 115: Solar Module Technologies

PARAMETERS	PERC	TOPCon	HJT
Cell Efficiency	23.2% - 23.7%	24.5% - 25.2%	24.5% - 25.2%
Module Efficiency	20.0% - 21.5%	22.0% - 23.0%	22.0% - 23.0%
Bi-faciality	70% - 75%	80% - 85%	80% - 90%
Complexity	Moderately complex	Less than HJT	Most complex
Low Light Performance	Good	Very good	Excellent
Suited for climate	Moderate	Hot and cold	Hot and cold
Capex per GW (Module) Rs bn	2.5	3.4	6.0
Temperature Co-efficient of Power (Pmax Temperature Coefficient)	0.35% / °C. PERC cells experience a more noticeable power decline at elevated temperatures	0.29% / °C. Offers a significant power improvement over PERC cell at elevated temperatures	0.24% to -0.26% / °C. Lowest temperature coefficient – HJT cells experience minimal power loss even at high temperatures.

Source: Industry, Waaree Energies DRHP, YES Sec

By 2023, the global solar market faced an oversupply crisis, leading to module prices crashing to a historic low of USD0.15/W. Despite the record-low pricing, India's BCD structure kept domestic module prices at USD0.23/W, making imports from China still attractive for certain developers. Meanwhile, advancements in TOPCon and HJT solar cells, boasting efficiencies of 24–26%, allowed global prices to stabilize at USD0.13/W, with China offering the lowest at USD0.10/W.

Exhibit 116: Complex Specification required as Technologies Upgrade

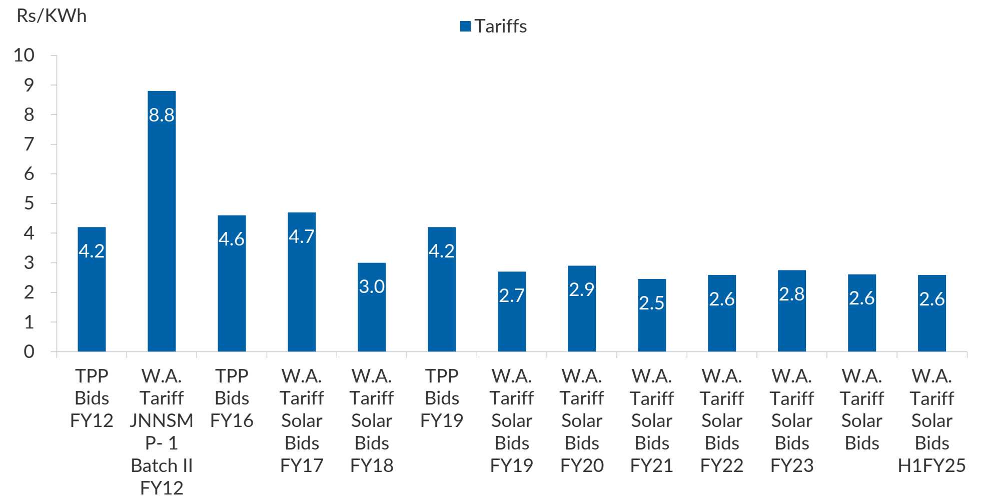


Source: Premier Energies DRHP, YES Sec

India's solar manufacturing landscape changed drastically, with total domestic capacity reaching 74 GW by FY25, attributed to expansions by Key Domestic Players. With an increasing focus on high-efficiency TOPCon cells, Indian module prices fell to USD0.20/W in 2024.

Evolution of Solar Tariffs in India

Exhibit 117: India's Tariffs YoY



Source: CRISIL intelligence, YES Sec

A solar tariff refers to the price at which electricity generated from a solar power plant is sold to buyers, typically state electricity distribution companies (DISCOMs) or industrial and commercial consumers. These tarifffs are determined through competitive bidding, where developers bid for the lowest price per unit of electricity (Rs/kWh). Lower tariffs make solar power more affordable but also impact the financial viability of developers.

Solar tariffs in India have significantly declined over the past decade on technological advancements, economies of scale, and policy interventions. In the early days of India's solar sector (before 2017), Feed-in Tariffs (FiT) were used, where regulators set a fixed tariff to ensure project viability. However, as solar costs dropped and competition increased, the government switched to competitive auctions conducted by agencies like SECI (Solar Energy Corporation of India) and NTPC, which resulted in record-low tariffs.

How Solar Tariffs Are Determined?

Solar tariffs depend on several factors:

Exhibit 118: Solar tariffs depend on several factors including

Source: Industry, YES Sec

Decline in Solar Tariffs: A Historical Overview

In the early 2010s, solar tariffs were as high as Rs 10–12/unit, making solar power less attractive compared to coal-based electricity. However, rapid declines in solar panel costs, improved efficiency, and policy reforms have driven tariffs down.

