



INDUSTRY REPORT ON RENEWABLE ENERGY

FINAL INDUSTRY REPORT
20th January 2025

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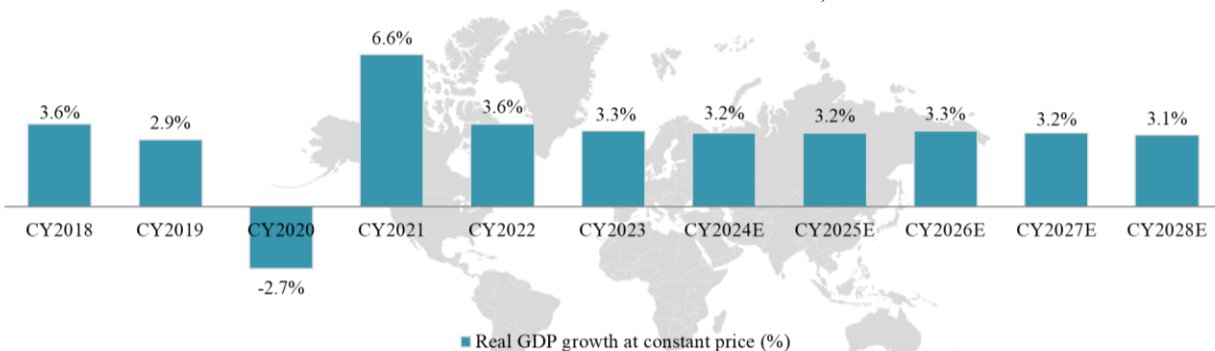
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1. MACROECONOMIC OVERVIEW OF GLOBAL ECONOMY

1.1 Real GDP review and outlook

In recent years, the global economy has demonstrated remarkable resilience and adaptability, rebounding strongly in CY2021 after the challenges posed by the COVID-19 pandemic and the recession in CY2020. However, as the recovery gained momentum, new challenges emerged in CY2022, including the Russia-Ukraine war, inflation, and supply chain disruptions, underscoring the need for continued vigilance and innovation to sustain growth. By CY2023, these challenges eased, establishing global GDP growth at 3.3%. The global economy is projected to grow at 3.2% for the next two years, 3.3% in CY2026, back to 3.2% in CY2027 before moderating to 3.1% in CY2028. However, there are associated risks due to higher interest rates and reduced government spending. India has been the fastest-growing major economy since last three years, with 8.2% real GDP growth in CY2023. In contrast, the US grew by 2.9%, China by 5.2%, while Europe struggled with just 1.2% growth, affected by the ongoing war and high energy prices.

Exhibit 1.1: Real GDP World Growth – Historic and Forecast, CY2018 – CY2028E



Source: IMF October 2024 forecast, Frost & Sullivan analysis

Exhibit 1.2: Real GDP Growth of Select Regions & Countries – Historic and Forecast, World, CY2018 – CY2028E

Country / Region	CY2018	CY2019	CY2020	CY2021	CY2022	CY2023	CY2024E	CY2025E	CY2026E	CY2027E	CY2028E
World	3.6%	2.9%	-2.7%	6.6%	3.6%	3.3%	3.2%	3.2%	3.3%	3.2%	3.1%
India	6.5%	3.9%	-5.8%	9.7%	7.0%	8.2%	7.0%	6.5%	6.5%	6.5%	6.5%
China	6.7%	6.0%	2.2%	8.4%	3.0%	5.2%	4.8%	4.5%	4.1%	3.6%	3.4%
United States	3.0%	2.6%	-2.2%	6.1%	2.5%	2.9%	2.8%	2.2%	2.0%	2.1%	2.1%
North America	2.8%	2.2%	-3.0%	6.0%	2.7%	2.8%	2.5%	2.1%	2.0%	2.1%	2.1%
Europe	2.3%	2.0%	-5.4%	6.4%	2.4%	1.2%	1.6%	1.6%	1.7%	1.6%	1.6%
Asia and Pacific	5.3%	4.2%	-0.8%	7.1%	4.1%	4.9%	4.5%	4.4%	4.3%	4.1%	4.0%
Middle East and Central Asia	2.7%	1.9%	-2.2%	4.4%	5.5%	2.1%	2.4%	3.9%	4.2%	3.9%	3.8%
Africa	3.4%	3.1%	-1.4%	4.7%	4.3%	3.3%	3.0%	4.2%	4.4%	4.3%	4.4%
Latin America and Caribbean	1.1%	0.2%	-6.9%	7.4%	4.2%	2.2%	2.1%	2.5%	2.7%	2.8%	2.7%

Source: IMF October 2024 forecast, Frost & Sullivan analysis

India remains the fastest-growing large economy, achieving a real GDP growth of 8.2% in CY2023, up from 7.0% in CY2022. This growth is expected to continue over the next five years, supported by stable domestic demand, private investments, favorable demographics, reducing dependency ratio, steady urbanization, IT revolution, increasing penetration of mobile and internet infrastructure amongst others. India has consistently outperformed the global average GDP growth rate, especially post-pandemic. While major economies like the US and China are also experiencing growth, India's strong economic performance is driven by factors such as a young population, government reforms, rising domestic consumption, and foreign direct investment. India's growth trajectory is promising, but challenges like infrastructure

bottlenecks and income inequality need to be addressed to sustain this momentum. The US economy grew by 2.9%, bolstered by increased consumer spending, investment, and government expenditures. China's economy expanded by 5.2%, driven by the easing of COVID restrictions. Meanwhile, Europe experienced muted growth of just 1.2%, hindered by ongoing issues such as the war and high energy prices.

India is the fifth-largest economy globally by nominal GDP (FY 2022) and ranks third in the world in terms of purchasing power parity (PPP). With robust economic growth, India is estimated to become a USD 5 trillion economy by FY2026 and is expected to surpass Germany and Japan to emerge as the third-largest economy by FY2030.

1.2 Inflation

Global inflation, after peaking at 8.6% in CY2022, eased to 6.7% in CY2023 and is projected to decline to 5.8% in CY2024. This decline is driven by tighter monetary policies and lower international commodity prices. Faster disinflation could ease financial conditions, while stronger reforms may boost productivity. However, new commodity price spikes or persistent inflation could prolong tight monetary policies.

The global economic outlook has seen significant improvements following the peak of inflation in 2022. After reaching a high of 9.4% year-on-year in Q3 of 2022, global inflation is projected to fall to around 3.5% by the end of 2024, marking a return to levels just below the average inflation rates seen in the two decades preceding the COVID-19 pandemic.

1.2.1 Key Factors Contributing to Disinflation and Economic Resilience:

Monetary Tightening and Its Effect:

- **Interest Rate Hikes:** Central banks, particularly in advanced economies, responded to soaring inflation with aggressive interest rate hikes, significantly slowing down demand and reducing inflationary pressures.
- **Monetary Easing on the Horizon:** As inflation comes closer to central bank targets, a reversal of this tightening policy is expected in 2025. This shift could support economic growth by reducing borrowing costs and encouraging investment and consumption.

While inflation has fallen globally, some low-income and developing countries have faced downward growth revisions, largely driven by rising geopolitical tensions and intensifying conflicts (e.g., the war in Ukraine).

Exhibit 1.3: Inflation Rate – Historic and Forecast, World, CY2018 – CY2028E

Country / Region	CY2018	CY2019	CY2020	CY2021	CY2022	CY2023	CY2024E	CY2025E	CY2026E	CY2027E	CY2028E
World	3.6%	3.5%	3.3%	4.7%	8.6%	6.7%	5.8%	4.3%	3.6%	3.4%	3.3%
India	3.4%	4.8%	6.2%	5.5%	6.7%	5.4%	4.4%	4.1%	4.1%	4.0%	4.0%
China	2.1%	2.9%	2.5%	0.9%	2.0%	0.2%	0.4%	1.7%	2.0%	2.0%	2.0%
United States	2.4%	1.8%	1.2%	4.7%	8.0%	4.1%	3.0%	1.9%	2.1%	2.1%	2.1%
North America	2.7%	2.0%	1.4%	4.7%	7.9%	4.2%	3.1%	2.0%	2.1%	2.2%	2.2%
Europe	2.2%	2.0%	1.2%	3.6%	10.0%	6.3%	3.5%	3.0%	2.5%	2.4%	2.4%
Asia and Pacific	3.1%	3.4%	3.2%	3.0%	6.3%	4.9%	4.4%	3.8%	3.4%	3.2%	3.2%
Middle East & Central Asia	9.6%	7.4%	10.3%	11.9%	13.4%	15.6%	14.6%	10.7%	8.5%	7.3%	6.6%
Africa	11.4%	9.4%	11.1%	12.3%	14.2%	18.2%	20.3%	13.9%	9.2%	8.0%	6.9%
Latin America and Caribbean	6.7%	7.6%	6.5%	9.9%	14.2%	14.8%	16.8%	8.5%	5.7%	4.4%	3.7%

Source: IMF October 2024 forecast, Frost & Sullivan analysis

These regions continue to experience challenges in supply chains, energy prices, and commodity costs, which hinder their economic recovery and growth potential, especially when compounded by ongoing conflicts.

The disinflationary process has eased global inflation to pre-pandemic levels. Growth projections of 3.2% for 2024 and 2025 indicate resilience, but developing and low-income economies may face challenges due to geopolitical tensions and economic instability. Central banks will likely begin easing their monetary policies, paving the way for a more supportive economic environment in the years to come.

1.3 Global interest rate outlook

The global interest rate outlook for CY2024 reflects a cautious easing stance by central banks amid persistent inflationary pressures and geopolitical uncertainties. While most major economies are expected to begin or continue rate-cutting cycles, the pace will likely be more measured compared to the

Exhibit 1.4: Global interest rate of major economies

	COUNTRY/REGION	CURRENT	PREVIOUS
<u>American Central Bank</u>	United States	4.50 %	4.75 %
<u>Australian Central Bank</u>	Australia	4.35 %	4.10 %
<u>Brazilian Central Bank</u>	Brazil	12.25 %	11.25 %
<u>British Central Bank</u>	United Kingdom	4.75 %	5.00 %
<u>Canadian Central Bank</u>	Canada	3.25 %	3.75 %
<u>Chilean Central Bank</u>	Chile	5.00 %	5.25 %
<u>Chinese Central Bank</u>	China	3.10 %	3.35 %
<u>Czech Central Bank</u>	Czech Republic	4.00 %	4.25 %
<u>Danish Central Bank</u>	Denmark	2.75 %	3.00 %
<u>European Central Bank</u>	Europe	3.15 %	3.40 %

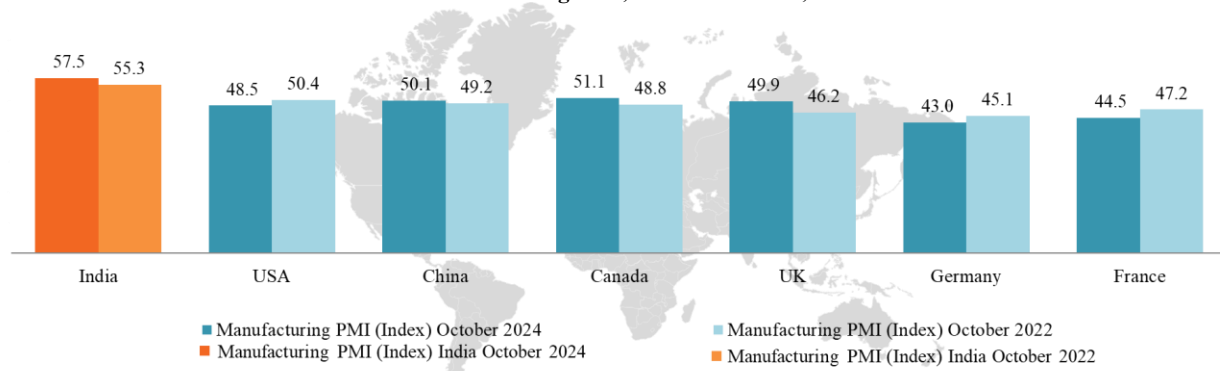
Source: Global rates, Frost & Sullivan analysis

aggressive tightening of previous years. The US Federal Reserve, for instance, may cut rates only modestly, with market pricing suggesting two reductions starting in the latter half of the year. Similarly, other advanced economies are poised for limited easing, constrained by the need to balance economic growth support with inflation control. Emerging markets like South Africa and Argentina may see minimal policy shifts, whereas Japan continues its gradual exit from ultra-loose monetary settings. Overall, rate reductions are expected to provide only mild relief to consumers and businesses as central bankers tread carefully in an environment of economic fragility and potential price shocks

1.4 Manufacturing Purchasing Manager's Index (PMI)

Comparing India, the US, China, Canada, the UK, Germany, and France, we see varying trends. India's manufacturing sector remains in expansion territory, and it has experienced growth. The US, Germany, and France have shown signs of slowing down. China, Canada, and the United Kingdom, however, have also shown signs of recovery. India's continued growth will depend on factors like government policies, global economic conditions, and domestic demand.

Exhibit 1.5: Manufacturing PMI, Select Countries, October 2024



Source: Trading Economics October 2022 to October 2024, Frost & Sullivan analysis

1.5 Growth drivers and issues impacting global economy

1.5.1 Growth Drivers

- **Technological Advancements:** Innovation in areas like artificial intelligence, automation, renewable energy, and biotechnology continues to drive productivity growth and create new industries.
- **Emerging Markets:** The growing middle class and increasing urbanization in emerging economies, particularly in Asia and Africa, contribute significantly to global demand and economic expansion.
- **Global Trade:** While facing some headwinds, international trade remains a key engine of growth, facilitating the exchange of goods, services, and technology across borders.
- **Investment in Infrastructure:** Public and private investment in infrastructure projects, such as transportation, energy, and communication networks, boosts economic activity and connectivity.
- **Demographic Trends:** In some regions, a young and growing workforce can provide a demographic dividend, contributing to economic output.
- **Urbanization:** Urbanization continues to drive global economic growth by fostering infrastructure development, increasing consumer demand, and enabling productivity gains through concentrated labor markets.
- **Financial Literacy and Growth:** Increasing financial awareness and access to investments are fueling global economic growth. For instance, global financial literacy rates are improving, with initiatives like the OECD's financial education programs reaching over 100 million individuals globally. Moreover, the World Bank reports that educational attainment has risen significantly, with global literacy rates reaching 87% in 2023, up from 83% in 2000. Such advancements in education and financial inclusion enhance workforce productivity, foster innovation, and broaden participation in the global economy.

1.5.2 Key Issues Impacting Growth

- **Geopolitical Instability:** Conflicts, tensions, and political uncertainties in various parts of the world create economic uncertainty and disrupt trade and investment flows. Ongoing supply chain bottlenecks, exacerbated by geopolitical events and the pandemic, continue to impact production and trade.
- **Inflation and Monetary Policy:** Rising inflation and the response of central banks through interest rate hikes can slow economic growth and increase the risk of recession.
- **Climate Change:** The increasing frequency and severity of extreme weather events, as well as the transition to a low-carbon economy, pose significant economic challenges and require substantial investments.

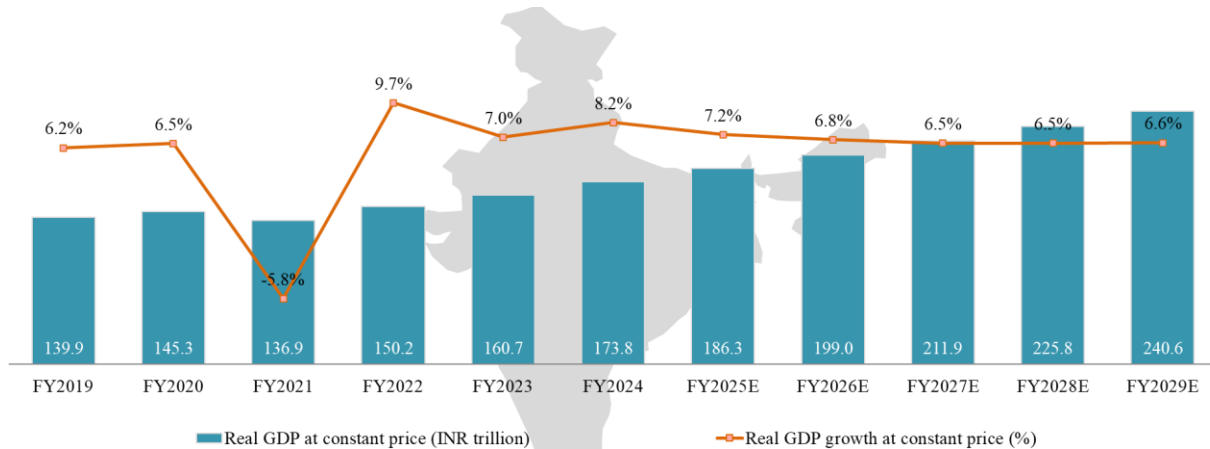
- **Debt Levels:** High levels of public and private debt in many countries can constrain economic growth and increase vulnerability to financial crises.
- **Inequality:** Rising income inequality within and between countries can lead to social unrest and hinder economic progress

2. MACROECONOMIC OVERVIEW OF INDIAN ECONOMY

2.1 Current state of Indian economy & outlook

Indian economy has shown robust performance in the last three financial years and achieved 8.2% real GDP growth in FY2024, outperforming many other major economies and least impacted by the inflationary pressure globally.

Exhibit 2.1: Annual Real GDP and Real GDP growth (Annual % Change) of India, Value in INR Trillion FY2019-FY2029E



Source: MoSPI (Annual Estimates of GDP at constant price, 2011-12 series), IMF, ADB, S&P, Frost & Sullivan Analysis

Structural reforms including disinvestment, increased FDI limits, and various Government of India (GoI) initiatives and schemes like Make In India, Production Linked Incentives (PLI), National Logistics Policy, PM Gati Shakti National Master Plan, Ease of Doing Business etc. have been introduced to strengthen India's manufacturing sector after the pandemic.

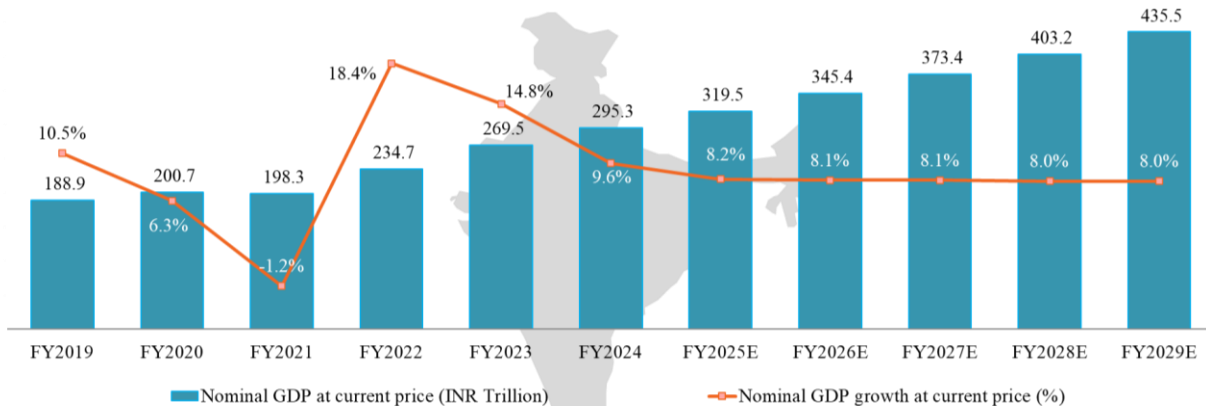
India's FY2025 budget emphasizes nine key priorities aimed at achieving 'Viksit Bharat' or a 'Developed India'. These priorities include a) enhancing productivity and resilience in agriculture, b) fostering employment and skilling, c) promoting inclusive human resource development and social justice, d) boosting the manufacturing and services sectors, e) advancing urban development, f) ensuring energy security, g) investments in infrastructure, h) innovation, research and development, and i) implementation of next-generation reforms. These priorities further underscore the government's vision for sustainable growth and development across multiple sectors.

In 2019, India set a USD 5 trillion economy target for FY2025, later extended by 18–24 months due to the pandemic. Having crossed USD 3 trillion in FY2022, India is likely to surpass USD 4 trillion by FY2025 and reach USD 5 trillion in 2–3 years, potentially becoming the third-largest economy by overtaking Germany and Japan.

Macro factors driving India's economic growth include a young demographic, urbanization-driven infrastructure demand, and global supply chain shifts. Policies like the Reserve Bank's monetary management, trade agreements boosting exports, and initiatives such as 'Digital India,' 'Skill India,' and 'Make in India' are fostering growth. Additionally, India's commitment to sustainability with 500 GW non-

fossil fuel capacity by 2030 and expanding financial inclusion further strengthens the economy. India's nominal GDP is projected to reach INR 319.5 trillion by FY2025E and INR 435.5 trillion by FY2029E.