Exhibit 119: Solar Tariff trend

2010-2016

High Cost Era
- Technology was nascent, cost of modules were high, and coal remained far cheaper

2017–2020

Record-Low Tariff
- In June 2020, SECI's ISTS-IX auction saw the lowest-ever solar tariff of Rs 2.36/unit.
- By November 2020, in the SECI Rajasthan-III auction, tariffs fell further to Rs 2/unit, setting a global benchmark.

2021-2023

Rising Costs and Tariff Increase
- Supply Chain Disruptions due to COVID-19 and global polysilicon shortages led to increased module prices.
- Imposition of BCD (April 2022) and higher GST (12% on modules, 18% on electrical components).
- Due to these factors, solar tariffs increased to Rs 2.79/unit in FY23, reversing the decade-long downward trend.
- This however is still significantly cheaper than coal-based electricity, where the average cost of generation stands at Rs 4-6/unit.

2024 onwards

Slight softentning and stabilization
- Despite falling module prices, tariffs edged down only modestly as bidders built in buffers for BCD, logistics and higher local content costs.
- Emerging auctions continue to show competitive pricing ~Rs 2.5-3/kwh indicating market stability
- Recent GST reduction from 12% to 5% on solar modules to ease cost pressures.

Source: Industry, YES Sec

State versus Central Tariffs: Why Do They Differ?

Solar tariffs in centrally auctioned projects (conducted by SECI/NTPC) tend to be lower than those in state-run tenders. This is due to:

Exhibit 120: Reasons for Central tariffs to be lower than State

- **Better Payment Security:** Central agencies offer stronger guarantees than financially weak state DISCOMs.
- **Creditworthiness:** Some state DISCOMs delay payments, leading developers to factor in a risk premium in their bids.
- **Project Scale:** Central auctions are for large-scale projects, benefiting from economies of scale.

Source: Industry, YES Sec

For example, in FY23, SECI auctions had an average tariff of Rs 2.53/unit, whereas state auctions by the Karnataka Electricity Regulatory Commission (KERC) were higher at ~Rs 3.10/unit for grid-connected solar projects. Some states like Andhra Pradesh and Karnataka have a 35% risk of payment delays, which forces developers to bid at higher tariffs.

Exhibit 121: State approved Solar Park Capacity (GW) as of Dec'24

Name of the State in which Solar Parks/UMREPPs are located	Total Capacity of Solar Park/ UMREPP (MW)	Capacity Under Award / Tendering (MW)	Capacity Awarded (MW)	Capacity Under construction (MW)	Capacity Commissioned (MW)
Andhra Pradesh	4,300	-	4,300	1,250	3,050
Chhattisgarh	100	-	100	-	100
Gujarat	12,150	3,770	8,380	7,380	1,000
Himachal Pradesh	53	21	32	-	32
Jharkhand	1,089	679	410	410	-
Karnataka	2,500	500	2,000	-	2,000
Kerala	255	100	155	50	105
Madhya Pradesh	4,780	2,002	2,778	515	2,263
Maharashtra	1,105	605	500	250	-
Mizoram	20	-	20	-	20
Odisha	340	200	140	140	-
Rajasthan	10,341	6,000	4,341	1,035	3,306
Uttar Pradesh	3,730	1,300	2,430	2,000	430
Total	**40,763**	**15,177**	**25,586**	**13,030**	**12,306**

Source: Industry, CRISIL intelligence, YES Sec

Statewise Solar Energy Potential

India has immense solar energy potential, with approximately 5,000 trillion kWh of solar energy incident annually on its landmass. This vast resource, coupled with government policies and technological advancements, positions India as a leader in solar energy adoption. The National Institute of Solar Energy (NISE) has estimated the country's solar potential at 750 GW, assuming solar PV modules cover just 3% of the available land area.

Exhibit 122: Top States with High Solar Energy Potential (Aug'25)

State	Potential (GW)	Installed Capacity (GW)	% Potential Achieved
Rajasthan	142.0	32.3	22.8%
Maharashtra	64.0	13.3	20.8%
Madhya Pradesh	62.0	5.6	9.0%
Andhra Pradesh	38.0	5.5	14.5%
Gujarat	36.0	21.9	60.8%
Karnataka	25.0	10.1	40.2%
Uttar Pradesh	23.0	3.5	15.1%
Telangana	20.0	5.0	25.0%
Chhattisgarh	18.3	1.5	8.4%
Tamil Nadu	18.0	10.8	60.1%

Source: MNRE; YES sec

Current Installed Capacity vs. Potential: Despite significant growth in solar capacity installations, there remains a huge untapped potential across India. As of Aug'25, India's cumulative solar installed capacity stood at 119 GW, achieving only 16% of its total potential. Gujarat, Tamil Nadu, and Karnataka have the highest percentage of their potential already utilized, whereas states like Maharashtra and Madhya Pradesh have a significant gap to bridge.