Exhibit 2.2: Annual Nominal GDP and Nominal GDP growth (Annual % Change), Value in INR Trillion, India, FY2019-FY2029E



Source: MoSPI (Annual Estimates of GDP at current prices), Worldometer; Frost & Sullivan Analysis

Make in India: ‘Make in India’ is an initiative which was launched on 25th September 2014 to facilitate investment, foster innovation, build best in class infrastructure and make India a hub for manufacturing, design, and innovation. The ‘Make in India’ scheme has paid significant dividends to India’s export and employment outlook. The PLI schemes in strategic industries are incentivizing the expansion of Indian manufacturing and production and making the nation globally competitive. Significant growth has been observed in sectors like pharmaceuticals, heavy chemicals, and electronics. This resulted in India being the fastest growing manufacturing market globally along with Vietnam.

It was one of the unique single, vocal for local initiative that promoted India’s manufacturing domain to the world. ‘Make in India’ initiative is not the state/district/city/area specific initiative, rather it is being implemented all over the country.

National Logistics Policy: To enhance ease of doing business and improve the liveability quotient, Prime Minister Narendra Modi unveiled the National Logistics Policy (NLP) on September 17, 2022, at Vigyan Bhawan, New Delhi. The policy targets reducing logistics costs from the current 13-14% to levels comparable with developed nations. This reduction aims to boost the competitiveness of Indian products in domestic and international markets. Furthermore, by enhancing efficiency across sectors, the NLP fosters value addition, enterprise growth, and economic development.

The National Logistics Policy (NLP) outlines four critical initiatives to achieve its goals:

Integration of Digital System (IDS): Focuses on the digital integration of systems across seven key departments, including road transport, railways, aviation, commerce, and foreign trade, to streamline operations and ensure seamless coordination.

Unified Logistics Interface Platform (ULIP): Facilitates smoother and faster cargo movement by enabling real-time and confidential information exchange. Leverages the National Industrial Corridor Development Corporation (NICDC) Logistics Data Bank Project to enhance logistics efficiency.

Ease of Logistics (ELOG): Aims to promote transparency and accessibility, ensuring the ease of conducting logistics businesses.

System Improvement Group: Monitors logistics-related projects regularly to ensure timely implementation and continuous improvement.

PM Gati Shakti National Master Plan: PM Gati Shakti integrates various infrastructure development schemes from multiple Ministries and State Governments to create a unified, efficient framework for nationwide connectivity and logistics enhancement. Key initiatives under this program include:

- **Bharatmala:** A flagship highway development project aimed at improving road connectivity across the country.
- **Sagarmala:** Focuses on port-led development and enhancing maritime logistics infrastructure.
- **Inland Waterways:** Develops and modernizes inland water transport to reduce logistics costs and enhance environmental sustainability.
- **Dry/Land Ports:** Establishes inland logistics hubs to streamline cargo movement and reduce congestion at major ports.

IUDAN (Ude Desh ka Aam Nagrik): Aims to enhance regional air connectivity and make air travel affordable for the common citizen.

By integrating these diverse infrastructure initiatives, PM Gati Shakti seeks to streamline logistics, improve multi-modal connectivity, and boost India's competitiveness in the global economy.

The PM Gati Shakti National Master Plan (NMP) has integrated 44 Central Ministries and 36 States/UTs, with 1,614 data layers incorporated. To ensure data accuracy, key infrastructure ministries have established a three-tier SOP system. SOPs for 8 infrastructure and 15 social sector ministries are finalized, with ongoing development for others.

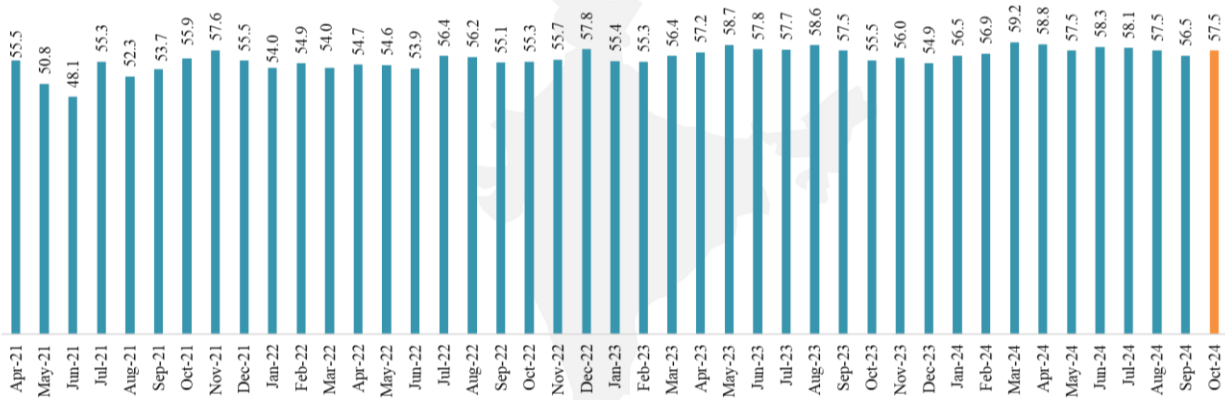
A 'Compendium of PM Gati Shakti Volume I and Volume II' has been developed and launched, that highlights the accomplishment stories of PM Gati Shakti. A milestone of assessing 208 big-ticket infrastructure projects worth INR 15.39 lakh Crores, of numerous Ministries adhering to PM Gati Shakti principles has been accomplished. Additionally, 434 projects under three economic corridors of the Ministry of Railways have been assessed and shared with the PMO and they are Mineral, Energy and Cement Corridors, High Traffic Density Corridors and Rail Sagar.

Ease of Doing Business: DPIIT is the Nodal Department for directing the initiatives under Ease of Doing Business which are aimed at initiating a favourable business environment.

India ranks 63rd in the World Bank's Doing Business Report (DBR), 2020 published in October 2019 before its suspension by the World Bank. India's rank in the DBR bettered from 142nd in 2014 to 63rd in 2019, registering a jump of 79 ranks in a span of 5 years.

2.2 India Manufacturing PMI (Purchase Managers Index)

The S&P Global India Manufacturing Purchasing Managers' Index measures the performance of the manufacturing sector and is derived from a survey of 500 manufacturing companies. India's manufacturing PMI fell to 56.5 in September, signaling slower growth but remaining in expansionary territory due to strong export demand. Rising input costs for materials like chemicals and cotton drove output prices to an 11-year high, adding inflationary pressure. GDP growth slowed in Q2 FY2024, hindered by weaker manufacturing and mining activity. As per the RBI's Monetary Policy Committee, it is expected to hold the repo rate steady at 6.5% while revising growth projections downward and inflation forecasts upward.

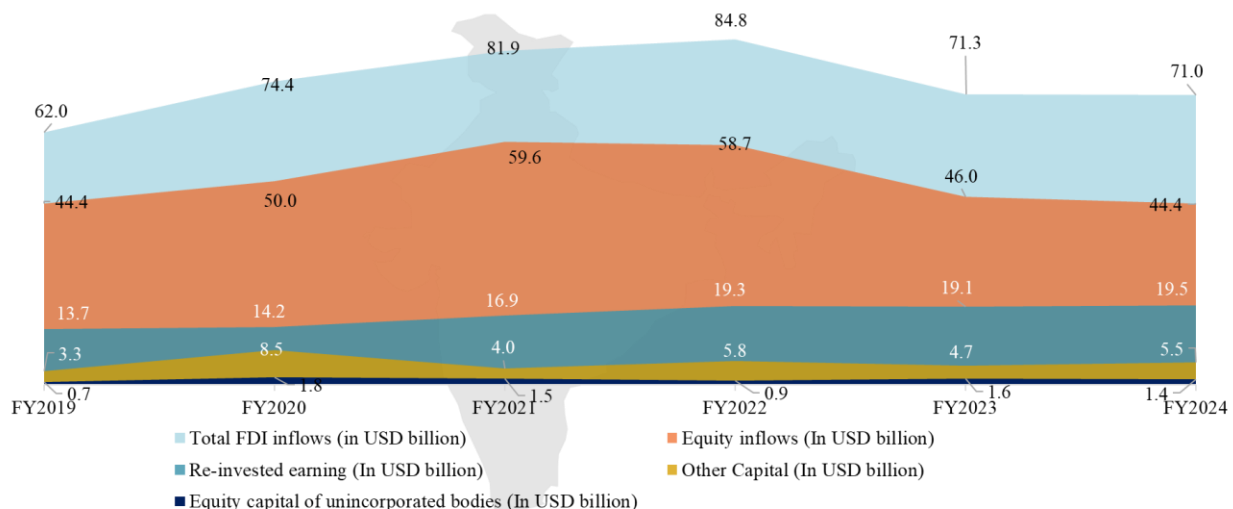
Exhibit 2.3: Manufacturing PMI, India, April 2021 to October 2024

Source: S&P, Frost & Sullivan Analysis

2.3 Foreign Direct Investment (FDI)

Foreign Direct Investment (FDI) in India has significantly increased in the last few years on the backdrop of improved 'Ease of Doing Business' ranking and proactive manufacturing policies from the Indian Government. The country received a record ~USD 435 billion FDI between FY2018 and FY2023. FDI reached a record ~USD 84.8 billion in FY2022 – the highest FDI in any fiscal year till date. Even though the FDI declined to ~USD 71.3 billion in FY2023, it is still at par with the last 6 year's average FDI in the country. India has achieved this feat despite the Indian government's restrictions on FDI from China.

India remains a resilient economy despite a decline in foreign direct investment (FDI) inflows, attributed to global challenges such as the Russia-Ukraine conflict and the aftermath of the COVID-19 pandemic. In FY 2022, India saw a record FDI inflow of USD 84.8 billion, including USD 7.1 billion into the services sector. Singapore was the top contributor in FY 2023 with USD 17.2 billion, followed by Mauritius (~USD 6.1 billion), the United States (~USD 6.0 billion), UAE (~USD 3.4 billion), and the Netherlands (~USD 2.49 billion). Other key contributors included the UK, Japan, Cyprus, Cayman Islands, and Germany

Exhibit 2.4: FDI inflow in India, in USD billion, FY2019 – FY2024

Source: RBI, Frost & Sullivan Analysis

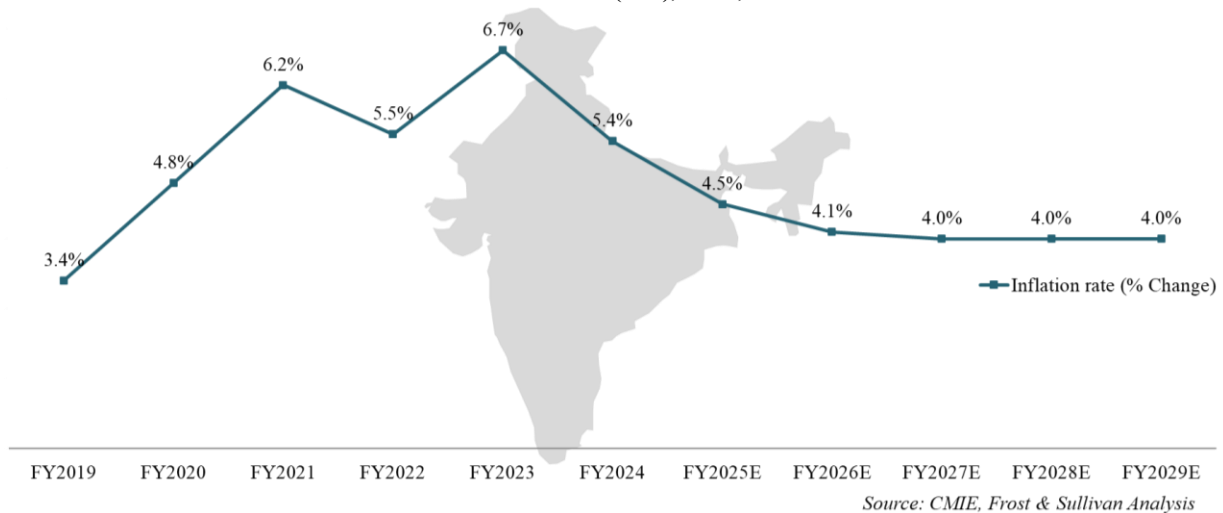
In FY2024, India has registered a gross FDI inflow of ~USD 71.0 billion. Despite high interest rates across the globe, India's FDI inflows remained steady as compared to its peer developing economies, because of the 'demand strength' of the economy.

India improved its rank from 142nd in 2014 to 63rd in the World Bank's Doing Business Report (DBR) 2020, reflecting a 79-rank rise. This improvement underscores the government's efforts to streamline regulations, reduce bureaucratic barriers, and create a more business-friendly environment, which has boosted investor confidence and supported the Make in India initiative.

2.4 Inflation

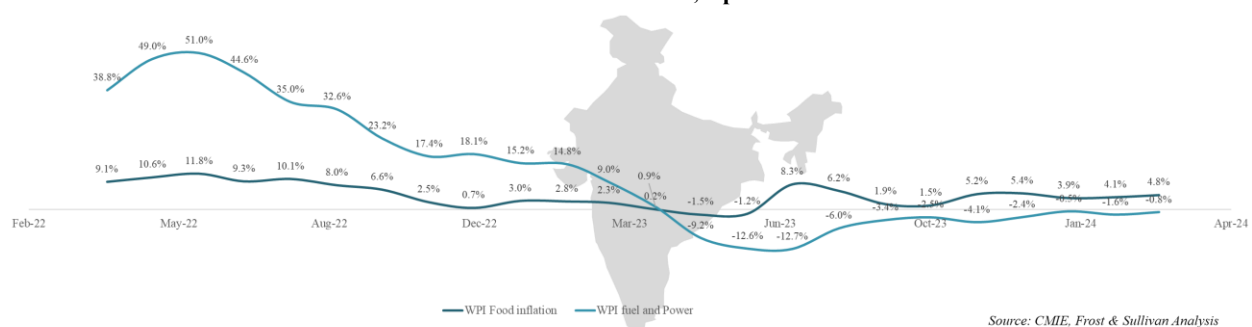
Inflation started showing an upward trend since FY2019 and increased to 6.7% in FY2023. Rising inflation emerged as a key macroeconomic concern in FY2023 with prices of almost every commodity touching new

Exhibit 2.5: Annual Inflation rate (CPI), India, FY2019 – FY2029E



heights. However, in line with the global trend, the inflation in India moderated to 5.4% in FY2024 due to a drop in commodity prices and actions taken by RBI. The RBI left its inflation forecast for FY2025 unchanged at 4.5% even though spike in crude oil prices and persisting worries about supply chain due to the Red Sea crisis. In the medium term, RBI expects the inflation to be stabilized at around 4% by FY2029

Exhibit 2.6: India WPI inflation Y-O-Y, April 2022 to March 2024



2.5 Per capita electricity consumption

Per capita electricity consumption varies with factors like industry intensity, purchasing power, household size, and efficiency standards. Among the top 10 global economies, the USA leads in per capita consumption, while India's is the lowest at 1,377 kWh, about one-third of the global average of 3,594 kWh as of CY2023. India's consumption rose from 1,149 kWh in FY2018 to 1,331 kWh in FY2023, growing at 8.1% and 6.1% in FY2022 and FY2023, respectively. This increase is due to village electrification, economic growth, and higher consumer durable use. Projections suggest per capita consumption will exceed 1,700 kWh by FY2028E and reach 2,025 kWh by FY2031E. The Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY) and Pradhan Mantri Sahaj Bijli Har Ghar Yojana (SAUBHAGYA) aimed to electrify

all villages and households, achieving 100% urban and 99.3% rural electrification by FY2022, according to World Bank data.

Exhibit 2.7: Per capita electricity consumption of global leading economies vs India, in kWh, CY2023

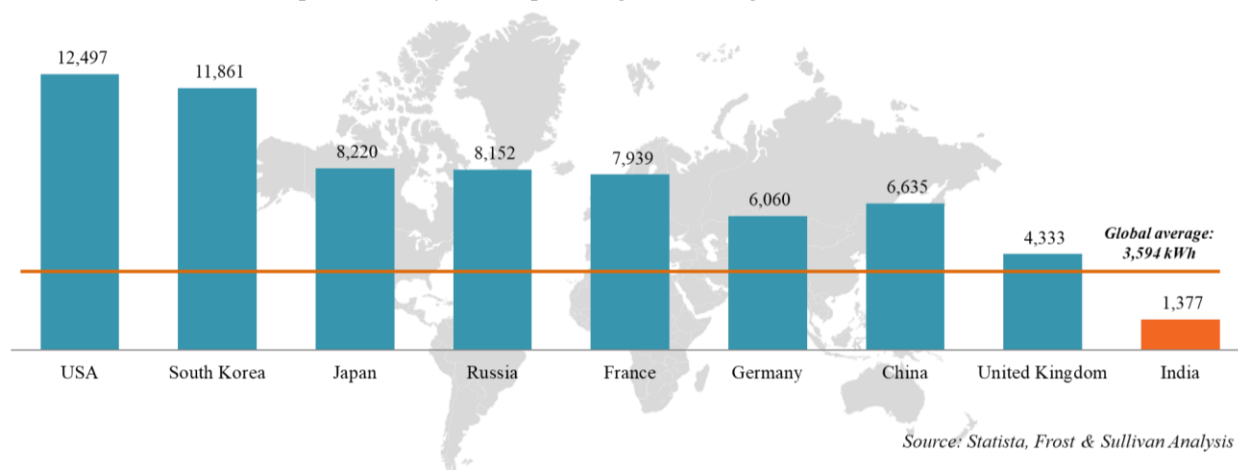
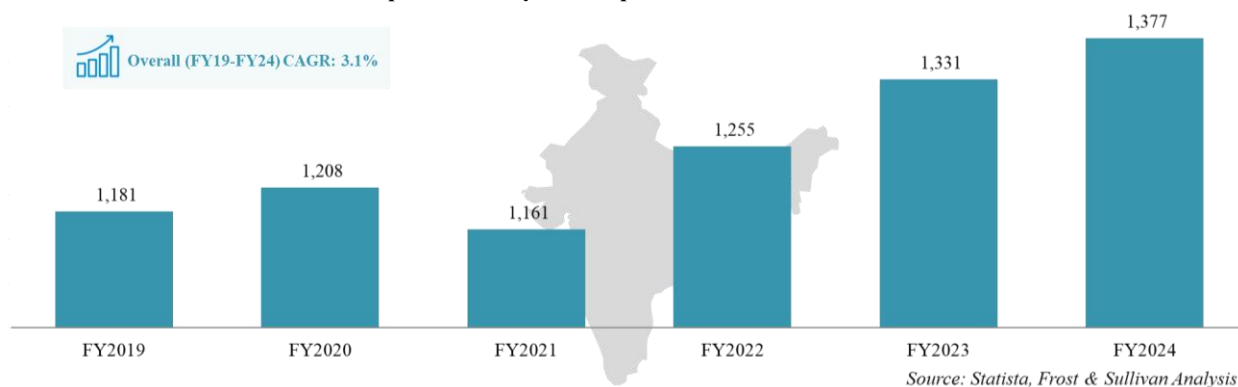


Exhibit 2.8: Per capita electricity consumption of India, in kWh, FY2018 to FY2024



2.6 Key factors driving the growth of Indian economy

Followings are some of the key factors driving the ascent of Indian economy:

- Urbanization:** Rapid urbanization in India is fueling economic growth by expanding cities, increasing infrastructure development, and creating new markets. As more people move to urban areas, there is a growing demand for goods, services, and housing, which stimulates economic activity and drives investments across various sectors.
- Young Population:** India's young population is a significant driver of its economy. With a large, tech-savvy, and dynamic workforce, the country is well-positioned to boost innovation, enhance productivity, and increase consumption. This demographic advantage offers substantial opportunities for businesses to tap into a growing consumer base and for policymakers to leverage the potential of a young labor force.
- Digital competitiveness:** Strong digital advantage with 900 million plus working-age population having affordable internet access at USD 0.16/GB in 2023 and 700 million smartphone users in 2023 that led to deeper inclusion and new demand for financial services, consumer goods, healthcare, and education. Per capita data consumption is among the highest in the world at 24.1 GB in 2023 and e-commerce share is already at 8% of the total data consumption in India. Technology services exports

crossed USD 193 billion in 2023 - there are 1,580 global capability centres in India in 2023 employing over 3.4 million employees, the sector accounts for 32% of the global technology workforce.