Emerging Trends: Hybrid, RTC, and Peak Power Tariffs

With increasing reliance on renewable energy, new types of bidding models have emerged:

- **Round-the-Clock (RTC) Power Tariffs:** These projects ensure 24x7 power supply by combining solar, wind, and battery storage. Due to storage costs, tariffs are higher, around Rs 3–5/unit compared to standalone solar projects.
- **Peak Power Supply (PPS) Tariffs:** Developers must provide power during peak demand hours (evenings/nights), often using battery storage or hybrid plants. This results in tariffs ranging from Rs 3.5–4.5/unit.
- **Thermal-Bundled Renewable Energy Tariffs:** Some projects mix coal and solar power to ensure reliability. These projects have higher tariffs between Rs 4–6.7/unit, making them less competitive.

Future Outlook on Solar Tariffs

Despite short-term fluctuations, solar tariffs are expected to decline to Rs 2–3/unit.

Exhibit 123: Drivers for sustainable low solar tariffs

Falling Module Prices:	Global oversupply and high-efficiency TOPCon & HJT solar cells will lower costs.
Increased Domestic Manufacturing:	India's PLI-backed 40 GW manufacturing expansion will reduce reliance on imports.
Policy Changes:	Removal of ALMM (Approved List of Models & Manufacturers) restrictions could allow cheaper Chinese imports, impacting tariffs.
Reduction in Customs Duty:	In the Union budget 2025, the government has restructured the 40% BCD on modules to 20% BCD and 20% AIDC, while on solar cells, its reduced from 25% (+2.5% SWS) to 20% (+7.5% AIDC). GST on modules has been reduced to 5% from 12% earlier.

Source: Industry, YES Sec

However, challenges remain, including DISCOM payment delays, high battery storage costs, and grid integration issues, which may keep tariffs from falling further.

India's solar energy sector is rapidly evolving, driven by ambitious government policies aimed at self-reliance, grid expansion, and domestic manufacturing growth. A combination of financial incentives, regulatory mandates, and non-tariff trade barriers has shaped the industry's trajectory, ensuring India reduces its dependence on imports and strengthens its renewable energy ecosystem.

Exhibit 124: Policies boosting the demand for Solar Modules

Demand related key Policies and Regulations	Supply related key Policies and Regulations
Renewable Purchase Obligation: 1) Mandates electricity distribution companies, open access consumers, and large captive power users to purchase a certain percentage of their total power consumption from renewable energy sources. 2) RPO target for DISCOMs and bulk users are set to rise from FY25 target of 29.9% to 43.3% in FY30	**Solar Park scheme** 1) Over 10 GW solar capacity commissioned across 50+ parks with dedicated infrastructure since 2014. 2) Provides CFA up to 20 lakh/MW or 30% of project cost to support park development.
PM Surya Ghar Muft Bijli Yojana (residential rooftop) 1) Promotes rooftop solar adoption by providing subsidies and incentives to households, enabling up to 300 units of free electricity per month. 2) Subsidy ranging from Rs30,000-78,000 based on capacity	**Transmission and evacuation system upgrades** 1) 2.4 trillion allocated under Green Energy Corridor Phases I & II to boost grid capacity for 500 GW renewable target by 2030. 2) GEC-I added 10,750ckm lines and 27,500 MVA; GEC-II targets 20,000ckm and 45,000 MVA by FY 2026.
PM Kusum Scheme (Agri-solar) 1) Supports the installation of solar pumps and grid-connected solar power plants. 2) Reducing farmers' dependence on diesel and grid electricity and enables them to generate additional income by selling surplus power. 3) 34.8 GW capacity addition by March 2026 using domestic modules.	**Standard competitive bidding framework** 1) Provides tariff-based bidding guidelines to ensure transparent and cost-efficient solar project allocation. 2) Promotes fair competition and timely execution of grid-connected solar and transmission projects.
CPSU Scheme 1) Provides Viability Gap Funding (VGF) up to Rs5.5mn/MW to Central/State PSUs and government organizations, for setting up grid-connected solar projects. 2) Targets 12 GW grid-connected solar power capacity with DCR modules.	**Liberalised investment regime** 1) Allows 100% FDI under automatic route in solar generation and manufacturing to attract global investment. 2) Supports domestic manufacturing through incentives and ease-of-doing business reforms.
Green Open Access Rules 1) Open Access is allowed for all consumers, with a reduced minimum load requirement of 100 kW for non-captive users and no limit for captive consumers. 2) Consumers procuring green energy beyond their RPO obligations will be eligible for Green Certificates.	**Mandatory storage capacity for solar projects** 1) New solar bids from Feb 2025 must include 10% energy storage with 2-hour backup to enhance grid reliability. 2) Aims to add 14 GW / 28 GWh storage capacity by 2030 for better renewable integration

Source: MNRE. NITI Aayog, YES Sec

National Solar Mission (NSM): A target of 100 GW by 2022 (achieved 70 GW by 2023); revised to 280 GW by 2030. Using mechanisms like Viability Gap Funding (VGF), bundling with thermal power, and solar parks.