- **Strong investment in Public infrastructure:** India has among the best metro airports in the world and is the third largest air traffic market having grown at a CAGR of 17% pre-Covid (FY2019) to FY2024. Investments in airport infrastructure are providing deeper access to remote areas. Similar investments in ports, railways and highways are creating a world-class transportation network that will enable the creation of an efficient and integrated ecosystem for manufacturing, logistics and exports. The government of India has set a plan to increase port handling capacity by four times to 10,000 MTPA by 2047.
- **A vibrant manufacturing base:** As Global supply chains are realigning, India is emerging as an alternative supply source given its raw materials, low labour costs, growing manufacturing knowhow, and entrepreneurial ability. Manufacturing sector accounts for ~15% of the nation's GDP in FY2024 and employs over 27 million workers. Indian government introduced a few landmark policies such as PLI to upsurge share of manufacturing to 25%.
- **Initiatives to reduce energy import and increase country's energy security:** India is working to achieve energy independence by 2047 and reduce the USD 100 billion spent annually on energy imports by increasing investments in renewable energy and green hydrogen. The government has set a goal of 500 GW of renewable capacity by 2030, requiring USD 300 billion in investments.
- **Stability in policy making:** A stable political climate has led to consistency and predictability in policies in the last decade promoting efficiency and agility in doing business. This has instilled confidence among the global investor and resulted in steady inflow of FDI into the country.
- **Demographic Profile of India:** India is undergoing a rapid process of urbanization, with projections indicating that by 2036, roughly 600 million people (or 40% of the population) will reside in towns and cities, compared to 31% in 2011. This shift is expected to significantly impact the economy, as urban areas are anticipated to contribute nearly 70% of the country's GDP. The success of this urban transformation will be crucial for India in realizing its goal of becoming a developed nation by 2047, marking the 100th year of independence.
- **Digitization:** As per RBI findings, India's core digital economy saw a rise from representing 8.5% of GVA in the year 2019 to 12.5% in the year 2023, marking a growth rate of 15.6% over the span of 2019-2023.

To ensure that India benefits from the digital economy and remains competitive on a global scale, it is crucial to create a digitally literate workforce capable of adapting to new technologies. Through collaboration between the government and the private sector, the country can build a robust infrastructure for digital growth and provide opportunities for millions to upskill and reskill, positioning India as a leader in the global digital transformation.

3. OVERVIEW OF GLOBAL POWER AND SOLAR SECTOR

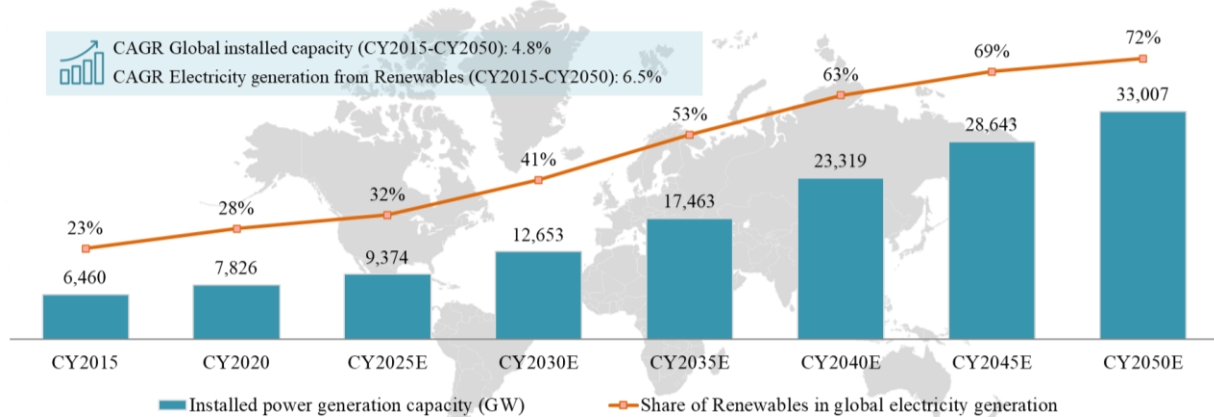
3.1 Global installed power generation capacity

As of the end of CY2023, the global installed power generation capacity reached approximately 9,063 GW. The Asia-Pacific region holds the largest share of this capacity, accounting for around 40%, driven by rapid economic growth and increasing energy demand in countries such as China and India. North America contributes 22% of the global capacity, supported by robust investments in energy infrastructure and

renewable energy projects, while Europe accounts for 18%, reflecting its focus on transitioning to cleaner energy sources.

India, a significant player in the global energy landscape, represents about 5% of the world's installed power generation capacity as of CY2023. The country's growing contribution highlights its ongoing efforts to expand energy access and integrate renewable energy sources into its power mix.

Exhibit 3.1: Growth in global installed power generation capacity, CY2015 – CY2050E



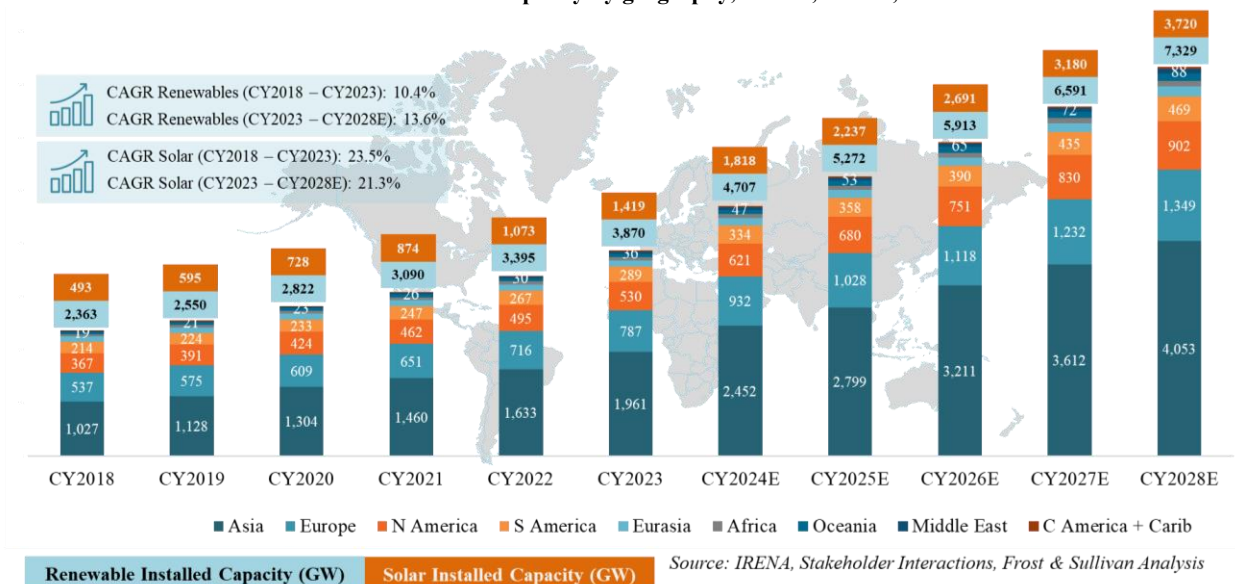
Source: Enerdata, Frost & Sullivan Analysis

Looking ahead, global installed power generation capacity is projected to grow at a compound annual growth rate (CAGR) of 4.8%, reaching approximately 33,000 GW by CY2050. This substantial increase will be largely driven by renewable energy, which is expected to account for nearly three-quarters of the new capacity additions. The shift towards renewable energy sources reflects global efforts to reduce carbon emissions and transition towards more sustainable and environmentally friendly energy systems.

3.2 Global installed Renewable Energy capacity

Renewable energy capacity is on a strong growth trajectory. The Compound Annual Growth Rate (CAGR) for renewables was 10.4% between 2018 and 2023, indicating a significant increase in installations during this period.

Exhibit 3.2: Renewables installed capacity by geography, Global, in GW, CY2018 - CY2028



Source: IRENA, Stakeholder Interactions, Frost & Sullivan Analysis

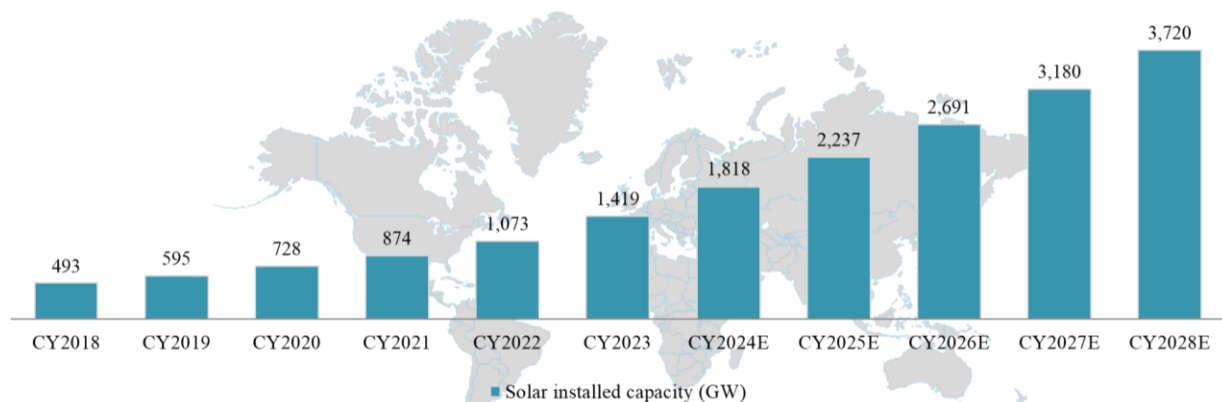
This growth is expected to accelerate further, with a projected CAGR of 13.6% from 2023 to 2028. This upward trend suggests a promising future for renewable energy, driven by factors such as increasing demand for clean energy, supportive government policies, and advancements in renewable energy technologies.

The Paris Agreement and COP meetings have driven global climate action, emphasizing low-carbon development and renewable energy (RE) capacity growth. From CY2018 to CY2023, global RE capacity grew at a 10.4% CAGR to reach 3,870 GW, with Asia leading at 51%, Europe at 20%, and North America at 14%. The global renewable energy capacity is set to grow from 3,870 GW in CY2023 to 7,329 GW in CY2028E, marking nearly a twofold increase in just five years. This rapid expansion highlights the accelerating shift toward sustainable energy solutions, with renewables playing a critical role in mitigating climate change and driving the global transition to a low-carbon economy.

3.3 Global installed solar capacity

Solar power is projected to grow from 1,419 GW in CY2023 to 3,720 GW by CY2028E, achieving a CAGR of ~21%. By CY2024E, solar power is expected to surpass hydropower, followed by natural gas in CY2026E and coal in CY2027E, becoming the largest installed electricity capacity globally.

Exhibit 3.3: Solar installed capacity, Global, in GW, CY2018 - CY2028E



Note: Future capacity has been calculated based on CY2023 actual installed capacity + annual capacity additions projected by IEA till CY2028

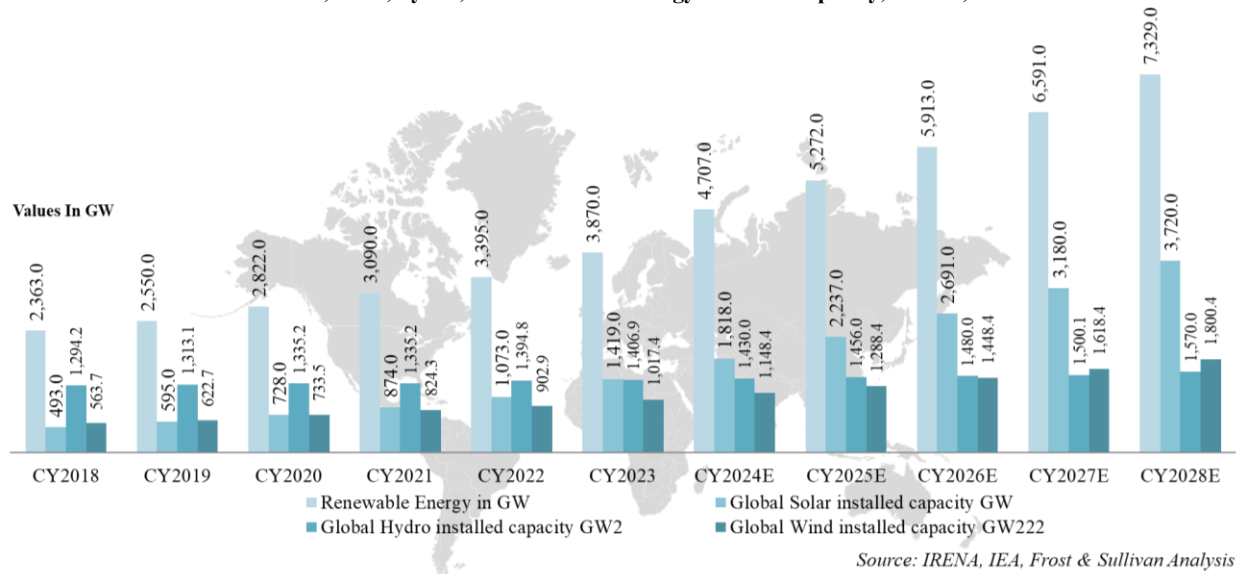
Source: IRENA, IEA, Frost & Sullivan Analysis

Solar PV has maintained a strong growth trajectory despite challenges like Covid-related disruptions and supply-chain issues. The Russia-Ukraine conflict has further emphasized the importance of energy security, accelerating the adoption of clean and renewable energy technologies worldwide.

3.4 Global solar, wind, hydro, and renewable energy capacity

Global renewable energy is rapidly expanding, with solar PV leading the charge. Wind energy also contributes significantly to this growth. Global wind energy capacity has steadily increased from 2018, indicating continued growth and investment in this renewable energy source. While solar PV has experienced more rapid growth, wind energy remains a significant contributor to the expanding global renewable energy landscape. The chart shows a substantial increase in global solar PV capacity, outpacing wind and hydro. This underscores solar PV's crucial role in the energy transition. Continued growth in both solar and wind energy is essential for achieving net-zero targets.

Exhibit 3.4: Global solar, wind, hydro, and renewable energy installed capacity, in GW, CY2018 - CY2028E

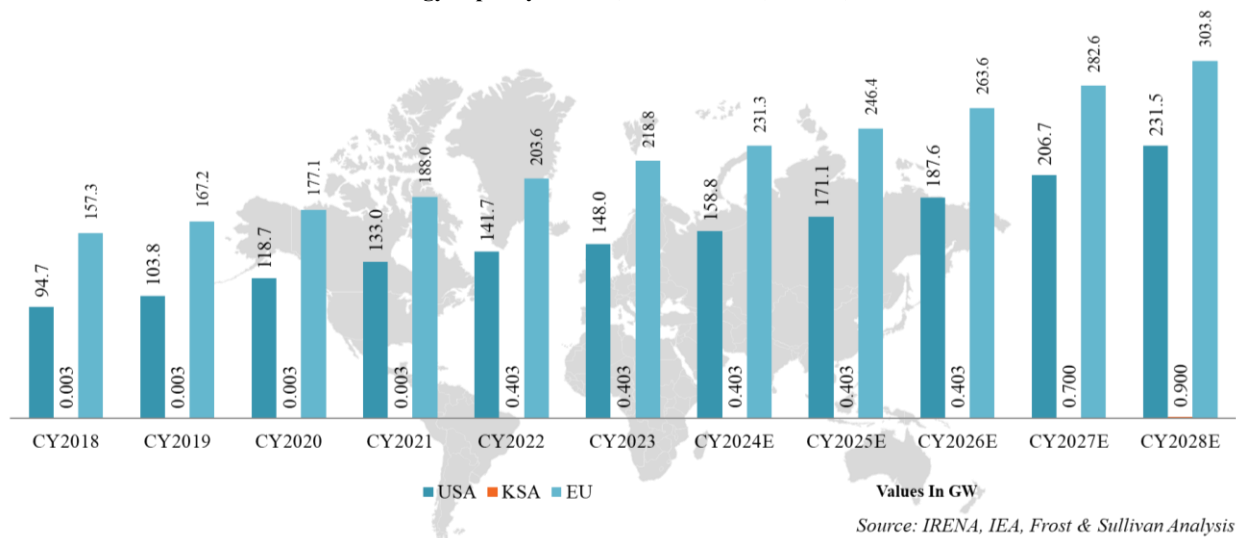


3.5 Solar and wind energy capacity in USA, EU and KSA

A. Wind Energy

From CY2018 to CY2023, the total wind capacity in the USA, KSA, and Europe together has grown at a CAGR of 7.8%. This indicates a growing reliance on wind energy as a sustainable power source. This trend is expected to continue in these regions, with a combined projected growth rates of 7.9% from CY2023 to CY2028.

Exhibit 3.5: Wind energy capacity in USA, EU and KSA, in GW, CY2018 - CY2028E



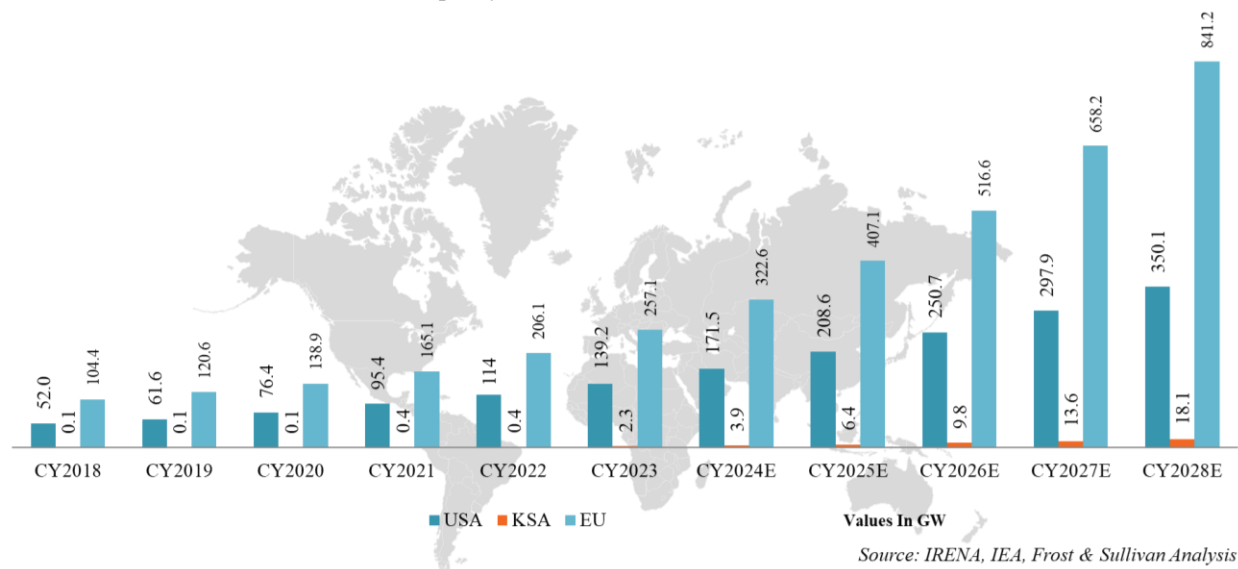
- **United States:** Grew at a CAGR of 9.4% from CY2018 to CY2023, with the same growth rate expected through CY2028E.
- **Saudi Arabia:** Noted a dramatic 167% CAGR from CY2018 to CY2023, with a more moderated forecast CAGR of 17% from CY2023 to CY2028E.
- **European Union (EU):** Grew at a CAGR of 6.8% from CY2018 to CY2023, with the same growth rate expected through CY2028E.

B. Solar Energy

From CY2018 to CY2023, solar capacity in the USA, European Union, and Saudi Arabia experienced notable growth, achieving a compound annual growth rate (CAGR) of approximately 21%. Projections indicate this trend will continue, with a CAGR of about 25% expected between CY2023 and CY2028.

Saudi Arabia led this growth, with its solar capacity expanding at a CAGR of approximately 94% from CY2018 to CY2023, driven by significant government investments in renewable energy projects under its Vision 2030 program. This momentum is expected to persist, with a projected CAGR of about 51% through CY2028. In the United States, solar capacity grew at a CAGR of around 22% from CY2018 to CY2023, supported by federal tax incentives and state-level renewable portfolio standards. This growth rate is anticipated to remain steady at similar levels during the CY2023 to CY2028 period.

Exhibit 3.6: Solar capacity in USA, EU and KSA, in GW, CY2018 - CY2028E



3.6 Drivers of Renewables energy globally

The global landscape for energy production is undergoing a significant shift. Driven by environmental concerns, economic factors, and technological advancements, renewable energy sources are experiencing a surge in growth.

A. Climate Change Concerns and Sustainability Goals:

- **Global Warming Threat:** Human activity, particularly fossil fuel combustion, is identified as the main cause of global warming. The urgency to address climate change and its impacts, such as extreme weather, rising sea levels, and ecological disruption, drives the adoption of renewable energy.
- **International Agreements:** The Paris Agreement, adopted in 2015, aims to limit global warming to well below 2 degrees Celsius, ideally 1.5 degrees Celsius, compared to pre-industrial levels. This agreement has led countries to set renewable energy targets and implement supportive policies.
- **Shifting Public Perception:** Increased public awareness of climate change has led to higher demand for renewable energy and pressure on governments and businesses to adopt sustainable practices.

B. Economic Competitiveness and Cost Reduction:

- **Technological Advancements:** Technological innovation has significantly driven down the costs of renewable energy technologies like solar panels, wind turbines, and geothermal systems. This ongoing

cost reduction has made renewable energy more competitive with traditional fossil fuels, particularly when considering long-term operational costs and environmental externalities.