Aatmanirbhar Bharat

Launched in May 2020, the Aatmanirbhar Bharat Abhiyan (Self-Reliant India Initiative) is a transformative economic strategy aimed at reducing India's dependence on imports, strengthening domestic manufacturing, and enhancing global competitiveness. It was introduced in response to global disruptions, particularly the COVID-19 pandemic, which exposed vulnerabilities in supply chains across industries.

Under this framework, the government announced a Rs 20tn (USD260bn) stimulus package, targeting key sectors such as manufacturing, agriculture, healthcare, defense, and energy. The policy's overarching goal is not isolationism, but rather integration with global markets while strengthening domestic capabilities.

The renewable energy sector is a core focus under Aatmanirbhar Bharat, aligning with India's commitment to achieving 500 GW of non-fossil fuel capacity by 2030 and reaching net-zero emissions by 2070. Given India's heavy reliance on imported solar modules, batteries, and key raw materials, the initiative aims to reduce external dependency while building domestic capacity in clean energy manufacturing.

PM-KUSUM Scheme – Solar to power Indian Agriculture

The Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM KUSUM) scheme was introduced to reduce diesel usage in irrigation, lower electricity costs for farmers, and promote decentralized solar power generation in rural areas. The government has allocated Rs 344.22bn in financial support, with a target of installing 34.8 GW of solar capacity by March 2026.

The scheme is implemented by state nodal agencies and consists of three main components:

Exhibit 125: Components of scheme

A	10GW of decentralized ground-mounted solar power plants to be installed on barren, fallow, or cultivable land. Individual farmers, solar developers, cooperatives, and panchayats can set up these plants and sell surplus power to the DISCOMs at pre-fixed tariffs.
B	Installation of 1.3mn standalone solar water pumps for farmers in off-grid areas, eliminating reliance on diesel-powered pumps.
C	Solarization of 3.5mn existing grid-connected agricultural pumps, either at the individual level or through feeder-level solarization (FLS).

Source: Industry, YES Sec

Exhibit 126: Scheme's current progress

PM-KUSUM (July'25)	Total sanctioned	Total installed
Component A (Solar capacity MW)	10,000	640.99
Component B (Standalone pumps nos)	1,272,758	853,330
Component C		
Total pumps sanctioned for individual (pump solarization)-IPS (Nos)	60,828	8,966
Total pumps sanctioned for Feeder (level solarization)-FLS (Nos)	3,561,855	645,975

Source: PM KUSUM portal, YES Sec

Progress and Implementation Challenges of PM-KUSUM Scheme

As of Jul'25, implementation has been slower than expected, with only 641MW of decentralized solar projects completed. While 1.27mn pumps were sanctioned, only 0.85mn pumps have been installed, individual pumps reached 8,966 out of 60,828 sanctioned. Similarly, feeder-level reached 0.65mn installations completed out of 3.56mn sanctioned.

A key driver for domestic manufacturers is the scheme's mandate for DCR modules, benefiting Premier Energies, Waaree Energies, and Tata Power Solar, which supply modules compliant with these standards.

Production-Linked Incentive (PLI) Scheme for Solar Manufacturing

The PLI scheme, launched by the Ministry of New and Renewable Energy (MNRE) in 2021, is a key initiative aimed at boosting domestic solar PV manufacturing and reducing reliance on imports. With a total outlay of Rs240bn (~USD3bn) across two tranches, the scheme incentivizes manufacturers to set up high-efficiency solar module and cell production in India. The incentives are linked to sales volume, local value addition, and efficiency, with higher benefits for fully integrated plants covering polysilicon, wafers, cells, and modules.

Exhibit 127: Capacity awarded under PLI scheme in GW

Player	Polysilicon	Wafer	Cells	Module	PLI Eligible Capacity	Amount Awarded (Rs bn)
Shirdi Sai Electricals Ltd	4.0	4.0	4.0	4.0	2.0	18.8
Reliance New Energy Solar Ltd	4.0	4.0	4.0	4.0	2.0	19.2
Adani Infrastructure Pvt. Ltd	0.7	0.7	0.7	0.7	0.4	6.6
Total PLI Tranche 1	**8.7**	**8.7**	**8.7**	**8.7**	**4.4**	**44.6**
Indosol Solar Private Limited	6.0	6.0	6.0	6.0	3.0	33.0
Reliance New Solar Energy Limited	6.0	6.0	6.0	6.0	3.0	31.0
FS India Solar Ventures Private Limited	3.4	3.4	3.4	3.4	1.7	11.8
Waaree Energies Limited		6.0	6.0	6.0	3.0	19.2
Avaada Electro Private Limited		3.0	3.0	3.0	1.5	9.6
ReNew Photovoltaics Private Limited		4.8	4.8	4.8	2.4	15.4
JSW Renewable Technologies Limited		1.0	1.0	1.0	0.5	3.2
Grew Energy Private Limited		2.0	2.0	2.0	1.0	5.7
VSL Green Power Private Limited			2.4	2.4	1.2	5.3
AMPIN Solar One Private Limited			1.0	1.0	0.5	1.4
TP Solar Limited			4.0	4.0	2.0	3.8
Total PLI Tranche 2	**15.4**	**32.2**	**39.6**	**39.6**	**19.8**	**139.4**
Total under Tranche 1&2	**24.1**	**40.9**	**48.3**	**48.3**	**24.2**	**184.0**

Source: MNRE, YES Sec

Under **Tranche I** (2021), Rs45bn (~USD600mn) was allocated for 8.7 GW of integrated manufacturing capacity, awarded to Reliance, Adani, and Shirdi Sai Electricals.

Tranche II (2022) expanded funding to Rs184bn (~USD2.25bn), supporting 39.6 GW of new capacity across Waaree Energies, Reliance, Indosol Solar, ReNew, and others. This initiative is expected to increase.

The scheme is driving technological advancements, with a focus on TOPCon and HJT solar cells. However, challenges such as overcapacity risks, lack of polysilicon production, and high capital requirements remain. Despite these hurdles, the PLI scheme positions India as a global solar manufacturing hub, aligning with international trends where the USA (Inflation Reduction Act) and China (National Solar Subsidy) are also heavily investing in solar manufacturing. To ensure sustainability, further policy refinements in export promotion, R&D support, and supply chain development will be crucial in maximizing the scheme's impact on India's renewable energy transition.

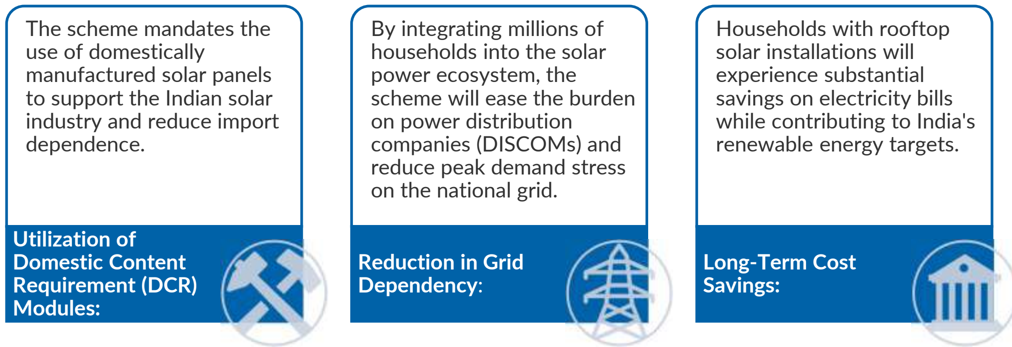
PM Surya Ghar Muft Bijli Yojana – Driving Rooftop Solar Adoption

Launched in Feb'24, the PM Surya Ghar Muft Bijli Yojana is a flagship initiative of the Government of India, designed to accelerate the adoption of rooftop solar systems by providing direct financial subsidies to households. The primary goal is to reduce dependency on conventional energy sources, promote self-sufficiency in power generation, and lower electricity costs for Indian families.

The scheme has been allocated a budget of Rs750bn, making it one of the most significant financial commitments by the Indian government toward decentralized solar energy. It aims to provide up to 300 units of free electricity per month to 10mn households, thereby reducing household electricity expenses and promoting sustainable energy consumption.

Financial assistance and Subsidy Structure: For systems up to 2 kW, the subsidy is Rs30,000-60,000 per kW. For systems ranging 2-3 kW, the subsidy is Rs60,000-78,000, and above 3 kW, the subsidy is Rs78,000. By Mar'25 the cumulative connections crossed 1mn households which is expected to further ramp up to 4mn by 2026.

Exhibit 128: Key Features & Impact of scheme



Source: Industry, YES Sec

CPSU Scheme: Government-Led Solar Projects (12 GW Target)

The Central Public Sector Undertaking (CPSU) Scheme Phase II is aimed at developing large-scale solar projects by government-owned entities to reduce reliance on imported energy and enhance energy security.