- **Government Subsidies and Incentives:** Many governments around the world offer financial incentives for renewable energy projects. These incentives include feed-in tariffs, tax credits, loan guarantees, and grants. These subsidies help bridge the cost gap between renewable and traditional energy sources, making renewable projects more attractive for investors and developers.
- **Market Diversification and Economies of Scale:** The renewable energy sector has witnessed significant growth, leading to economies of scale. This translates to lower manufacturing costs for renewable energy equipment and improved efficiency in project development. This further enhances the economic competitiveness of renewable energy across various applications.

C. Energy Security and Independence:

- **Geopolitical Tensions and Fuel Price Volatility:** The global energy market is susceptible to geopolitical tensions and disruptions. Dependence on fossil fuels imported from specific regions can leave countries vulnerable to price fluctuations and supply chain interruptions. Renewable energy sources, particularly those that can be harnessed locally (solar, wind, geothermal), offer greater energy security and independence, reducing reliance on volatile fossil fuel markets.
- **Decentralized Generation:** Renewable energy sources like solar panels and small wind turbines can be deployed on a distributed basis, closer to where the electricity is consumed. This decentralized approach reduces reliance on centralized power grids, which can be vulnerable to disruptions, and allows for a more resilient energy infrastructure.

D. Technological Innovation and Advancements:

- **Efficiency Improvements and Storage Solutions:** Ongoing research and development are continuously improving the efficiency of renewable energy technologies. Additionally, advancements in energy storage solutions like batteries are essential for managing the intermittency of some renewable sources (solar, wind). Improved storage allows for smoother integration of renewables into the grid and helps overcome limitations associated with variable power generation.
- **Smart Grid Integration and Smart Technologies:** Integrating renewable energy sources effectively requires a modernized grid infrastructure. Smart grid technologies enable better communication between energy producers and consumers, facilitating a more efficient and flexible energy system. Additionally, smart technologies like smart meters and demand-side management tools allow for optimized energy usage and grid management.

E. Corporate Sustainability Initiatives and Consumer Demand:

- **Corporate Social Responsibility (CSR):** Many corporations are increasingly adopting sustainability goals and incorporating renewable energy into their operations. This is driven by a combination of factors: reducing their environmental footprint, appealing to environmentally conscious consumers, and potentially lowering energy costs in the long term. As corporations demand more renewable energy, it creates a larger market and further drives up investment in the sector.
- **Consumer Preferences and Green Products:** Consumers are increasingly making purchasing decisions based on sustainability considerations. This shift in consumer behavior creates a market demand for products and services powered by renewable energy. Additionally, the rise of "green" products and services further incentivizes businesses to adopt renewable energy solutions.

3.7 Key Policies Driving Renewable Energy Growth by Country

A. United States (USA)

The USA has a range of policies to promote renewable energy adoption. Key federal tax credits include the Investment Tax Credit (ITC), which provides a tax credit for a portion of solar project costs, and the Production Tax Credit (PTC), which supports wind energy by offering financial incentives for electricity production from renewable sources. Many states have Renewable Portfolio Standards (RPS) that require utilities to obtain a certain percentage of their electricity from renewable sources by specific deadlines, fostering long-term demand for renewable energy. Additionally, the Department of Energy (DoE) offers loan guarantees to mitigate financial risks associated with large-scale renewable energy projects, encouraging lenders to finance such ventures.

B. The European Union

The European Union has implemented a range of key renewable energy policies to drive its energy transition and achieve climate goals. The Renewable Energy Directive (RED II) sets a binding target of at least 32% renewable energy in the EU's total energy consumption by 2030, with further ambitions under RED III. The "Fit for 55" package aims for a 55% reduction in net greenhouse gas emissions by 2030, while the Green Deal strives to make Europe climate-neutral by 2050. The EU Emissions Trading System (ETS) encourages renewable investments by pricing carbon emissions, and the Just Transition Mechanism supports regions and industries in the shift from fossil fuels to renewables. The RePowerEU plan accelerates renewable projects in response to energy security challenges, especially in solar, wind, and green hydrogen. Additionally, the Clean Energy Package focuses on improving energy efficiency and integrating renewables into the grid, while Horizon Europe funds innovation in renewable energy technologies. Member states are required to outline their renewable strategies through National Energy and Climate Plans (NECPs), and the Offshore Renewable Energy Strategy targets 300 GW of offshore wind capacity by 2050. These policies collectively foster a greener, more sustainable energy future for the EU.

C. Kingdom of Saudi Arabia (KSA)

The Kingdom of Saudi Arabia (KSA) is transitioning towards renewable energy as part of its Vision 2030 plan, which aims to diversify the economy away from oil dependence. Vision 2030 targets 50% of electricity generation from renewable sources by 2030, including 40 GW of wind capacity. The National Renewable Energy Program (NREP) supports this goal with financial incentives such as feed-in tariffs and competitive auctions for project selection. Saudi Aramco is investing in renewable energy projects both domestically and internationally, reflecting a commitment to diversification and sustainability. The 2020 Solar Small-Scale Regulatory Framework governs grid-connected PV systems from 1 kW to 2 MW with a net-billing scheme and a 5 MW aggregate capacity limit per off-taker. The 2022 Self-Consumption Regulatory Framework, issued by the Water and Electricity Regulatory Authority (WERA), covers various renewable technologies and establishes regulatory requirements for both grid-connected and off-grid systems, enhancing consumer protection and efficiency without a specified capacity limit.

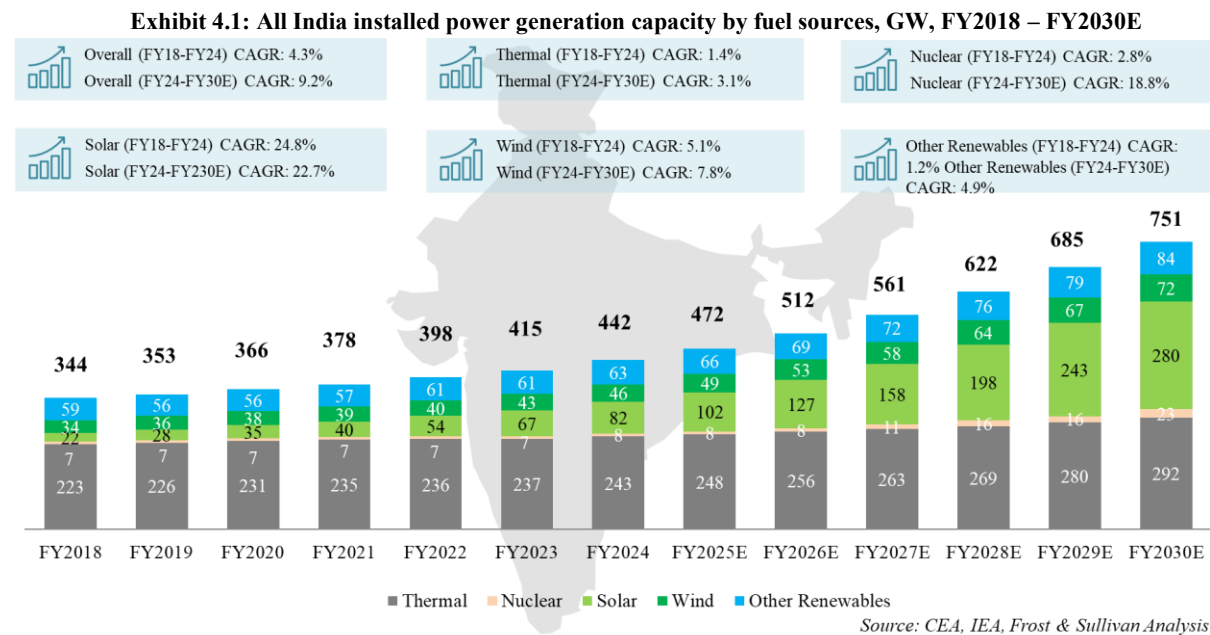
4. OVERVIEW OF THE INDIAN POWER AND RENEWABLE SECTOR

4.1 Growth in installed Power generation capacity in India

India's electricity generation capacity has grown exponentially since independence, expanding over 100-fold in response to rising demand for electricity across the country. Renewable energy is steadily gaining prominence in India's energy mix, as shown by the substantial growth of solar and wind power installations. India's commitment to reducing carbon emissions is reflected in its growing focus on solar and wind energy.

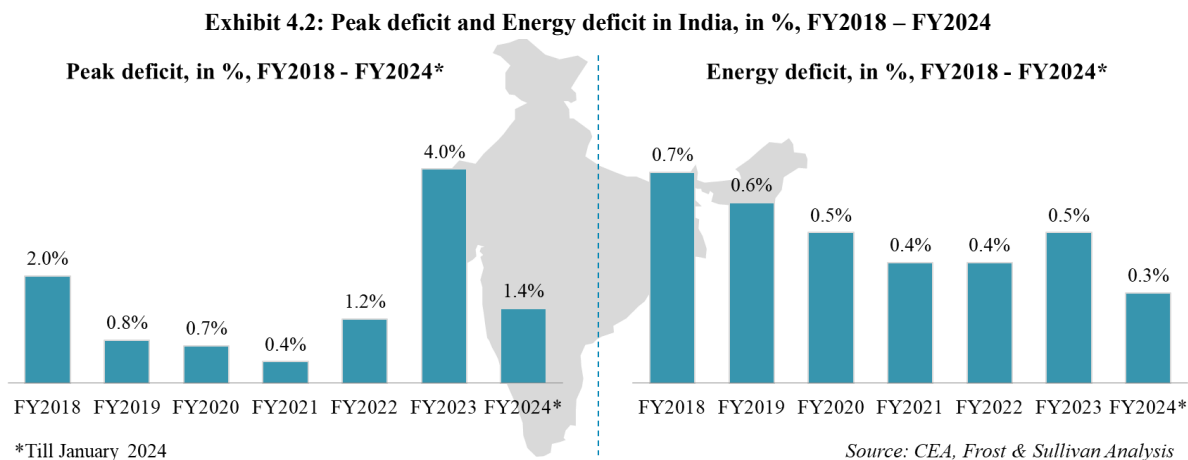
Despite challenges like the dominance of thermal power, India's renewable energy progress sets an example for other emerging economies. This shift aligns with the country's net-zero goals and contributes significantly to mitigating climate change.

India is transitioning from coal-based power to renewable energy, with a projected total power generation capacity of 751 GW by FY2030E and a renewable energy target of 500 GW by CY2030, including 280 GW from solar power. In FY2024, the government allocated USD 885 million (INR 73,270 million) for solar initiatives, including grid and off-grid systems and the PM-KUSUM program for solar pumps in agriculture. Additionally, 81 coal plants are set to be replaced with renewable energy sources by 2026, contributing to India's net-zero carbon emissions goal and its role in the global renewable energy transition.



4.2 Overview of Power demand-supply scenario in India

India's peak power deficit improved from ~17% in FY2008 to 0.4% in FY2021 but rose to 1.2% in FY2022 and 4.0% in FY2023 due to a surge in electricity demand and insufficient capacity additions. As of January, 2024, the peak deficit has reduced to 1.4%.



To address future energy deficits, the government plans to add 88 GW of baseload thermal power, aiming to meet peak demands of 295 GW by FY2028 and 366 GW by FY2032. Converting renewable energy

plants to round-the-clock (RTC) plants will also help manage deficits. Between FY2018 and FY2023, the energy deficit remained stable at 0.4%–0.7%. In FY2023, the energy requirement was 1,513 billion units, with 1,506 billion units supplied. The deficit further decreased to 0.3% in the first 10 months of FY2024.

4.3 Factors that will drive electricity demand in India

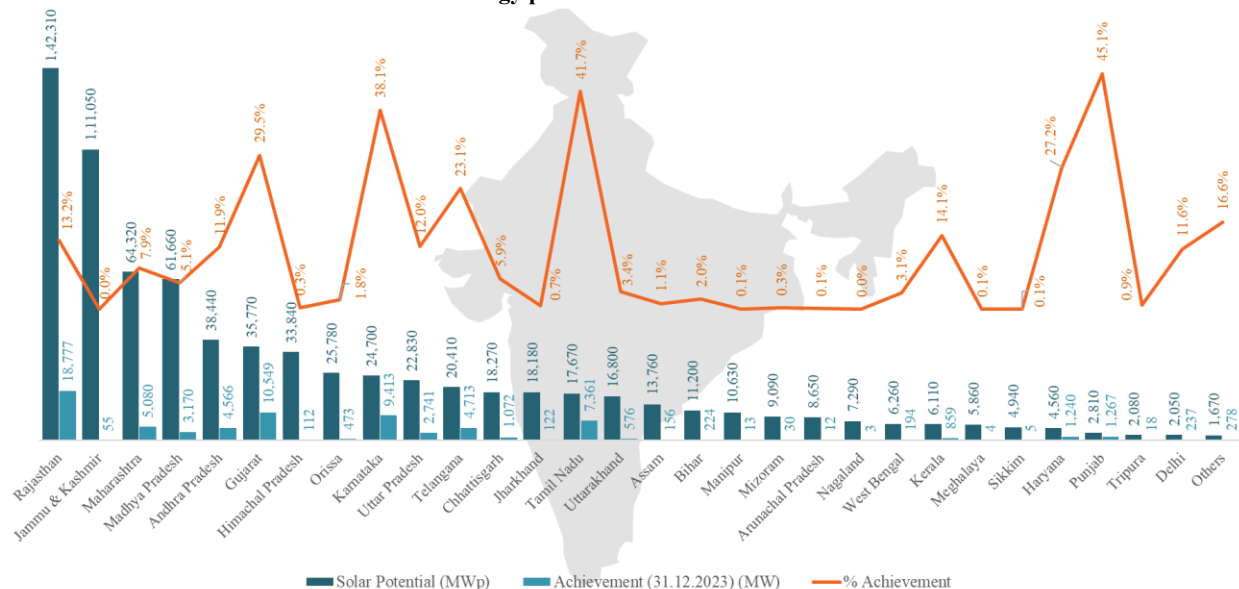
India's electricity demand is set to rise significantly due to urbanization and industrialization. By CY2040, an additional 270 million people are expected to join the urban population, increasing residential floor space to over 50 billion square meters. This will drive higher electricity use for appliances and amenities. Industrial growth, fueled by initiatives like 'Make in India,' the PLI scheme, and Atmanirbhar Bharat Abhiyaan, will boost energy consumption, with the industrial sector's share of energy use projected to rise from 36% to 41% by CY2040E. The expansion of EV charging infrastructure, with a target of 10,000 public stations by CY2025 and 2 million by CY2030, will add 4-5 billion units of electricity demand. Additionally, the National Hydrogen Mission aims to produce 5 MMT of green hydrogen by CY2030, requiring INR 8 trillion investment and 125 GW of renewable energy.

4.4 India's Solar power generation potential

India possesses immense solar energy potential, with approximately 5,000 trillion kWh of solar energy received annually, translating to 4-7 kWh per square meter per day. This abundant resource positions the country as a key player in harnessing solar energy for sustainable development. According to the National Institute of Solar Energy, India's theoretical potential for solar power generation stands at approximately 748 GWp, based on the assumption that 3.0% of the nation's wasteland can be utilized for installing Solar PV modules.

As of December 2023, India has tapped into around 10% of this potential, with a total installed solar capacity reaching 73 GW. This significant progress reflects India's commitment to renewable energy expansion, supported by favorable government policies and large-scale projects. Leading the charge in solar capacity addition are states like Rajasthan, Gujarat, Karnataka, Tamil Nadu, and Maharashtra, which collectively account for 70% of the country's total installed solar capacity. Rajasthan and Gujarat, with their vast expanses of arid land and high solar insolation, have emerged as frontrunners in this space.

Exhibit 4.3: State-wise Solar energy potential and achievement at the end of December 2023



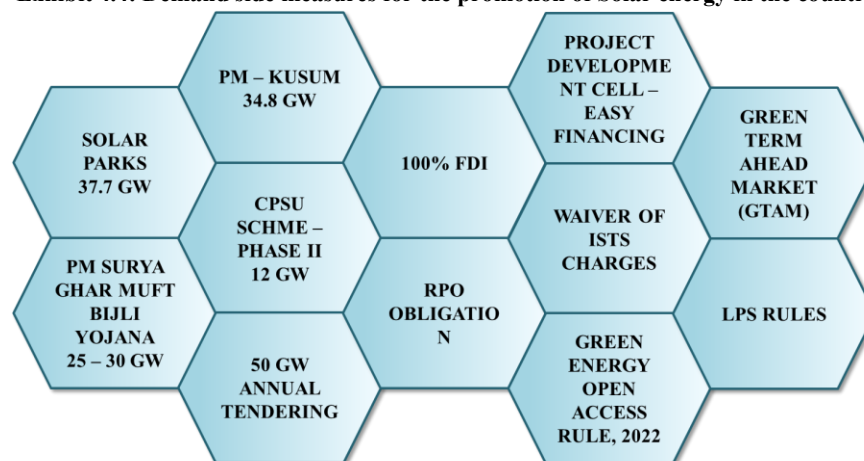
When evaluating the utilization of solar potential, Punjab leads with approximately 45% of its estimated capacity achieved, driven by innovative solar projects and efficient land use. Tamil Nadu follows closely with 42%, leveraging its solar parks and industrial demand for renewable energy. Karnataka, known for its pioneering solar initiatives, has utilized about 38% of its potential, while Gujarat stands at 30%, showcasing robust growth in solar investments. Haryana, with its focus on distributed solar solutions, has reached a 27% utilization rate. These achievements underline India's proactive approach to advancing solar energy, driven by ambitious targets, state-level initiatives, and the aim to meet its renewable energy goals. This trajectory not only enhances energy security but also contributes significantly to reducing greenhouse gas emissions and combating climate change.

4.5 Policy initiatives to drive the Solar sector in India

In recent years, the Indian government has introduced a range of initiatives aimed at fostering the growth of the solar power sector. On the demand side, several schemes have been implemented to support the ambitious target of achieving 300 GW of installed solar capacity by CY2030. These measures include financial incentives for solar power adoption, such as subsidies for rooftop solar installations, as well as initiatives to encourage large-scale solar projects through competitive bidding and tariff-based incentives.

On the supply side, the government has enacted policies to attract investment in domestic solar manufacturing, with the goal of reducing reliance on imports, particularly from Chinese and Southeast Asian countries. These policies include production-linked incentives (PLI), which offer financial support to domestic manufacturers of solar components, as well as anti-dumping measures aimed at protecting local producers from unfair competition. Together, these efforts aim to strengthen India's solar manufacturing ecosystem while ensuring the country meets its renewable energy goals.

Exhibit 4.4: Demand side measures for the promotion of Solar energy in the country



Source: Frost & Sullivan Research & Analysis

A. Solar Parks – ~38 GW

This scheme underscores India's commitment to solar energy, aiming to establish 51 Solar Parks each of 500 MW and above by 2025-26, with a cumulative capacity of ~38 GW.

These parks will serve as pivotal hubs for solar energy generation, stimulating investments and fostering an environment conducive to solar power development, thereby enhancing affordability and accessibility. Till the end of December 2023, approx. ~11 GW of solar projects have been commissioned under this scheme.

B. PM Surya Ghar Muft Bijli Yojana: 25-30 GW

With an allocation of over INR 750 billion, the scheme provides capital subsidies to install rooftop solar panels and offers up to 300 units of free electricity per month to about 10 million households. Its goal is to reduce household electricity costs, promote sustainable energy practices, and decrease reliance on traditional energy sources. The scheme requires the use of Domestic Content Requirement (DCR) solar modules. The government has proposed to provide the below subsidies for the implementation of this programme:

- For up to 2 kW - INR 30,000 per kW
- For additional capacity up to 3 kW - INR 18,000 per kW
- Total subsidy for systems larger than 3 kW - Maximum INR 78,000

As per Frost & Sullivan analysis, this scheme is expected to generate 25–30 GW of rooftop solar installation opportunities over the next 2-3 years.

C. PM-KUSUM Scheme – ~35 GW

The Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) aims to reduce diesel use in farming, enhance water and energy security, increase farmer income, and reduce pollution. It targets adding ~35 GW of solar power by March 2026 with a central financial support of INR 344 billion. The three components of the scheme are:

- **Component A:** Setting up of 10,000 MW of decentralized ground/stilt mounted solar power plants on barren/fallow/pasture/marshy/cultivable land of farmers. Such plants can be installed by individual farmer, solar power developer, cooperatives, panchayats, and farmers producer organizations.
- **Component B:** Installation of 1.4 million stand-alone Solar Water Pumps in off-grid areas.
- **Component C:** Solarization of 3.5 million grid connected agriculture pumps through (i) Individual Pump Solarization and (ii) Feeder Level Solarization.

Solar water pumps use solar energy to pump water, offering a clean, efficient alternative to diesel-powered systems. They reduce carbon footprints, require minimal maintenance, and are offered by companies which manufactures the solar modules while sourcing pumps externally.