- **Financial Support:** The maximum VGF was Rs 7mn/MW for the first two tranches, later reduced to Rs 5.5 mn/MW for the third tranche, determined through transparent bidding using VGF as the key parameter.
- **Competitive Bidding:** SECI (Solar Energy Corporation of India) conducts auctions to allocate capacity.
- **Target Capacity:** 12,000 MW of grid-connected solar projects.
- **Status of implementation:** Under this Scheme, the Government has so far sanctioned about 8.2 GW capacity of solar PV power plants to selective government entities.

Approved List of Models and Manufacturers (ALMM)

Reinstated in 2024, this policy stipulates that developers can only utilize modules from the list for government-sponsored PV projects, which includes only firms that manufacture in India. The primary reason for using non-price criteria in solar PV auctions has been India's Approved List of Models and Manufacturers (ALMM) policy, which was reinstated in 2024.

The ALMM system permits developers to utilize only modules from the list for PV projects involving the government.

Only domestically manufactured solar modules are included in **ALMM List I**. As of Mar'25, ALMM-approved module capacity stood at 74 GW.

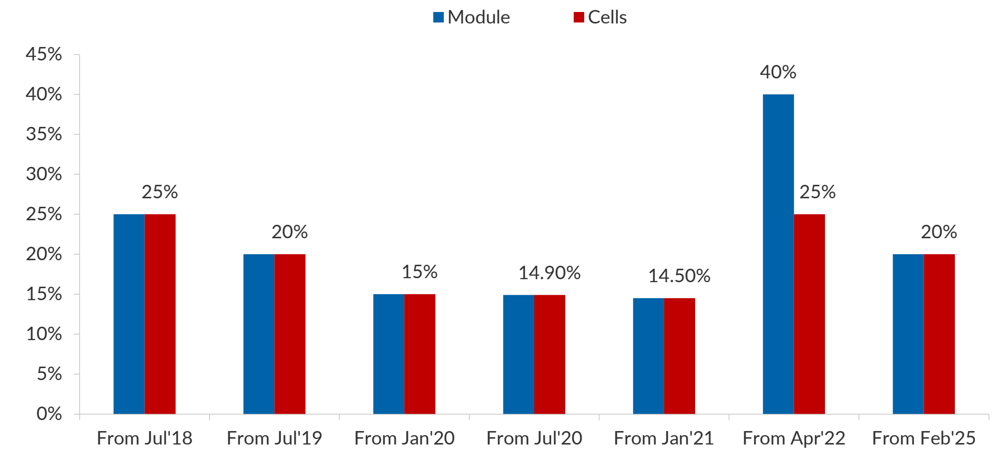
ALMM List II (ALCM): Expected to be implemented from **June 1, 2026**, ALCM is similar to ALMM but specifically applies to solar cell manufacturing**.** It mandates domestic cell usage in all ALMM-listed modules. Non-compliance could lead to delisting from ALMM List I, pressuring manufacturers to source locally. These measures serve two purposes: 1) Encourage large-scale investments in local manufacturing, 2) Ensure a stable demand pipeline for domestic producers. As of the initial release, about **13 GW** of solar cell manufacturing capacity from six manufacturers has been enlisted.

NRE has proposed **ALMM List III** in mid Sep'25 which mandates the use of domestically manufactured wafers by Jun'28, ensuring nationwide backward integration.

Other key government policies include

- **Wind-Solar Hybrid Policy:** Announced in 2018, this policy aims to promote large grid-connected wind-solar PV hybrid systems. This arrangement allows for efficient utilization of transmission infrastructure and land. Combining solar and wind power helps address the intermittency challenge and improves grid stability. The policy allows flexibility in the share of wind and solar components in hybrid projects, but one resource must be at least 25% of the rated power capacity of the other.
- **Renewable Purchase Obligations (RPOs):** RPOs are a mechanism by which state electricity commissions are obliged to purchase a certain percentage of power from renewable energy sources. In 2022, the Government of India introduced **uniform RPO targets** across states, with the trajectory set to rise progressively to around **43.3% by FY30**. Pricing for compliance is determined through the Renewable Energy Certificate (REC) market, which now operates without fixed floor or ceiling prices under the revised REC Regulations, 2022.
- The **Domestic Content Requirement (DCR) policy** is a government initiative designed to boost India's solar manufacturing sector by mandating the use of domestically produced solar modules and, in some cases, solar cells for specific projects. It primarily applies to government-backed schemes such as the CPSU Scheme Phase II, KUSUM, and select SECI tenders, ensuring that Indian manufacturers receive demand protection against cheaper imports, mainly from China. While this policy helps in reducing import dependency, enhancing energy security, and creating local jobs, it also increases costs for developers, as Indian-made modules are currently priced higher than imported alternatives.
- **Customs Duty & GST:** In the Union budget 2025, the government has restructured the 40% BCD on modules to 20% BCD and 20% AIDC, while on solar cells, its reduced from 25% (+2.5% SWS) to 20% (+7.5% AIDC). GST has been reduced to 5% (Sep'25) from earlier 12% on modules (which was reduced from 18% in 2023).

Exhibit 129: Amendments in Import Duties



Source: Industry, YES Sec

Exhibit 130: Infrastructure & Grid Integration

Solar Parks	Green Energy Corridors	Solar-Wind Hybrid Policy
57 parks sanctioned (37 GW operational); Bhadla (Rajasthan) is the world's largest (2.2 GW). Land allocation simplified via state facilitation (e.g., Gujarat's 50% land cost subsidy).	Investment of Rs120bn to strengthen transmission for RE (ISTS charges waived till 2025).	PLF improves to 35-40% vs. standalone Solar's ~20%.

Source: Industry, YES Sec

Energy Storage: The Backbone of Renewable Growth

Exhibit 131: List of FDRE/RTC tenders concluded between April 2021 – July 2025

Bidding scheme	Result month	Winning tariffs discovered (Rs/unit)		Capacity (MW)		Winners
		Lowest	Highest	Tendered	Allotted	
REMCL Pan India RTC	Apr-23	3.99	4.27	1,000	960	Sprng Akshay Urja, NTPC RE Ltd., Ayana Power, O2 Power
SECI Multiple States Tranche VI (Peak Power)	Apr-23	4.64	4.73	1,200	1,200	AMP Energy Green, ReNew Vikram Shakti, Hero Solar Energy, ACME Cleantech
SJVN, Storage Hybrid Tranche-I (Peak Power)	Nov-23	4.38	4.39	1,500	2,368	Juniper Green Energy Ltd., Tata Power Renewable Energy, ACME Cleantech Solutions, Solarcraft Power India, Hero Solar Energy; TEQ Green Power XVI; , Renew Solar power
REMCL RTC	Jan-24	4.25	4.43	750	650	ACME Cleantech Solutions, ReNew Solar Power, Tata Power Renewable, O2 Power, NTPC REL, Torrent Power
NHPC Pan India WSH Storage (Firm power) Tranche-II	Feb-24	4.55	4.64	1,500	1,400	BN Hybrid power 1, Hero Solar Energy, Solarcraft Power India 20, Juniper Green Energy Ltd., Renew Solar Power, ACME Cleantech Solutions
NTPC Pan India WSH Storage Tranche-I (Firm power)	Mar-24	4.64	4.73	3,000	1,584	ABC Cleantech (Axis Energy), ACME Cleantech Solutions, Juniper Green Energy Ltd., Hero Solar Energy, Serentica Renewables India 11, Tata Power REL
SECI Pan India (firm power) Tranche-IV	Jul-24	4.98	4.99	630	630	Vena Energy, Hero Solar Energy, JSW Neo Energy, Hexa Climate Solutions, Serentica Renewables India 11
NHPC Pan India Tranche-II	Sep-24	4.37	4.38	1,200	1,200	Essar Renewables, Juniper Green Energy Ltd., Serentica Renewables, Hexa Climate Solutions, Avaada Energy
SJVN Pan India Tranche-II	Oct-24	4.25	4.26	1,200	1,200	Hero Solar Energy, Solar pack, Juniper Green Energy Ltd., ReNew , Avaada Energy
NTPC Pan India Tranche-II	Nov-24	4.69	4.7	1,200	760	Hexa Climate Solutions, Avaada Energy, Acme Solar Holdings
NHPC Pan India Tranche-III	Dec-24	4.48	4.56	1,200	1,200	Rays Power Infra, Avaada Energy, Acme Solar Holdings, Juniper Green Energy Ltd.
SECI RTC 1.2GW	May-25	5.06	5.08	1200	420	Hero Solar, Hexa Climate, Sembcorp, Jindal India Power, ABC Cleantech
SJVN 1.2 GW FDRE	Jul-25	4.82	4.91	1200	448	Renew Solar, EG Energy, Dineshchandra, Serentica Renewables, Tata Power Renewable Energy

Source: Industry, Crisil intelligence, YES Sec

New Energy

The role of energy storage in India's renewable energy expansion is becoming increasingly critical. As solar and wind power penetration grows, managing intermittency becomes a top priority for maintaining grid stability. To address this, the government has launched ambitious energy storage initiatives, including tenders for 4GW of Battery Energy Storage Systems (BESS) and incentives for pumped hydro storage projects. Additionally, battery manufacturing incentives under the PLI scheme are expected to enhance domestic production capacity, reducing reliance on imported lithium-ion cells.