D. CPSU Scheme – Phase II – 12 GW

The CPSU Scheme Phase-II, also known as the Government Producer Scheme, is a significant initiative from the Indian government to promote domestic solar power generation and enhance energy security. The key features of this scheme are:

- **Financial Assistance:** The scheme offers Viability Gap Funding (VGF) of up to INR 7 million per MW to incentivize participation and address project cost viability concerns.
- **Capacity Target:** The scheme initially aimed to develop a total of 12,000 MW of grid-connected solar power capacity through plants set up by the eligible entities. While the deadline for the project commissioning has already passed, the scheme continues to be operational for unallocated projects.
- **Implementation:** The scheme is implemented through a competitive bidding process managed by the Solar Energy Corporation of India (SECI). Eligible entities can submit proposals for setting up solar power plants, and SECI selects the most competitive proposals based on pre-defined criteria.

With government initiatives like the PM-KUSUM, PM-Surya Ghar Muft Bijli Yojana, and the CPSU scheme in play, there is an emphasis on utilizing DCR solar modules within the domestic solar market.

Along with these demand-side measures; the Indian government has also initiated a number of initiatives to strengthen the domestic Solar manufacturing industry. A brief description of some of the notable supply-side measures have been provided below:

E. Production Linked Incentive (PLI)

The Indian Govt. has implemented Production Linked Incentive (PLI) Scheme for the national programme on high efficiency Solar PV modules, for achieving manufacturing capacity of Giga Watt (GW) scale with an outlay of INR 240 billion. The scheme offers incentives to the selected Solar PV module manufacturers on manufacture and sale of high efficiency Solar PV modules. The scheme is applicable for the first five years from the actual commissioning date or from the scheduled commissioning date, whichever is earlier. The objectives of the scheme include the following:

- To build up Solar PV manufacturing capacity of high-efficiency modules.
- To bring cutting-edge technology to India for manufacturing of high efficiency modules. The scheme will be technology agnostic, however the technologies that would yield better module performance will be incentivized.
- To promote setting up of integrated plants for better quality control and competitiveness.
- To develop an ecosystem for sourcing of local materials involved in the solar manufacturing industry.
- Employment generation and technological self-sufficiency.

F. 50 GW Annual Tendering

India's renewable energy push is receiving a major boost with the "MNRE - 50 GW bidding every year" initiative. This ambitious policy aims to significantly increase solar power generation capacity by setting a fixed annual target of 50 GW for bidding rounds. This predictable schedule fosters investor confidence and potentially leads to lower solar power prices through competition. The policy is expected to accelerate solar capacity growth, enhancing energy security, and creating new jobs. With 80% of the annual target focused on solar, this initiative represents a major leap forward in India's journey towards a cleaner and more secure energy future fueled by the sun.

G. 100% Foreign Direct Investment (FDI)

The Government of India's Foreign Direct Investment (FDI) policy allows up to 100% FDI in renewable energy projects, including solar power generation and distribution. Under the Automatic Route, the non-resident investor or the Indian company does not require any approval from Government of India for the investment.

H. RPO Obligation

The declaration of trajectory for Renewable Purchase Obligation (RPO) up to the year FY2030 is a key policy implemented by the Indian government to promote renewable energy, specifically focusing on solar power. The declaration defines a gradual increase in the RPO percentage for each state over the years until FY2030 and imposes penalty in case of non-compliance. This provides clarity and certainty for investors and developers in the renewable energy sector, allowing them to plan their investments with confidence. By creating a guaranteed market, the RPO encourages developers to invest in solar and other renewable projects, leading to an increase in generation capacity. Diversifying the energy mix by increasing the share of renewables reduces dependence on imported fossil fuels and enhances energy security.

I. Project Development Cell

The Project Development Cell (PDC) aids investors in entering the Indian solar power market. It provides information on solar policies, investment opportunities, and regulatory processes, and supports land acquisition and grid connectivity. The PDC also conducts investor outreach through conferences and roadshows, facilitates project financing, and connects investors with developers and consultants. It advocates for the solar sector and addresses investor concerns with government bodies.

J. Waiver of ISTS charges

In March 2023, the Central Electricity Regulatory Commission (CERC) amended the CERC (Sharing of Inter-State Transmission Charges and Losses) Regulations, 2020. This amendment waives ISTS charges for renewable energy and pumped hydroelectric projects that begin commercial operations by June 30, 2025. The waiver also applies to any solar, wind, or other sources eligible for waiver of inter-state transmission charges, which are scheduled to be commissioned on or before June 30, 2025.

K. Green Energy Open Access Rules, 2022

Green Energy Open Access Rules, 2022 (Green Open Access Rules) is a policy aimed at facilitating the purchase of renewable energy by large consumers directly from generators, bypassing the traditional distribution network.

Key Provisions of the rules are:

- **Minimum Consumption Threshold:** Only large consumers with a minimum contract demand or sanctioned load (typically 100 kW or more) can avail of Green Open Access.
- **Streamlined Process:** The rules aim to simplify the process for obtaining approvals and entering into agreements for direct purchase of renewable energy.
- **Green Certificates:** Consumers who purchase renewable energy through Green Open Access are eligible for green certificates, which can be used to meet their Renewable Purchase Obligation (RPO).

Benefits for Solar Power are:

- **Increased Demand:** By creating a new market segment for large consumers, the policy can significantly increase demand for solar power.
- **Economic Advantages:** Large consumers might benefit from potentially lower prices through direct purchase and avoid some distribution charges.

L. Green Term Ahead Market (GTAM)

The Green Term Ahead Market (G-TAM) is a platform that allows bulk buyers of electricity to purchase renewable energy (RE) on a short-term basis. The G-TAM allows buyers such as corporates and discoms with a contracted load of 1 MW or more to purchase RE from sellers such as merchant RE projects or discoms with surplus RE. The G-TAM features contracts such as Green-Intraday, Green-Day-ahead Contingency (DAC), Green-Daily and Green-Weekly. The GTAM enables transactions between buyers and sellers through bilateral trading. There are four types of short-term contracts that are covered under the GTAM – Intra-day contracts, Day-ahead contracts, Daily contracts, and Weekly contracts.

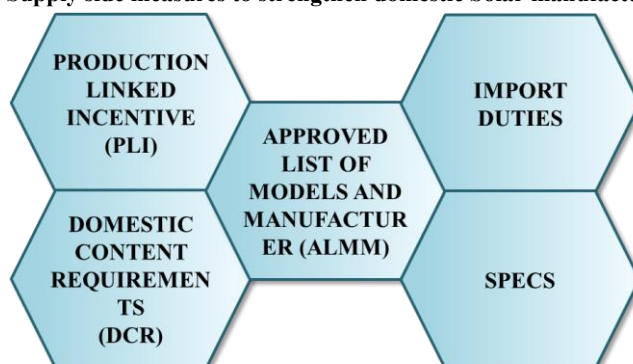
M. LPS Rules (Late Payment Surcharge)

The Electricity (Late Payment Surcharge and Related Matters) Rules, 2022 (LPS Rules) aim to tackle delayed payments by Discoms (distribution companies) to generators and transmission companies. Additionally, the rules establish a clear timeline for settling outstanding dues, promoting transparency in billing and payments. This not only improves cash flow for all stakeholders but also minimizes disputes

and creates a more predictable environment for investment, ultimately benefiting solar power producers by ensuring timely payments and potentially attracting further investment in the sector.

4.6 Supply side measures to strengthen domestic Solar manufacturing industry

Exhibit 4.5: Supply side measures to strengthen domestic Solar manufacturing industry



Source: Frost & Sullivan Research & Analysis

A. The PLI Scheme

The PLI Scheme is being implemented in two tranches as follows:

- **Tranche-I:** Under this tranche, Indian Renewable Energy Development Agency Limited (IREDA), the implementing agency on behalf of MNRE for the PLI Scheme, issued Letters of Award (LOA) in November and December 2021 to three successful bidders for setting up of 8,737 MW capacity of fully integrated Solar PV Module manufacturing units with an outlay of INR 45 billion.
- **Tranche-II:** MNRE, on 30th September 2022, issued guidelines for implementation of Tranche-II with an outlay of INR 195 billion. In this tranche, Solar Energy Corporation of India (SECI), the implementing agency on behalf of MNRE, issued Letters of Award (LOA) to 11 bidders in April 2023 for setting up 39,600 MW of fully / partially integrated solar PV module manufacturing units.

B. Domestic Content Requirement (DCR)

The Domestic Content Requirement (DCR) policy in India mandates that a certain percentage of components, including solar cells and modules, used in government-funded solar projects must be sourced from domestic manufacturers. This percentage is set to increase from 40% to 55% over the coming years, with incremental increases each year: 45% for projects starting in CY2025, 50% in CY2026, and 55% thereafter.

The DCR policy aims to stimulate domestic manufacturing, create jobs, and reduce dependence on imports by guaranteeing a market for locally produced solar components. It also helps domestic manufacturers by reducing competition from cheaper imported components, allowing them to establish themselves and benefit from economies of scale and technological advancements. Additionally, the policy encourages investment in research and development (R&D), fostering technological innovation and enhancing the global competitiveness of Indian manufacturers.

The policy applies to grid-connected solar power plants, rooftop solar installations on government buildings, and off-grid solar solutions. In August of the previous year, the Ministry waived DCR requirements for projects awarded before June 20, 2023. To further ensure adherence to DCR, the Indian government plans to set up a data repository to monitor compliance and curb imports.

C. Approved List of Models and Manufacturers (ALMM)

The ALMM program establishes a pre-approved list of reliable solar photovoltaic (PV) modules and cell manufacturers. This program ensures quality and efficiency of solar installations in India by requiring developers and investors to source their equipment from ALMM-listed vendors. By promoting high-quality domestic and imported products, ALMM fosters trust and encourages the adoption of reliable solar solutions throughout the country. The ALMM policy was introduced in April 2022 and after being under suspension for FY2024, the policy is again in effect from April 1, 2024. As per the latest list published by MNRE, the ALMM list still does not mention any foreign manufacturer. The ALMM program, by ensuring that solar photovoltaic (PV) modules and cell manufacturers meet high-quality standards, indirectly benefits fixed tilt solar structural component manufacturers. Since the program requires developers and investors to source equipment from ALMM-listed vendors, it promotes the use of reliable and efficient solar products. This focus on quality encourages the deployment of solar installations, including fixed tilt structures, which are commonly used in such projects. Additionally, with the exclusion of foreign manufacturers from the current ALMM list, there is likely to be an increased demand for domestically produced modules and, consequently, for locally manufactured fixed tilt structural components that support these installations.

D. Import Duties

Customs Duty Exemptions: Exemptions on basic customs duty (BCD) have been introduced for machinery and equipment used in the manufacturing of solar cells and modules, aimed at reducing costs for manufacturers. Additionally, the BCD exemptions for goods used in the production of silicon wafers, EVA sheets, and photovoltaic ribbons have been extended until March 31, 2026. Similar exemptions have also been granted for parts and raw materials required for the manufacturing of lithium-ion cells and batteries, with the extension running until the same date, March 31, 2026.

New Customs Duties: A 10% basic customs duty (BCD) on solar glass and a 5% BCD on tinned copper interconnects for solar cells and modules has come into effect from October 1, 2024. Additionally, the customs duty exemption on active energy controllers for renewable power inverters has expired on September 30, 2024. In support of renewable energy efforts, an allocation of INR 750 billion has been made for the PM Suryaghar Muft Bijli Yojana, which aims to install rooftop solar systems and provide free electricity up to 300 units for 1 crore households.

4.7 Key drivers of Electricity generation from Solar/ Wind energy

A. Government Policies and Initiatives: Government support plays a pivotal role in shaping the future of India's solar energy sector. Initiatives like the National Solar Mission, which targets achieving 100 GW of solar power capacity, have been instrumental in driving growth. Furthermore, incentives such as solar subsidies, tax exemptions, and Renewable Purchase Obligations (RPOs) provide strong encouragement for individuals and businesses to adopt solar power, fostering investment and accelerating the transition to renewable energy.

B. Declining Cost of Solar Panels: The cost of solar photovoltaic (PV) panels has drastically decreased over the past decade, driven by advancements in manufacturing technologies and economies of scale. This cost reduction has significantly enhanced the accessibility and appeal of solar energy, making it a viable and attractive option for businesses, industries, and households across India.

Since Q1 of CY2023, the cost of utility-scale solar projects in India has consistently declined over five consecutive quarters. This downward trend culminated in Q1 2024, which recorded a historic low with average project costs decreasing by 7.1% compared to the previous quarter.

In Q1 of CY2024, India achieved a significant milestone by installing over 10 GW of solar systems, setting a new record for quarterly installations.

C. International Solar Alliance (ISA): India's leadership in establishing the International Solar Alliance (ISA) has solidified its position as a global hub for solar energy collaboration. The ISA focuses on promoting solar energy adoption in countries located between the Tropic of Cancer and the Tropic of Capricorn, regions blessed with abundant sunlight. This initiative has attracted substantial international investment and technological support, boosting India's solar energy projects and enhancing its role in the global renewable energy landscape.

D. Corporate and Industrial Adoption: India's corporate and industrial sectors are progressively adopting solar energy as a strategy to lower energy costs and achieve sustainability objectives. Businesses are increasingly turning to large-scale solar power plants and commercial rooftop solar installations to reduce their carbon footprint and minimize electricity expenses, making solar energy a preferred choice for cost-effective and environmentally responsible energy solutions.

The rising electricity demand and escalating grid tariffs for commercial and industrial (C&I) customers are accelerating the adoption of rooftop solar power. This option is not only cleaner and more cost-effective but also provides tariff certainty for up to 25 years, making it a compelling choice for businesses.

C&I users consume nearly 49% of India's electricity, yet only 3.5% of their power procurement is from renewable sources, highlighting a significant untapped opportunity. Notably, C&I rooftop solar installations dominate the sector, accounting for 70-80% of all rooftops solar deployments in the country, reflecting its vast potential for growth.

The declining cost of solar equipment is significantly reducing the payback period for rooftop solar projects in India. Under the capital expenditure (Capex) model, businesses can now achieve payback within a shorter span of 3-4 years. In the operating expenditure (Opex) model, solar tariffs are highly competitive, ranging from ₹3.5 to ₹4 per kWh (USD 0.047–0.053), which is less than half the average grid tariff for commercial and industrial (C&I) users in most states.

The medium, small, and micro enterprises (MSME) segment within the C&I sector is expected to drive solar adoption aggressively in the coming years, leveraging its cost-effectiveness and sustainability benefits.

E. India's Data Centre Boom Opens up A Fresh Segment For Green Developers and Green Hydrogen: India's data centre capacity is set to double from 1 GW to 2 GW by the end of 2023, driven by the growing adoption of AI. This surge highlights the energy-intensive nature of data centres, prompting operators to explore renewable energy, energy-efficient technologies, and green hydrogen solutions for sustainability. Leading players like CtrlS Datacenters, NTT, and Sify Technologies are investing in solar power to meet energy needs and sustainability goals. CtrlS aims for 100% renewable energy by 2030 and net-zero emissions by 2040, while NTT and Sify have implemented large-scale solar initiatives. The integration of green hydrogen also plays a critical role in reducing carbon footprints and ensuring energy security for AI-driven infrastructure.

4.8 International policies aiding export of Indian solar power components

The Indian solar Photovoltaic (PV) industry is experiencing a significant growth spurt, and international policy changes are playing a key role in propelling this momentum. Following is a breakdown of how specific international policies from the US and China are impacting Indian solar PV component exports:

A. United States Inflation Reduction Act (IRA):

- **Policy Overview:** The IRA, a landmark piece of US legislation enacted in August 2022, aims to combat climate change and boost domestic clean energy manufacturing. It includes several provisions that can incentivize the import of solar PV components from countries like India.
- **Impact on Indian Exports:**
 - **Tax Credits:** The IRA extends and expands tax credits for renewable energy projects, including solar installations. This increased demand for solar in the US market creates a significant opportunity for Indian solar component manufacturers.
 - **Importer Neutrality:** The IRA removes existing tariffs on solar cells and modules from certain Southeast Asian countries. However, it maintains a technology-neutral approach, meaning Indian manufacturers can compete based on price and quality.
 - **Focus on Domestic Manufacturing:** While the IRA incentivizes domestic manufacturing within the US, it doesn't explicitly exclude imports. Indian manufacturers can leverage their cost competitiveness and established production capacity to cater to the growing US solar market.
- **Commentary on Solar tracking and mounting products:** The specific impact on Indian exports of solar tracking and mounting products (e.g., mounting systems, racking) is less clear at this stage. The IRA primarily focuses on solar cells and modules. However, the overall growth of the US solar market due to the IRA could indirectly lead to increased demand for solar tracking and mounting products as well.

B. US Forced Labor Prevention Act: Under international policies aiding the export of Indian solar power components, UFLPA (U.S. Forced Labor Prevention Act) plays a key role in ensuring that solar supply chains remain free of forced labor. As the U.S. is a significant market for solar components, the implementation of UFLPA creates a framework where Indian manufacturers must ensure compliance with labor standards. This act prohibits the import of solar components that may involve forced labor, incentivizing Indian manufacturers to adopt ethical labor practices and improving their export opportunities in global markets. By adhering to such standards, Indian companies can gain access to markets that prioritize sustainability and human rights, further boosting the export of Indian solar components.

C. China + 1 Strategy:

- **Policy Overview:** This is not a specific policy but rather a broader strategic shift by some countries, particularly in Southeast Asia, to diversify their supply chains away from a heavy reliance on China. This creates an opportunity for Indian manufacturers to fill the gap.
- **Impact on Indian Exports:** The China + 1 strategy presents a significant opportunity for Indian solar PV component manufacturers. As companies look to diversify their sourcing, India, with its established manufacturing base and competitive production costs, emerges as a viable alternative.

4.9 Indian Wind Power Sector

India boasts a robust domestic wind power industry that has consistently driven sector expansion. This growth has fostered a strong ecosystem, honed project operation capabilities, and established a robust manufacturing base with a capacity of approximately 15,000 MW annually as of FY2024. As a testament to this success, India currently ranks fourth globally in terms of installed wind energy capacity.

The government actively promotes wind power projects nationwide by attracting private sector investment through various fiscal and financial incentives. Examples include accelerated depreciation benefits and concessional customs duty exemptions on specific wind turbine components. Notably, the Generation Based Incentive (GBI) Scheme was previously available for wind projects commissioned before March 31st, 2017.

A. Tapping the wind energy – Challenges and opportunities

Wind energy has emerged as a critical pillar in India's ambitious clean energy transition. Harnessing the power of the wind holds immense potential to address the nation's growing energy demands while mitigating climate change impacts. However, despite its leadership in renewable energy and a robust domestic wind power industry, India's wind energy sector has encountered headwinds in recent years, hindering its full potential.

Opportunities: Harnessing the Wind's Power

- **Untapped Wind Power Potential:** India has over 695 GW of untapped wind power potential at 120 meters, offering a significant opportunity for clean energy.
- **Technological Advancements:** Improvements in wind turbine technology and storage solutions enhance efficiency and reduce costs, increasing competitiveness with other renewables.
- **Cost Reduction Strategies:** Optimizing logistics, supply chains, and financing models can improve the viability and competitiveness of wind energy projects.
- **Hybrid Power Solutions:** Combining wind and solar energy in hybrid projects can optimize power generation and enhance grid stability.
- **Job Creation and Economic Growth:** The wind energy sector can generate substantial employment and drive economic growth, especially in rural areas where wind farms are located.

Additionally, the growing adoption of hybrid projects, such as Wind-Solar Hybrid (WSH) and Floating Solar with Wind (FDRE) projects, has revived interest in the wind energy sector. These hybrid projects have proven to be a key contributor to the growing integration of wind energy into the broader renewable landscape, further enhancing grid reliability and efficiency.

These opportunities for the wind energy sector complement the growth drivers identified under solar energy development, such as technological innovation, investment in infrastructure, and supportive government policies, positioning wind power as a critical component of India's clean energy future

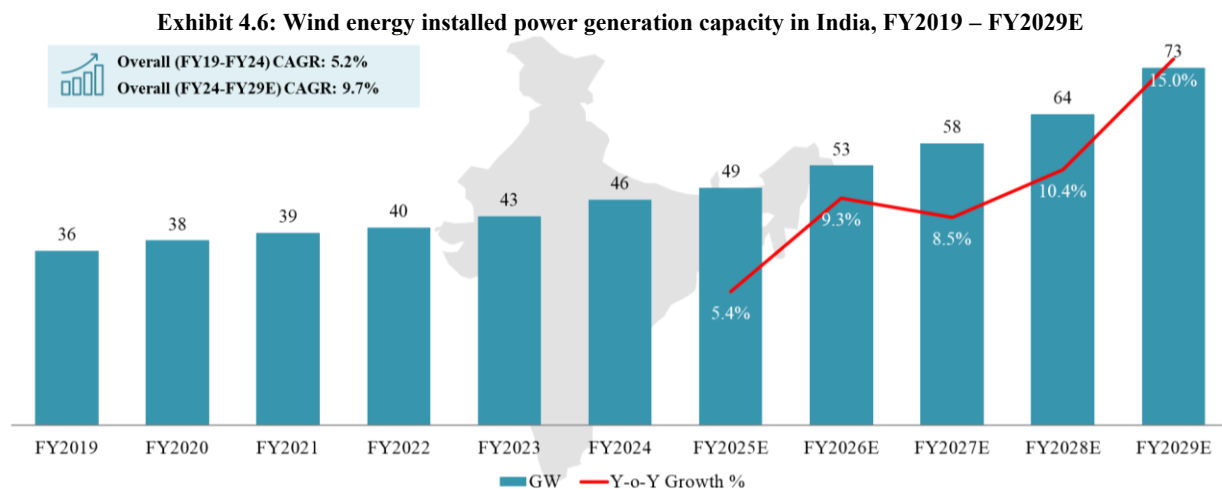
Challenges and Obstacles

- **Land Acquisition Hurdles:** Securing large tracts of land for wind farms, especially in densely populated areas, can be time-consuming and costly due to complex approval processes and right-of-way clearances.
- **Transmission Infrastructure Bottlenecks:** Existing power transmission infrastructure often cannot handle large-scale wind power integration, leading to curtailment and reduced investor confidence.
- **Financial Stress of DISCOMs:** Financial difficulties among distribution companies lead to delayed payments to wind power generators, causing cash flow problems and deterring investment.
- **Competition from Falling Solar Costs:** Declining solar PV costs make solar energy more attractive, putting wind energy at a competitive disadvantage, especially in high-solar regions.