By 2030, India aims to develop 50GWh of battery storage capacity, a crucial step toward achieving round-the-clock renewable energy availability. Declining battery costs, improved efficiency, and advancements in grid-scale storage solutions will further accelerate adoption in the coming years.

Energy Storage & Round-the-Clock (RTC) Power

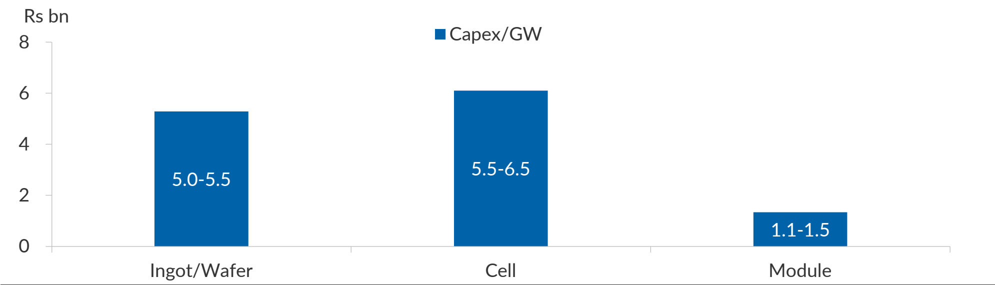
- **Battery Costs:** Fell to USD55/kWh (2025), enabling solar + storage at Rs6-7/kWh as per PVmagazine.
- **Indian power producers** are expected to bid for storage included solar parks from 2025 while tariffs are expected to rise in favor of compensating the increased cost.

Key players in the value chain

Solar power generation in India is led by large integrated players such as TATA Power, JSW Energy, NTPC Green, Acme Solar holdings and Adani Green Energy. These companies focus on developing utility-scale solar power projects across the country and are instrumental in achieving high plant load factors (typically between 15% and 20%) despite solar's inherent intermittency. Companies secure long-term power purchase agreements (PPAs) that provide stable revenue streams and help drive the nation's renewable targets. Their experience in grid integration and operational excellence enables them to manage variability effectively, ensuring that solar generation contributes reliably to India's overall power mix.

In the **modules manufacturing segment**, companies like Waaree Energies, Premier Energies, Vikram Solar, Reliance New Energy and Mundra Solar (a subsidiary of Adani Enterprises) play a pivotal role. These manufacturers produce high-efficiency solar PV modules with annual capacities in the gigawatt range, meeting both utility-scale and distributed energy needs.

Exhibit 132: Capex required for setting up plants across Solar Value Chain



Source: Company, YES Sec

Upstream in the solar value chain, ingot and cell manufacturing is crucial for producing the high-purity silicon substrates needed for solar cells. Mundra Solar has established significant capacity in this area, operating facilities in Mundra, Gujarat, where it manufactures monocrystalline silicon ingots. This capability allows Adani Green Energy to control a larger portion of the value chain, ensuring consistent quality and mitigating dependency on imported polysilicon, a market dominated by China. With domestic demand for high-quality ingots and cells on the rise, investment in this segment is becoming increasingly strategic for long-term competitiveness in the Indian solar market.

Backward integration towards ingot and wafer is expected to further drive down the cost of modules in the DCR segment where companies like Waaree Energies, Premier Energies, Reliance industries, Adani Enterprises (Mundra solar), Shirdi Sai electricals have already announced their plans to start ingot-wafer facility. Except Premier Energies all the other companies have already received PLI for their backward integration while Premier Energies have started discussion with the government.

The **Engineering, Procurement, and Construction (EPC)** segment converts solar potential into operational assets. EPC cost is usually around 6-8% of the total cost, where companies such as Waaree Renewable Technologies (Listed subsidiary of Waaree Energies), Premier Energies and Acme Solar have built strong reputations for designing, constructing, and commissioning utility-scale solar projects. Their business models emphasize rapid project execution, cost efficiency, and high plant load factors, often underpinned by long-term PPAs that secure steady cash flows.

Last by not the least, the **operations, maintenance**, and hybrid systems segment ensure the longevity and reliability of installed solar projects. Companies like NTPC Green, Tata Power, and JSW Energy have developed sophisticated O&M frameworks that incorporate real-time monitoring, predictive maintenance, and performance optimization strategies. Additionally, hybrid renewable systems that integrate solar with battery storage or wind power are emerging to address intermittency issues. NTPC Green is at the forefront of deploying solar-plus-storage systems that provide dispatchable power and enhance grid stability. This integration not only maximizes renewable asset utilization but also positions these companies as key enablers in India's broader transition to a resilient, low-carbon energy future.

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