- **Uncertainty in Policy Framework:** Frequent policy changes create uncertainty for investors, hindering effective project planning and financing. A stable policy environment is needed for sustainable growth in wind energy.

B. India's Wind energy installed capacity

Recognizing the untapped potential of wind energy, the Indian government has taken significant steps over the past 1.5 years to revitalize the sector and strengthen its role in the country's energy mix. Key measures include introducing specific carve-outs for Wind Renewable Purchase Obligations (RPOs), overhauling the auction mechanism to attract developers, and committing to 10 GW of exclusive annual wind tenders to meet renewable energy targets. These efforts aim to drive at least 25 GW of new wind capacity additions by FY2029E. This renewed focus underscores the sector's vital role in diversifying India's energy portfolio and advancing its sustainable energy goals, complementing the rapid growth of solar and other renewables.



Source: GWEC India, CEA, Frost & Sullivan Analysis

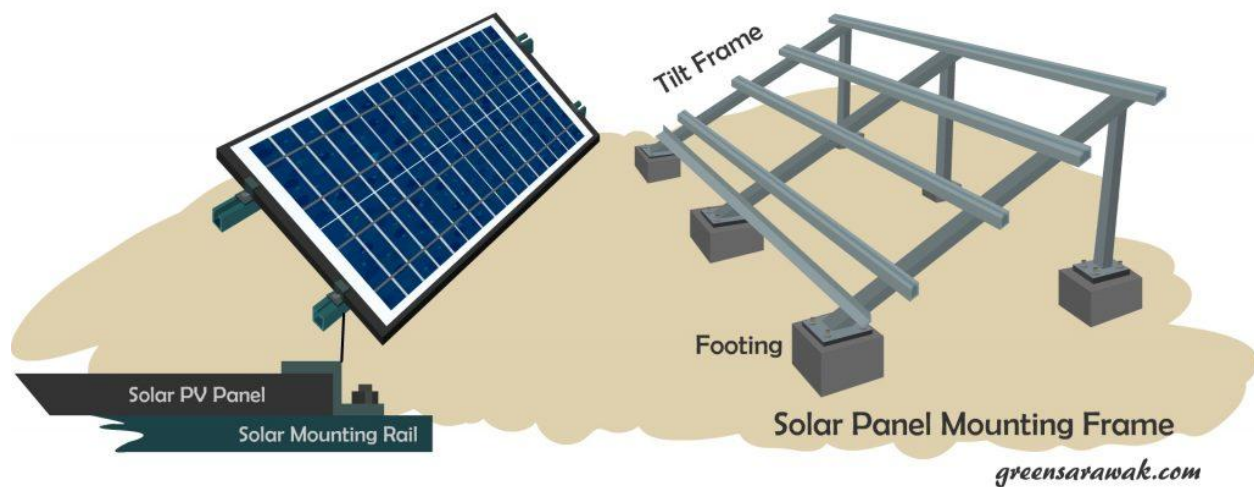
5. FIXED TILT SOLAR TECHNOLOGY ADOPTION WORLDWIDE

5.1 Overview of Fixed tilt solar technology

Fixed tilt solar technology, widely adopted in India, involves photovoltaic panels mounted at a fixed angle optimized for maximum solar radiation at specific locations. Known for its cost-effectiveness, simplicity, and reliability, this technology is particularly popular in utility-scale solar farms and rooftop installations. It suits India's diverse geography, with designs tailored to the country's latitude. Fixed tilt systems dominate due to lower installation and maintenance costs, aligning well with India's cost-sensitive renewable energy market. However, their efficiency is limited compared to tracking systems, and they require more land. Despite these challenges, fixed tilt solar remains a critical component of India's renewable energy strategy, supported by government initiatives like the National Solar Mission, and is expected to continue playing a significant role in the country's transition to sustainable energy.

Fixed tilt solar panels are mounted at a fixed angle and orientation, and the components of a fixed tilt solar system include:

- **Solar panels:** The panels are mounted at a fixed angle to capture the most sunlight.
- **Mounting structure:** The mounting structure keeps the panels at a constant angle throughout the year.
- **Balance of system (BOS):** This includes all components of the system other than the panels, such as wiring, switches, inverters, battery bank, and battery charger.



5.2 Global analysis of fixed tilt markets

The global solar market is witnessing a decisive shift from fixed-tilt installations to tracker-based systems, with fixed-tilt penetration declining sharply from 77% in CY2018 to a projected 30% by CY2028E. This trend underscores the growing preference for trackers, which enhance energy yield by optimizing sunlight capture. The decline is particularly stark in the United States, where fixed-tilt systems have seen their market share dwindle to just 5% by CY2023, signaling an almost complete transition. A similar dynamic is observed in Saudi Arabia (KSA), where fixed-tilt systems have entirely phased out, potentially reflecting the impact of targeted government initiatives, local energy goals, or specific project requirements. In Europe, while the shift is slower, the decline from 40% in CY2018 to an estimated 2% by CY2026E and eventually expected to completely phase out illustrates the broader global movement away from fixed-tilt installations in favour of more efficient alternatives.

Exhibit 5.1 (a): Analysis of annual fixed tilt penetration, Global, in %, CY2018 – CY2028E

Country / Region	CY2018	CY2019	CY2020	CY2021	CY2022	CY2023	CY2024E	CY2025E	CY2026E	CY2027E	CY2028E
Global	77.0%	73.0%	68.0%	63.0%	58.0%	53.0%	48.0%	43.0%	39.0%	35.0%	30.0%
USA	40.0%	32.0%	25.0%	16.0%	10.0%	5.0%	3.0%	2.0%	2.0%	1.0%	0.0%
KSA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Europe	40.0%	32.0%	25.0%	16.0%	10.0%	5.0%	3.0%	2.0%	2.0%	1.0%	0.0%

Source: Stakeholder interaction, Frost & Sullivan Analysis

The global fixed-tilt market was valued at approximately USD 71,646 million in CY2018 and experienced significant growth, reaching an estimated USD 135,585 million in CY2023, with a CAGR of 13.6% during this period. However, the market is projected to decline, reaching approximately USD 89,874 million by CY2028, reflecting a negative CAGR of around 7.9% from CY2023 to CY2028.

Exhibit 5.1 (b): Analysis of annual fixed tilt installed capacity, Global, in GW, CY2018 – CY2028E

Country / Region	CY2018	CY2019	CY2020	CY2021	CY2022	CY2023	CY2024E	CY2025E	CY2026E	CY2027E	CY2028E
Global	78.3	85.4	102.8	107.4	132.5	198.7	193.1	181.3	179.1	172.9	161.9
USA	3.3	3.1	3.7	3.0	1.9	1.2	1.0	0.7	0.8	0.5	0.0
KSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Europe	3.1	5.2	4.6	4.2	4.1	2.6	1.9	1.4	1.5	0.9	0.0

Source: Stakeholder interaction, Frost & Sullivan Analysis

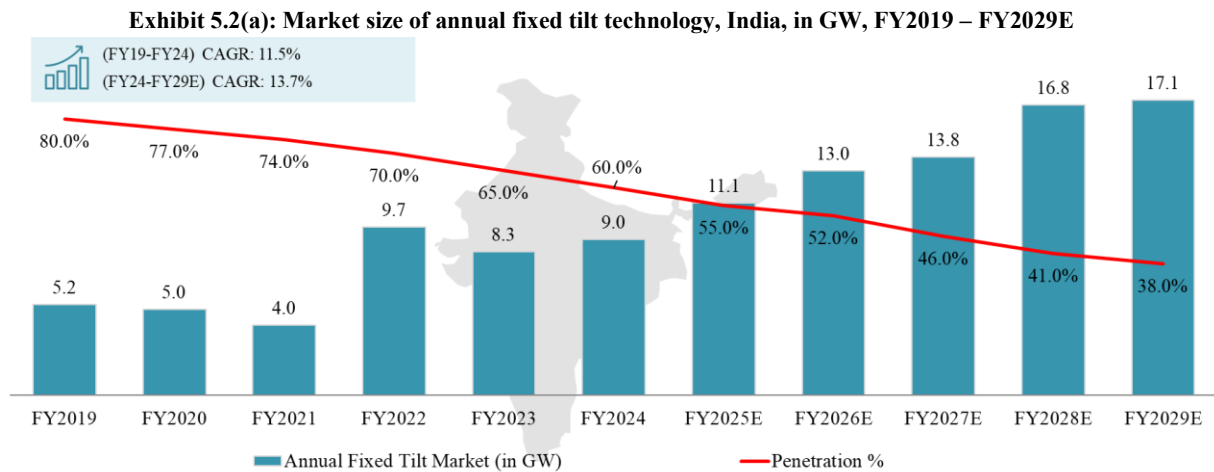
Exhibit 5.1 (c): Market size of annual fixed tilt technology, Global, in USD Million, CY2018 – CY2028E

Country / Region	CY2018	CY2019	CY2020	CY2021	CY2022	CY2023	CY2024E	CY2025E	CY2026E	CY2027E	CY2028E
Global	71,646	72,351	85,449	81,295	94,029	135,585	125,253	116,244	108,422	101,385	89,874
USA	4,142	3,604	4,282	3,209	1,863	1,176	892	667	738	397	0.0
KSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Europe	2,963	4,552	3,788	3,427	3,234	1,942	1,395	1,006	1,108	616	0.0

Source: Stakeholder interaction, Frost & Sullivan Analysis

5.3 Analysis of India's fixed-tilt market

In certain regions of India, fixed-tilt solar systems are preferred over single-axis trackers due to their cost efficiencies. Fixed tilt panels, with fewer moving parts, are simpler to install and require less maintenance, leading to lower overall costs.

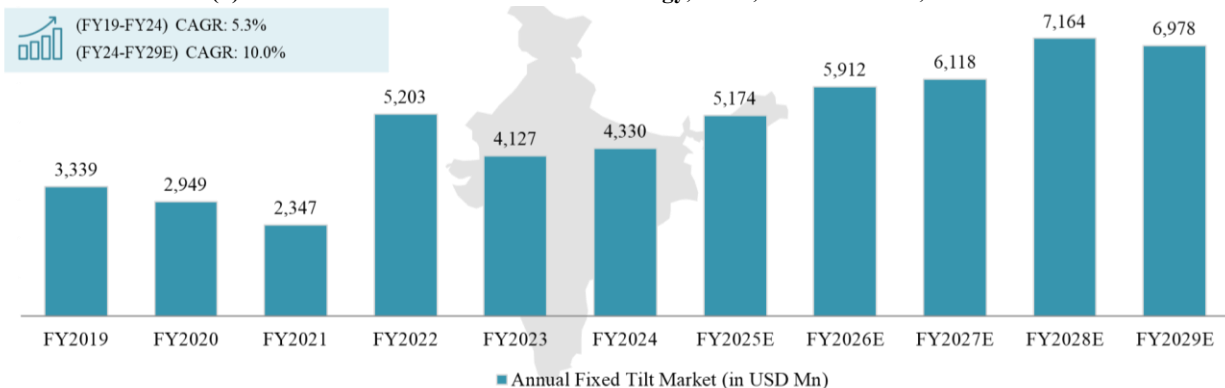


Source: Stakeholder interactions, Frost & Sullivan analysis

There is a growing push from renewable energy players to innovate and improve efficiency for tracker components to trade-off the high cost of operations and maintenance for a solar power plant with higher revenue generation due to efficient solar tracking components. In certain parts of India, fixed-tilts are preferred over single-axis trackers primarily because of the economies of scale.

This makes fixed-tilt systems more accessible for a range of applications. The fixed angle allows for accurate forecasts of energy output, resulting in efficient planning and resource allocation. Their space-efficient design makes them suitable for installations where there is limited real estate. They also minimize shading between panels, optimizing energy capture across the solar array. The cost advantages and efficiencies gained from using fixed tilt systems make them a more viable and attractive option for large scale solar projects.

The global solar market is experiencing a significant shift towards tracker systems, with fixed-tilt installations steadily declining, i.e., from 77% market share in CY2018, and projected to drop to 30% by CY2028E. Despite the decrease in global market share, India stands out as a bright spot as, with the market value projected to experience a significant upward trajectory i.e., growing from 5.2 GW in FY2019 to 9 GW in FY2024 growing at a CAGR 11.5% and project to reach to 17.1 GW in FY2029E estimated to grow at a CAGR of 13.7%. Despite these advantages, emerging economies like India are rapidly embracing solar trackers.

Exhibit 5.2 (b): Market size of annual fixed tilt technology, India, in USD Million, FY2019 – FY2029E

Source: Stakeholder interactions, Frost & Sullivan analysis

By FY2029E, fixed tilt is expected to constitute 38% of the market, while the overall market for trackers is projected to grow significantly. India's fixed tilt solar market value, which was USD 3,339 million in FY2019 reached USD 4,330 in FY2024 growing at a CAGR of 5.3% and is anticipated to reach USD 6,978 million by FY2029E projected to grow at a CAGR of 10.0%. The market is maturing, with both fixed-tilt and tracking systems expanding, but the growth rate for trackers is outpacing that of fixed-tilt systems, resulting in a decreasing relative share for fixed-tilt systems.

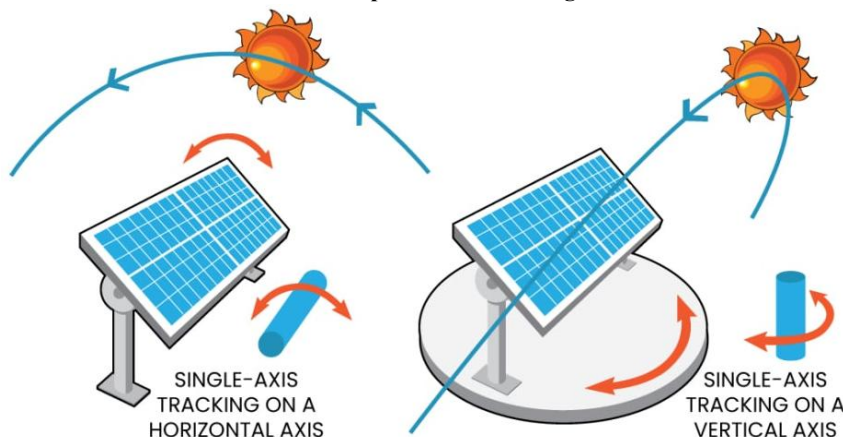
6. EVOLUTION OF SOLAR TRACKER TECHNOLOGY

6.1 Introduction to Solar Tracker Technology

In the pursuit of maximising solar energy capture, photovoltaic (PV) technology has taken a significant leap forward with the introduction of solar trackers. The trackers dynamically adjust the position of solar panels throughout the day, mimicking the sun's apparent movement across the sky. This strategic reorientation significantly boosts energy production compared to fixed-tilt mounting systems, where panels remain static at a predetermined angle. Solar trackers represent a crucial innovation, offering a powerful tool to optimize solar energy capture and increase overall electricity generation from PV systems.

A. Single-axis trackers

Single-axis solar trackers employ a robust mechanism to optimize solar energy capture. A dedicated tracking mechanism, such as a rack and pinion system or a screwdriver, physically adjusts the tilt of the photovoltaic (PV) panels throughout the day. Sophisticated sensors, including solar trackers or light position sensors, continuously monitor the sun's position.

Exhibit 6.1: Pictorial representation of Single-axis trackers

The control system acts as the central processing unit, interpreting sensor data and calculating the optimal panel tilt angle to maximize sunlight capture. This calculation can be based on pre-programmed algorithms or real-time sun-tracking data. The control system then transmits precise commands to the tracking mechanism, ensuring the panels maintain a near-perpendicular angle to the sun's rays as it traverses the east-west arc. This dynamic optimization significantly minimizes the angle of incidence, maximizing sunlight capture and leading to a substantial increase in energy production compared to fixed-tilt mounting systems. The efficiency increase of a single-axis tracking system compared to a fixed-tilt solar panel can typically range between 15% and 25% in terms of energy output.

B. Dual-axis trackers

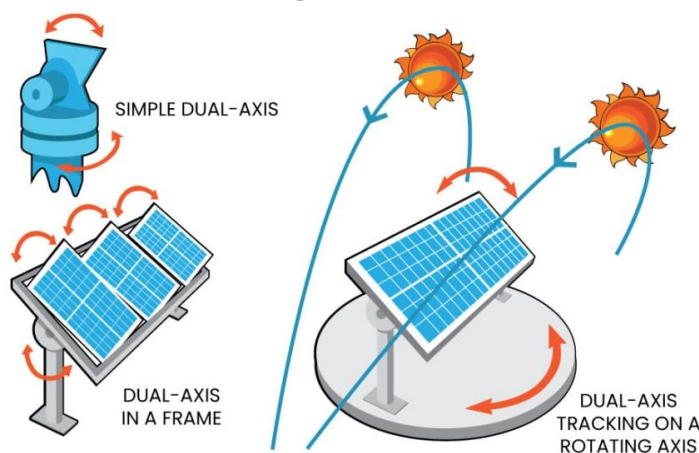
Dual-axis solar trackers represent the benchmark of optimization in solar energy capture technology. Unlike their single-axis counterparts, these sophisticated systems boast the ability to adjust the panels on both the east-west and north-south axes.

This comprehensive movement allows for unparalleled precision in maintaining a near-perpendicular angle to the sun's rays throughout the day, regardless of the season or time of day.

Dual-axis trackers use a sophisticated mechanism, often involving screwdrivers or hydraulic systems, to adjust solar panels on both horizontal and vertical axes. Light position sensors continuously monitor the sun's location. The control system processes this data in real-time to determine optimal tilt angles, ensuring panels are always positioned to maximize sunlight exposure.

This dual-axis adjustment enhances energy production by 5%-10% more than single-axis trackers by maintaining optimal panel orientation throughout the day. However, this increased efficiency comes with higher initial costs and potentially more frequent maintenance.

Exhibit 6.2: Pictorial representation of Dual-axis trackers



C. Primary use case: Solar tracker applications

Utility-Scale Solar Farms: Maximizing energy generation on vast spans

Large-scale solar farms, often spread across vast expanses of land, are a cornerstone of the renewable energy revolution. Their primary objective is maximizing electricity production for grid integration. By dynamically adjusting the panels throughout the day to maintain a near-perpendicular angle to the sun, trackers can significantly increase energy output compared to fixed-tilt systems. This translates to:

- **Enhanced Project Viability:** Increased energy production from single-axis tracking systems improves a project's financial viability by generating more electricity for sale to the grid, leading to a faster return on investment.
- **Levelized Cost of Energy (LCOE),** making the project more cost-effective over its lifetime. This reduction in LCOE enhances the overall viability, as the cost of generating each unit of electricity decreases, making the project more competitive and attractive to investors.
- **Land Use Optimization:** Trackers allow for denser packing of panels on the available land due to their ability to optimize energy production from each panel. This maximizes energy output while minimizing land use, a crucial consideration for large-scale projects.
- **Grid Integration Benefits:** Increased and more consistent energy production from tracker-equipped solar farms can enhance grid integration by providing reliable renewable energy during peak demand periods.

Commercial and Industrial Rooftop Systems: Making the Most of Limited Space

Commercial and industrial rooftops often present unique challenges for solar installations. Space constraints are a major concern, limiting the number of panels that can be deployed. Solar trackers offer a compelling solution in these scenarios. By optimizing panel tilt for maximum sunlight capture throughout the day, trackers can significantly increase energy production even on rooftops with limited area. This translates to:

- **Increased Electricity Savings:** The ability to generate more electricity from a limited number of panels helps businesses offset their electricity bills to a greater extent, leading to substantial cost savings.
- **Improved Sustainability Profile:** Businesses seeking to enhance their environmental credentials can utilize solar trackers to generate more clean energy onsite, reducing their reliance on traditional energy sources.
- **Greater System Flexibility:** In some cases, solar trackers can be programmed to adjust panel tilt for seasonal variations in sun angles or to avoid shading from nearby structures, further optimizing energy production on rooftops.

Remote Off-Grid Applications: Powering communities in isolation

In remote locations where grid access is limited or non-existent, standalone solar PV systems are often the primary source of electricity. Here, maximizing energy production is crucial for powering homes, businesses, and vital infrastructure. Solar trackers play a transformative role in these off-grid applications including:

- **Enhanced energy security:** Increased electricity generation from trackers ensures greater self-sufficiency for remote communities, reducing their dependence on other unreliable fuel sources.
- **Improved system reliability:** Trackers can help overcome seasonal variations in sunlight availability in some regions, ensuring a more consistent and reliable supply of solar energy throughout the year.
- **Reduced reliance on generators:** Increased solar energy production through tracking can decrease dependence on diesel generators, which are often noisy, polluting, and expensive to operate, especially in remote locations.

Concentrated Solar Power (CSP) plants: Precise tracking for enhanced efficiency

Concentrated Solar Power (CSP) plants utilize mirrors to focus sunlight onto a receiver, generating heat for electricity production. While not all CSP configurations utilize trackers, some employ them to precisely adjust the mirror orientation throughout the day. This provides several key benefits including:

- **Maximized heat generation:** Precise tracking ensures that the concentrated sunlight is directed at the receiver throughout the day, maximizing heat generation and overall plant efficiency.
- **Increased energy output:** By capturing more concentrated sunlight, tracking systems can contribute to a significant increase in the overall electricity generation capacity of the CSP plant.
- **Operational flexibility:** In some cases, trackers can be programmed to adjust mirror orientation based on weather conditions, optimizing heat capture even during periods of cloud cover.

Agricultural Applications: Dual-purpose systems for sustainable farming

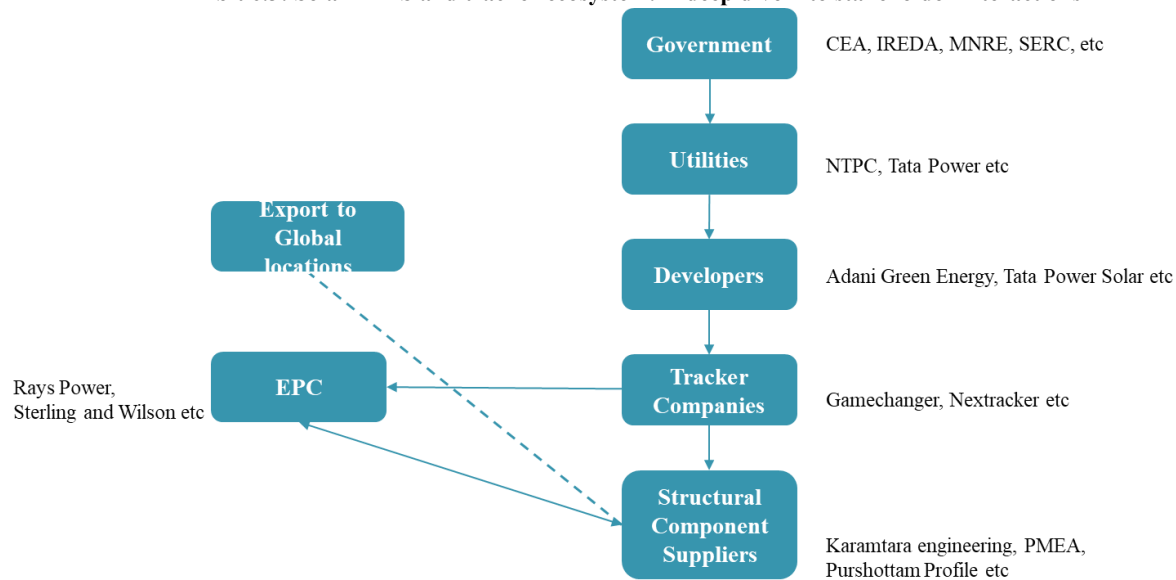
- Integrating solar trackers with agriculture optimizes land use by combining energy production with farming. Solar trackers add unique advantages over fixed solar panels in agricultural applications:
- **Maximized Energy Production:** Trackers ensure panels follow the sun's trajectory, producing more energy compared to fixed systems, even in smaller land areas. This makes them especially valuable for land-scarce agricultural regions.
- **Dynamic Shading for Crops:** Unlike fixed panels, solar trackers provide dynamic shading patterns throughout the day, promoting better growth conditions for shade-tolerant crops without excessively blocking sunlight.
- **Efficient Water Management:** The trackers' movement reduces the creation of constant shaded areas, minimizing soil moisture imbalance and evaporation in specific zones, thereby improving irrigation efficiency.
- **Adaptability to Crop Cycles:** Trackers can be adjusted or programmed to accommodate seasonal farming needs, ensuring both energy production and optimal crop growth

6.2 Solar project ecosystem: A deep dive into stakeholder interactions

The solar tracker industry thrives on a complex and dynamic ecosystem, where numerous stakeholders collaborate to bring this technology to life. Each player has a distinct role, and their interactions are crucial for the successful implementation of solar tracker projects. The chart below highlights the intricate web of interactions between these key participants:

A. Government: Setting the stage for growth

- **Role:** The government acts as the architect of the solar tracker landscape. They establish policies and incentives that influence project feasibility and technology adoption.
 - **Policy & incentive development:** Governments collaborate with industry stakeholders (developers, utilities, tracker companies) to understand current trends and challenges. Based on this input, they develop targeted policies like:
 - Financial subsidies or tax breaks specifically for projects utilizing solar trackers.
 - Feed-in tariffs that offer premium rates for electricity generated using solar trackers due to their higher energy output.
 - Streamlined permitting processes for projects employing solar tracking technology.

Exhibit 6.3: Solar MMS and tracker ecosystem: A deep dive into stakeholder interactions

Source: Stakeholder consultation, Frost & Sullivan Analysis

Non exhaustive list of players and they are listed in the alphabetical order

○ **Research & Development (R&D) initiatives:**

- Funding research into innovative tracking algorithms for even more precise panel positioning.
- Supporting the development of next-generation tracker components with higher efficiency and lower maintenance requirements.
- To promote local economic development and job creation, governments may introduce policies that encourage domestic manufacturing of solar tracker components.
 - Offering tax breaks or subsidies to structural component manufacturers within the country.
 - Establishing quality standards and certification programs for domestically produced tracker components.

B. Utilities: Driving demand for renewable energy

- **Investment in solar farms:** Utilities invest in large-scale solar farms utilizing solar trackers. This increases renewable energy capacity within their grid mix and diversifies their generation sources. Collaboration with developers involves:
 - **Joint project exploration:** Utilities, government, and developers work together to identify suitable locations for solar farm projects and assess the feasibility of using solar trackers based on factors like sun angles and land availability.
 - **Power Purchase Agreements (PPAs):** Utilities negotiate PPAs with developers to secure the electricity generated by the solar farm at a pre-determined price. The guaranteed high energy output from solar trackers can be a negotiating advantage for utilities.
 - **Integration into the grid:** Utilities ensure the seamless integration of solar tracker projects into the electricity grid. This collaboration with developers and EPC companies involves:

- **Grid capacity assessments:** Utilities analyze the existing grid infrastructure to ensure it can handle the additional electricity generated by the solar farm. Upgrades might be necessary in some cases.
- **Connection agreements:** Utilities and developers negotiate connection agreements that outline the technical specifications for connecting the solar farm to the grid.

C. Developers: The project spearheads

- **Role:** Developers in solar tracker projects act as the central coordinators, driving the project from initial concept to completion. They are responsible for bridging the gap between various stakeholders and ensuring the project's viability and success.
 - **Feasibility studies:** Developers conduct comprehensive feasibility studies to assess the viability of utilizing solar trackers in a specific project. This involves:
 - **Site analysis:** Developers analyze the proposed location's sun angles, wind patterns, and soil conditions to determine the suitability of solar trackers and select the most appropriate tracking technology (single-axis vs. dual-axis).
 - **Financial modeling:** Developers create financial models that factor in the potential energy output from solar trackers, upfront costs of the technology, and potential government incentives.
 - **Project development:** Once feasibility is established, developers secure land, permits, and financing for the project. This requires interaction with:
 - **Landowners:** Developers negotiate land leases or purchase agreements with landowners for the solar farm site.
 - **Permitting authorities:** The developers work with relevant government agencies to obtain permits for construction and grid interconnection.
 - **Financial institutions:** Developers secure project financing from banks or other financial institutions. The projected high energy output of solar trackers can improve project bankability.
 - **Collaboration with EPC companies:** Developers partner with EPC companies to design and construct the solar farm. This involves:
 - **Request for Proposals (RFPs):** Developers issue RFPs outlining project specifications and inviting bids from qualified EPC companies.
 - **Contract negotiation:** Developers negotiate contracts with the chosen EPC company, clearly outlining the scope of work, responsibilities, and performance guarantees related to the solar tracker system integration.

D. Tracker companies: The technology providers

- **Role:** Tracker companies are the innovators behind the solar tracker technology. They design and supply critical tracking components, interacting with several key players.
 - **Understanding project requirements:** Tracker companies work closely with developers and EPC companies to understand the specific needs of the project. This involves:
 - **Site visits and data analysis:** Tracker companies visit the proposed project site to assess factors like wind loads, soil composition, and available space. They also analyze weather data

and sun angles to recommend the most suitable tracking technology (single-axis vs. dual-axis) and specific tracker model.

- **Technical specifications:** Tracker companies provide detailed technical specifications for their proposed tracking systems, including load capacity, tracking range, and wind speed tolerance which is crucial information for the EPC company's engineering design team.
- **Selection process:** While developers play a lead role in selecting the tracker company, EPC companies can also influence the decision based on factors like:
 - **Track record:** The EPC company's experience with specific tracker brands and their familiarity with installation and maintenance procedures.
 - **Compatibility:** Ensuring the chosen tracker system seamlessly integrates with the EPC company's preferred design and construction methods.
 - **After-sales support:** The tracker company's reputation for providing reliable after-sales support and readily available spare parts for maintenance.

E. EPC companies: The Builders

- **Role:** EPC companies (Engineering, Procurement, and Construction) are the builders who translate plans into reality. Their interactions are crucial for successful project execution:
 - **Solar farm design:** EPC companies work with developers to design the solar farm layout, incorporating the chosen solar tracker technology. This involves:
 - **3D modeling:** Creating detailed 3D models of the solar farm layout, ensuring optimal placement of panels, trackers, and electrical components.
 - **Structural engineering:** EPC companies perform structural engineering calculations to ensure the tracker systems can withstand wind loads, snow accumulation, and other environmental factors.
 - **Procurement:** EPC companies procure all necessary materials for the project, including:
 - **Solar panels:** Selecting high-efficiency solar panels compatible with the chosen tracking system.
 - **Trackers:** Procuring the chosen solar tracker system from the selected tracker company based on the agreed-upon specifications and quantities.
 - **Structural components:** Sourcing high-quality structural components like tracker frames, support structures, and drive mechanisms, often working directly with structural component manufacturers.
- **Collaboration with structural component manufacturers:**
 - EPC companies collaborate with structural component manufacturers to ensure the components meet project specifications and comply with relevant safety standards. This involves:
 - **Quality Assurance:** EPC companies may conduct quality checks on the structural components at the manufacturing facility or upon delivery to the project site.
 - **Compliance with standards:** Ensuring the components comply with industry standards and local building codes for structural integrity and wind resistance.

F. Structural component manufacturing companies: The backbone providers

- **Role:** Structural component manufacturers provide the foundation for the solar tracker systems. Their interactions complete the ecosystem.
 - **Manufacturing expertise:** These companies manufacture key components like tracker frames, support structures, and drive mechanisms based on specifications provided by tracker companies. This involves:
 - **Material selection:** Choosing robust and corrosion-resistant materials like galvanized steel or aluminum for the structural components.
 - **Manufacturing processes:** Employing high-quality welding techniques and fabrication processes to ensure the structural integrity of the components.
 - **Meeting project requirements:** Structural component manufacturers work closely with EPC companies and tracker technology companies to ensure their components:
 - **Match the design specifications:** The components must perfectly integrate with the chosen tracker model and the overall solar farm design.
 - **Comply with project deadlines:** On-time delivery of components is crucial for the EPC company to maintain the project schedule.

6.3 Solar Tracker penetration and market size

A. Global

The global solar photovoltaic (PV) market has experienced remarkable growth, with annual capacity additions rising at a CAGR of 29% between CY2018 and CY2023. In CY2023, global capacity additions reached 375 GW and are projected to grow to 540 GW by CY2028E, at a CAGR of 7.6%. Solar trackers, a critical component in enhancing solar PV efficiency by aligning panels with the sun's movement, are poised to capture a significant share of this growth. By CY2028E, approximately 70% of annual capacity additions are expected to include solar trackers.

Globally, more than 750 GW of solar trackers are anticipated to be installed between 2024 and 2030, highlighting their growing importance in utility-scale solar projects. By 2027, over 100 GW of trackers are projected to be installed annually, with North America and Europe, Middle East, and Africa (EMEA) regions leading this growth.

Annual capacity additions surged from under 10 GW in CY2018 to 25 GW in CY2023, nearly tripling over five years. The U.S. is now a dominant player in the global solar tracker market, driven by supportive government policies, renewable energy incentives, and the expanding scale of utility solar installations. This robust growth trajectory positions North America as a key driver of global solar tracker adoption in the coming years. As we look to the future, USA is poised to remain a key driver of global solar tracker adoption. In CY2024E, the USA is anticipated to add a significant 32.3 GW of solar capacity, further solidifying its leadership in the sector. Looking ahead to CY2028E, this momentum is expected to continue, with the USA projected to add 52.2 GW, reflecting an ongoing strong trajectory in both installation capacity and technological innovation.

Exhibit 6.4: Annual solar PV capacity additions, in GW, (excluding India) CY2018 – CY2028E

Country / Region	CY2018	CY2019	CY2020	CY2021	CY2022	CY2023	CY2024E	CY2025E	CY2026E	CY2027E	CY2028E
Global	101.7	117.0	151.2	170.5	228.4	374.9	402.3	421.7	459.2	493.9	539.6
USA	8.2	9.6	14.9	19.0	19.0	24.8	32.3	37.1	42.1	47.2	52.2
KSA	0.0	0.03	0.3	0.03	0.001	2.1	10.0	21.0	34.0	47.0	58.7
Europe	7.8	16.2	18.3	26.3	40.9	51.1	62.0	68.0	77.0	88.0	106.0

Source: Stakeholder interaction, Frost & Sullivan Analysis

Saudi Arabia is emerging as a pivotal market for solar tracker penetration in the Middle East, underpinned by its abundant solar energy resources and ambitious renewable energy goals outlined in Saudi Vision 2030. A notable example is the PIF4-Haden project, owned by ACWA Power, which is set to feature 2.3 GW of advanced SkyLine II single-axis trackers supplied by Arctech. This project, slated for commercial operation by 2027, represents a significant step in advancing solar tracker adoption in the region and underscores Saudi Arabia's leadership in utility-scale solar projects.

Exhibit 6.5 (a): Annual solar tracker capacity additions, in GW, (excluding India) CY2018 – CY2028E

Country / Region	CY2018	CY2019	CY2020	CY2021	CY2022	CY2023	CY2024E	CY2025E	CY2026E	CY2027E	CY2028E
Global	23.4	31.6	48.4	63.1	95.9	176.2	209.2	240.4	280.1	321.0	377.7
USA	4.9	6.5	11.2	16.0	17.1	23.6	31.3	36.4	41.3	46.7	52.2
KSA	0.0	0.0	0.3	0.0	0.0	2.1	10.0	21.0	34.0	47.0	58.7
Europe	4.7	11.0	13.7	22.1	36.8	48.6	60.1	66.6	75.5	87.1	106.0

Source: Stakeholder interaction, Frost & Sullivan Analysis

Europe is undergoing a solar energy transformation, with ambitious plans to scale its installed PV capacity from 224 GW in 2022 to 750 GWDC by 2030, as part of the EU Solar Energy Strategy. This expansion requires annual installations to grow from ~ 22 GW in CY2021 to 70 GW by the second half of this decade. Germany, a key market in the region, plans to install 215 GW of solar PV capacity by 2030, adding 160 GW of new capacity. Solar trackers are expected to play a critical role in this expansion, enabling higher efficiency and grid integration of solar PV systems across the continent.

Globally there is a significant increase from the 23 GW annual capacity addition in CY2018 to approximately 176.2 GW capacity of annual addition in CY2023, reflecting a rapidly growing preference for solar trackers as a technology to optimize energy capture. Growth has been driven by a fall in tracker prices, efficiency gains over time and intense competition in the downstream market forcing developers to optimize the operational design of projects. The U.S. solar tracker market has seen remarkable growth, with capacity expanding more than tenfold from CY2018 to CY2023 and expected to reach 52 GW of annual addition by CY2028E.

Exhibit 6.5 (b): Annual penetration of tracker system across regions of interest (excluding India), in %, CY2018 – CY2028E

Country / Region	CY2018	CY2019	CY2020	CY2021	CY2022	CY2023	CY2024E	CY2025E	CY2026E	CY2027E	CY2028E
Global	23.0%	27.0%	32.0%	37.0%	42.0%	47.0%	52.0%	57.0%	61.0%	65.0%	70.0%
USA	60.0%	68.0%	75.0%	84.0%	90.0%	95.0%	97.0%	98.0%	98.0%	99.0%	100.0%
KSA	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Europe	60.0%	68.0%	75.0%	84.0%	90.0%	95.0%	97.0%	98.0%	98.0%	99.0%	100.0%

Source: Stakeholder interaction, Frost & Sullivan Analysis

This surge highlights the growing recognition of solar trackers' benefits, which enhance energy capture by aligning panels with the sun's path. Key factors driving this expansion include favorable policies such as tax credits and renewable portfolio standards, which incentivize investment in solar technology.

Additionally, in regions with land constraints, solar trackers optimize energy output on a smaller footprint, making them increasingly attractive. Technological innovations further boost their appeal by improving design and performance.

In contrast, the Kingdom of Saudi Arabia (KSA) showcases a unique market dynamic with 100% penetration of solar trackers, a result of government mandates requiring their use for all utility-scale projects. This strong policy support reflects a commitment to maximizing solar efficiency. Globally, while established markets like KSA and North America experience robust growth due to mature infrastructure and incentives, China has seen slower adoption of solar trackers in recent years.

Exhibit 6.5 (c): Solar tracker system market, Global, in USD Mn, CY2018 – CY2028E

Country / Region	CY2018	CY2019	CY2020	CY2021	CY2022	CY2023	CY2024E	CY2025E	CY2026E	CY2027E	CY2028E
Global	25,217	31,321	47,149	55,984	79,877	141,244	159,926	182,339	198,375	224,577	255,309
USA	7,767	9,573	16,058	21,061	20,963	27,939	36,038	40,835	45,167	49,181	52,605
KSA	0	29	338	31	1	1,919	8,344	17,751	26,614	37,089	42,187
Europe	5,112	11,124	13,067	20,688	33,466	42,440	51,871	56,711	62,481	70,132	84,111

Source: Stakeholder interaction, Frost & Sullivan Analysis

B. India

India is the third largest market in terms of annual solar PV capacity additions when compared to Europe, USA, and Kingdom of Saudi Arabia, and its solar tracker market is experiencing a remarkable growth trajectory.

India is witnessing a surge in solar tracker adoption due to their ability to boost efficiency by aligning panels with the sun throughout the day, offering a 16% energy advantage over fixed-tilt systems. Recent projects highlight this trend: Tata Solar Power commissioned India's largest single-axis tracker system at the 300 MW Dholera Solar Power Plant in Gujarat in April 2022. GameChange Solar is supplying Genius Trackers to Sterling and Wilson for the 750 MWp Khavda Solar Park, also in Gujarat. Meanwhile, Nexttracker has deployed over 5 GW of trackers in India, mostly in Gujarat, and expanded its annual manufacturing capacity in the country to 10 GW. These advancements reflect the growing cost-effectiveness and efficiency of tracker systems in India's solar landscape.

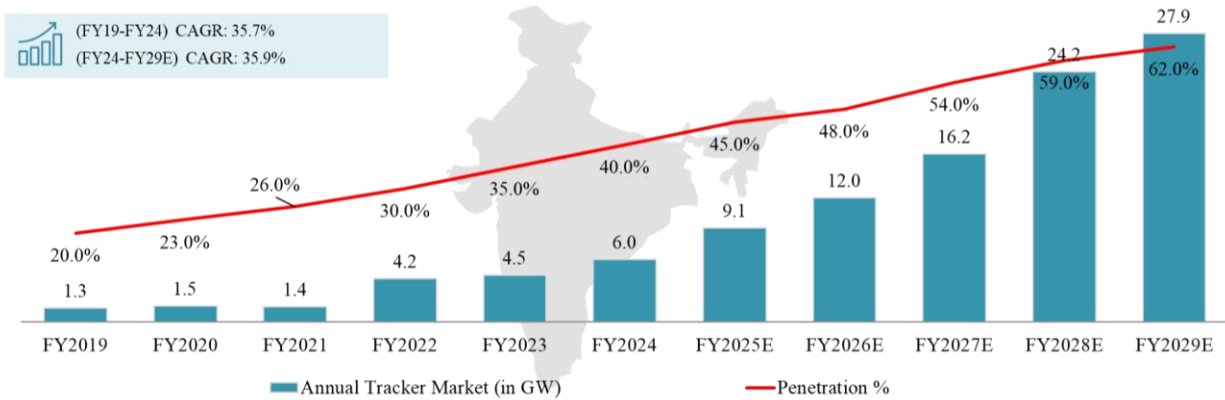
With the increasing emphasis on solar capacity expansion in India and expected moderation in raw material prices, the installed capacity of solar projects in the country rose from 12.8 GW in FY2023 to 15 GW in FY2024. The Government of India has implemented several regulatory measures to support the growth of the solar sector, including domestic content requirements, performance-linked incentive schemes, and the imposition of basic customs duties. These steps are designed to further promote the addition of solar capacity. Since gaining acceptance in 2016, tracker installations have surged due to declining prices, improved commercial viability, and growing investor awareness. The need to maximize power output in a competitive market has further fueled demand for this technology. While India's starting point for tracker adoption was relatively low, the future looks bright. This rapid growth can be attributed to factors including:

- **Policy tailwinds:** Supportive government policies, like the Jawaharlal Nehru National Solar Mission (JNNSM), are encouraging investment in solar energy, including solar trackers.
- **Cost competitiveness:** The global decline in solar tracker prices has made them a more attractive option for developers in India.

- **Expanding economy and rising energy demand:** Mirroring trends in other emerging economies, India's growing economy and increasing energy needs create a strong market for solar energy solutions, with trackers playing a key role.

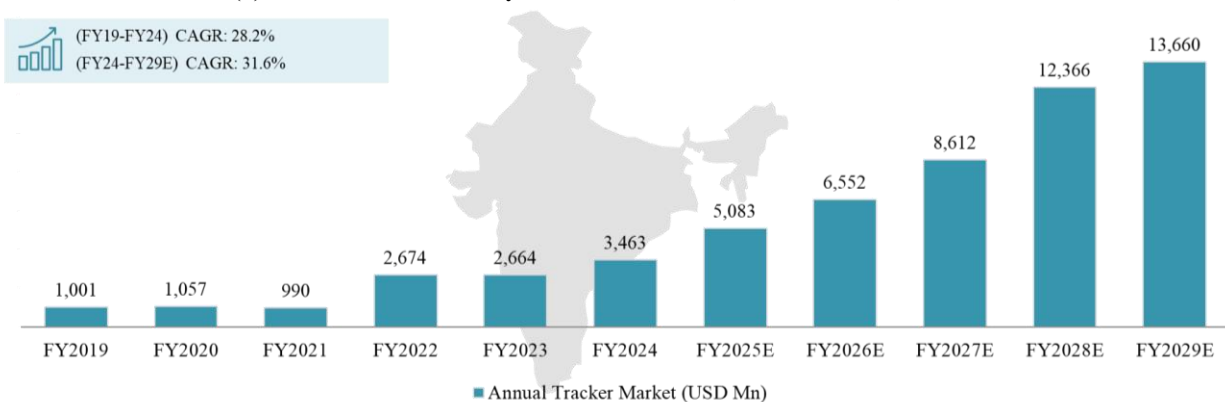
By FY2029E, India's solar tracker market penetration is expected to reach nearly 62%, with an annual installed capacity of 27.9 GW. This signifies a remarkable shift towards this technology, solidifying its position as a crucial player in India's clean energy future.

Exhibit 6.6 (a): Annual solar tracker system penetration in India, in GW, penetration in %, FY2019 – FY2029E



India, with its cost-competitive advantage and growing domestic manufacturing base, is well-positioned to become a major player in the global solar tracker market. The Indian solar tracker market stands at USD 3,463 million as of FY2024, more than three times its value of USD 1,001 million in FY2019, with a Compound Annual Growth Rate (CAGR) of 28.2% for the period FY2019-FY2024E.

Exhibit 6.6 (b): Annual solar tracker system market in India, in USD million, FY2019 – FY2029E



This trend suggests the continued diversification and expansion of the market in the coming years, as is seen in the projected market. The country is expected to have a market of USD 13,660 million by FY2029E, growing at an estimated CAGR of 31.6% for FY2024-FY2029E.

Note: It is important to note that this analysis of global solar tracker market penetration trends is drawing insights from annual data for the period CY2018 – CY2028. For India, numbers are presented in FY terms. It is essential to acknowledge that these figures represent new installations and do not encompass the potential for retrofitting existing fixed-tilt systems.

6.4 Leading Solar Tracker technology suppliers

A. Nextracker LLC.



Company Overview	• Nextracker LLC, headquartered in Fremont, California, and established in 2013, is a leading global solar tracker company. Nextracker the world's largest solar tracker provider consistently maintained its leadership in the global solar tracker market for the past seven years, with a market share ranging from 26% to 33%. This sustained performance underscores Nextracker LLCs position as the largest and most reliable provider of solar tracking solutions, reflecting its pivotal role in advancing solar energy deployment worldwide.	
Operating Regions	• U.S.A • KSA • UAE • India • Australia	• Chile • Brazil • Mexico • China • Europe
Market Share	• 28-30% (by global shipments)	
Offerings	• Solar Trackers (NX Horizon, NX Horizon Low Carbon-35% less carbon footprint, NX Horizon XTR-All Terrain, NX Horizon Hail Pro- Hail risk mitigation) • Software (TrueCapture- Yield optimisation and software control, NX Navigator- Tracker health monitor and weather risk mitigation) • Skill Development (PowerworX- instructions for solar workers) • Service (NX Global Services)	
Production capacity	• 50 GW/year	
Financial indicators CY2023	• Revenue	• USD 2,281 Million
Key Clients	• NTPC Renewable Energy Limited • Serentica Renewables • ACWA Power	• IbVogt • Vale S.A.

B. Array Technologies



Company Overview	• Array Technologies was established in 1996 and its headquarters is in Albuquerque, New Mexico, U.S.A. With its key strength in utility-scale solar trackers, they have expanded its manufacturing capacities and engineering resources to cover three continents. They recently acquired one of Europe's leading tracker manufacturers, STI Norland in line with this.	
Operating Regions	• U.S.A • UK • Italy • Brazil • South Africa • Spain • Australia • Egypt • Turkey	• Mexico • Japan • Argentina • Australia • Chile • Romania • Peru • Portugal • South Africa

	- Canada - Botswana
Market Share	21-24% (by global shipments)
Offerings	- Solar Trackers (DuraTrack, STI H250, OmniTrack, SmarTrack) - Services and Training
Production capacity	50 GW/year
Financial indicators CY2023	- Revenue - USD 1,576.6 million
Key Clients	- EDF Renewables - sPower - Pacific Partners - Lightsource BP - Primergy Solar

C. PV Hardware



Company Overview	With its headquarters in Cheste, Valencia, PV Hardware started in 2011 and has been providing its products and services majorly across Europe, U.S.A, Africa and Australia. Apart from in house manufacturing and solar trackers, they also provide services such as structural calculations and on-ground installations.	
Operating Regions	- Europe - U.S.A - Australia - Egypt - Kuwait	- KSA - South Africa - Turkey - Jordan
Market Share	8-11% (by global shipments)	
Offerings	- Solar Trackers (AxoneDuo Infinity, Monoline 2P) - Fixed-tilt racking (SolarFix) - PV Cleaners - Smart controllers (DBox5)	- Software (ProInsights SCADA) - Logistics - Mounting services and training to third-party - Structural calculations (Wind-tunnel tests, Pull Out Test- POT)
Production capacity	30 GW/year	
Financial indicators CY2023	Revenue	NA
Key Clients	- ACWA Power - NEOM - Madras	- DEWA - Vena Energy

D. GameChange Solar



Company Overview	GameChange Solar was established in 2012 with its headquarters in Norwalk, Connecticut, USA. GameChange is the third largest global provider of solar tracker solutions for utility-scale and ground-mounted distributed generation solar projects. The company has delivered over 35 GW of solar tracker and fixed tilt systems.	
Operating Regions	U.S.A	Chile

	• South Africa • Zimbabwe • India • Australia • Spain	• Saudi Arabia • Egypt • Brazil • Mexico • Canada
Market Share	• 5-7% (by global shipments)	
Offerings	• Solar Tracker (Genius Tracker 1P, 2P, 1P-2Row), MV Transformer (GeniusBOS), Fixed Tilt Systems (MaxSpan, MaxDensity), Fixed Tilt solar racking system (Ultrafix), Ballasted Ground Systems (Pour in Place, Precast), Project Management Solutions	
Production capacity	• 55 GW/year	
Financial indicators CY2023	• Revenue	NA
Key Projects & Clients	• AMEA Power • Bison Energy	• ACCIONA Energía • Sabanci Renewables

E. Arctech



Company Overview	• Arctech, established in 2009 in Jiangsu, China, went public on China's STAR market in 2020. The company provides fixed-tilt structures, solar trackers, and BIPV solutions. It has set up global R&D centres and collaborates with academic institutes. As of 2023, Arctech has supplied over 68 GW of tracking and racking across 40 countries.	
Operating Regions	• Japan • India • U.S.A • UAE • KSA	• Burkina Faso • Mexico • Chile • Brazil • Argentina
Market Share	• 6-8% (by global shipments)	
Offerings	• Solar Trackers (SkyLine, SkyLine II, SkyWings, SkySmart II, Snow Protection System), Fixed Structures (Single Pole, Dual Pole, Continuously Adjustable, Actuator Adjustable R Tube, Adjustable), Building Integrated PV products/practices (BIPV Smart RooftopII), Solar Carport (SkyHarbor Single Row and Double Row)	
Production capacity	• 30 GW/year	
Financial indicators CY2023	• Revenue	• USD 882.3 Million
Key Clients	• Badeel • ACWA Power	• China Machinery Engineering Corporation (CMEC)

7. OVERVIEW OF SOLAR TRACKING AND MOUNTING PRODUCTS

7.1 Introduction to Solar Tracker Manufacturing Technologies

Solar trackers improve energy capture by adjusting their position throughout the day, relying on stamped and rolled metal products for their structure. Stamped metal forms the bearing housing assembly for

rotation, while rolled steel provides the module mounting rails. These components ensure robust support, precise dimensions, and structural integrity. Stamped parts like rails and brackets add reinforcement and attachment points.

These metal products offer versatility and customization. Stamping allows for various shapes and sizes to accommodate different applications and panel types, and can be adapted to different metals for weight, strength, and corrosion resistance. This adaptability ensures compatibility with diverse designs and simplifies assembly with precise shapes and pre-drilled holes. Additionally, both stamping and rolling are cost-effective, producing large quantities of components at low unit costs while minimizing waste and reducing long-term operational costs through durability and low maintenance.

7.2 Leveraging the Advantages: Sourcing Solar Tracker Components from Indian Manufacturers

The global solar energy landscape is witnessing a surge, with India emerging as a key player. This growth is fueled by a confluence of factors, including ambitious renewable energy targets, abundant sunshine hours, and a thriving domestic manufacturing ecosystem. For companies involved in solar tracker production, strategically sourcing crucial components from Indian manufacturers presents a compelling opportunity to enhance competitiveness and unlock significant advantages.

1. Cost Competitiveness

- **Favorable labour rates:** India boasts a skilled workforce with competitive labour rates compared to established manufacturing hubs. This translates into significant cost savings for solar tracker manufacturers when sourcing MMA from Indian suppliers. The cost benefits can be particularly pronounced for labour-intensive processes like stamping and welding involved in MMA production.
- **Economical material acquisition:** India possesses a robust metal industry, offering domestic availability of steel and aluminium at competitive prices. This proximity to raw materials translates into lower material acquisition costs for Indian manufacturers of these solar tracker components, further contributing to overall cost advantages for solar tracker companies.
- **Duty optimization:** Strategic sourcing from India can help leverage existing free trade agreements or preferential duty structures. By partnering with Indian suppliers, solar tracker manufacturers can potentially minimize import duties and optimize their overall landed costs.

2. Enhanced Supply Chain resilience: Mitigating risks

- **Geographical Proximity:** Sourcing components from India shortens the supply chain for solar tracker manufacturers, particularly those located in Asia. This geographical proximity facilitates smoother logistics, faster response times for order fulfilment, and reduced reliance on long-distance transportation, which can be susceptible to disruptions.
- **Reduced vulnerability to global events:** Global events like geopolitical tensions or trade wars can significantly impact supply chains. Sourcing from India lessens dependence on geographically distant suppliers, mitigating potential disruptions and enhancing overall supply chain resilience for solar tracker manufacturers.
- **Improved inventory management:** The shorter lead times associated with sourcing from Indian manufacturers enable solar tracker companies to implement leaner inventory management strategies. This reduces the risk of stockouts and the associated financial burdens, leading to improved operational efficiency.

3. Fostering innovation: A collaborative approach

- **Skilled workforce and engineering expertise:** India boasts a large pool of skilled engineers and technicians with a strong foundation in metalworking and manufacturing. Partnering with Indian suppliers unlocks the potential for collaborative innovation in MMA design, leading to potentially more cost-effective or functionally optimized components.
- **Adaptability and flexibility:** Indian manufacturers are known for their adaptability and ability to cater to specific requirements. This flexibility allows solar tracker companies to work with Indian suppliers to develop customized components that meet their unique needs and project specifications.
- **Focus on sustainable practices:** The Indian government and a growing segment of Indian manufacturers are prioritizing sustainable manufacturing practices. Solar tracker companies sourcing from India can potentially benefit from this focus, aligning their own sustainability goals with those of their suppliers.

4. Leveraging government initiatives: A supportive ecosystem

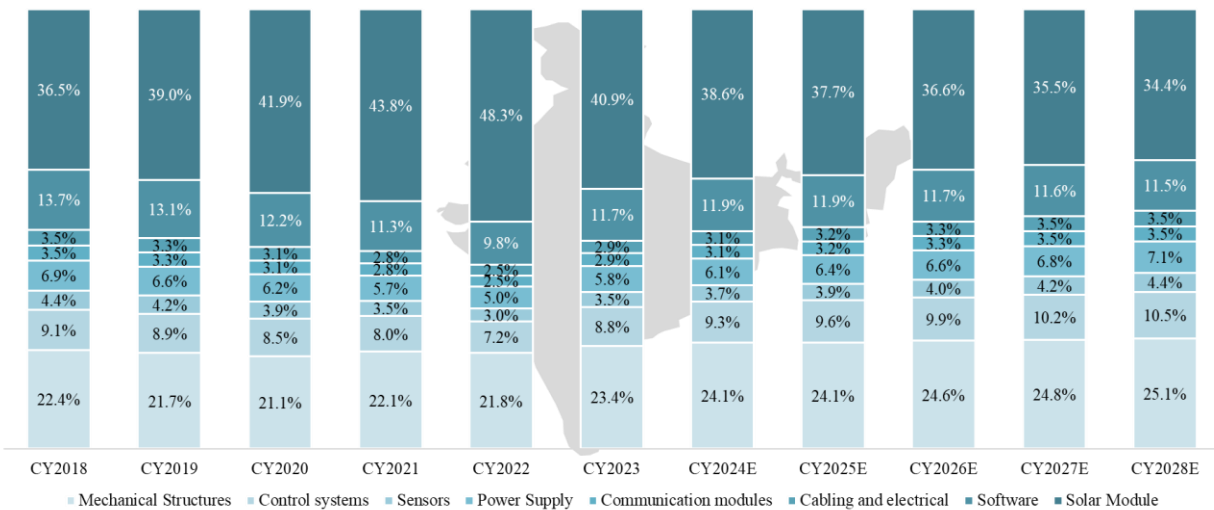
- **Production-Linked Incentive (PLI) Schemes:** The Indian government has implemented Production-Linked Incentive (PLI) schemes for various sectors, including solar equipment manufacturing. These schemes offer financial incentives to companies establishing or expanding their manufacturing facilities in India. Solar tracker manufacturers sourcing MMA from PLI-compliant Indian suppliers can potentially benefit indirectly from these initiatives.
- **Focus on "Make in India":** The Indian government's "Make in India" initiative aims to promote domestic manufacturing and self-reliance. By sourcing from Indian suppliers, solar tracker companies can align themselves with this national mission, potentially opening doors to future partnerships or collaborations.
- **Ease of doing business:** The Indian government has undertaken significant reforms to simplify the process of doing business in the country. These reforms can benefit solar tracker manufacturers by streamlining the sourcing process and fostering a more business-friendly environment.

7.3 Costing of solar tracking and mounting products

A. Cost breakup of solar plant with tracker

A cost breakdown per watt for a solar tracker reveals a complex interplay between several key components. In CY2023, dominating the cost structure are solar modules (40.9%) responsible for converting sunlight into electricity and mechanical structures (23.4%) that enable the tracker's movement for optimal panel positioning throughout the day. Beyond hardware, software (11.7%) plays a critical role. This software functions as the system's control centre, utilizing advanced algorithms to maximize energy production by optimizing panel positioning. Control systems (8.8%) translate the software's instructions into the physical movements of the tracker, while a reliable power supply (5.8%) ensures continuous operation.

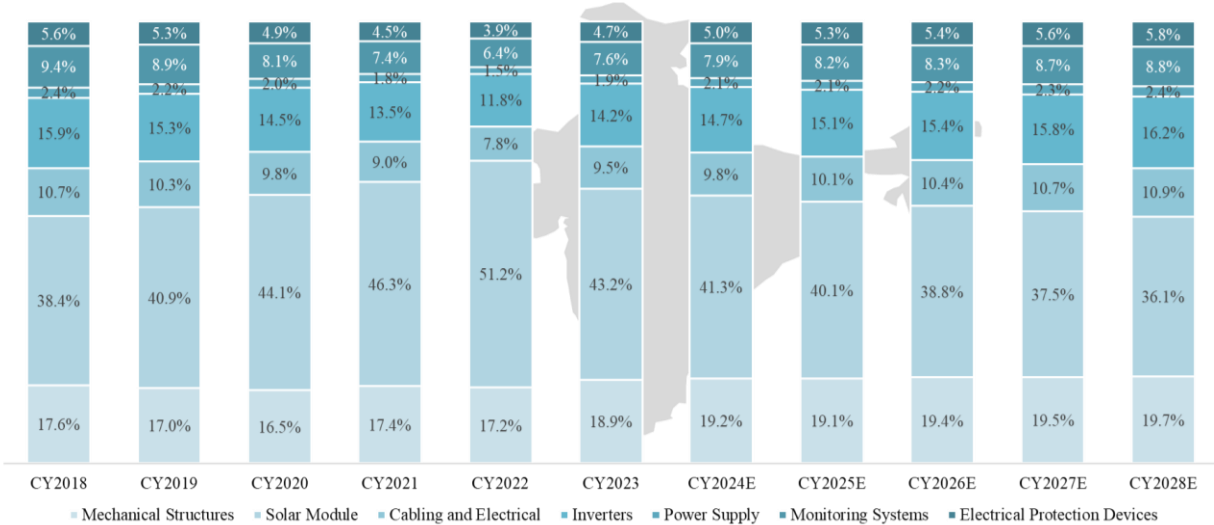
Sensors (3.5%), though a smaller cost component, play a crucial role by gathering data on wind speed and sun position, vital for both safety and efficiency. The remaining cost (5.8%) is attributed to cabling and electrical components (2.9%) that function as the system's nervous system, carrying power and signals, and communication modules (2.9%) that enable remote monitoring and troubleshooting.

Exhibit 7.1: Cost breakup of components used in solar plants with the tracker, CY2018 – CY2028E

Source: Stakeholder interaction, Frost & Sullivan Analysis

B. Cost breakup of solar plant with fixed tilt

Unlike solar trackers with their complex moving parts, fixed-tilt systems present a simpler cost structure. Solar modules remain the most significant expense, claiming around (43.2%) of the cost.

Exhibit 7.2: Cost breakup of components used in fixed tilt solar plants, CY2018 – CY2028E

Source: Stakeholder interaction, Frost & Sullivan Analysis

After all, they're the workhorses, directly converting sunlight into electricity. However, fixed-tilt systems rely heavily on robust mechanical structures. Amounting to roughly (18.9%) of the total cost, they securely hold the panels at the optimal angle year-round. This ensures maximum sun exposure and energy generation. Material quality and engineering are crucial for these structures to withstand harsh weather conditions. Although cabling and electrical components (9.5%) are a smaller cost component, their role in efficiently transmitting power from panels to the inverter and maintaining proper signal flow for system monitoring is vital. Inverters (14.2%), electrical protection devices (4.7%), power supply and monitoring systems together amount to roughly (9.5%), round out the cost breakdown.

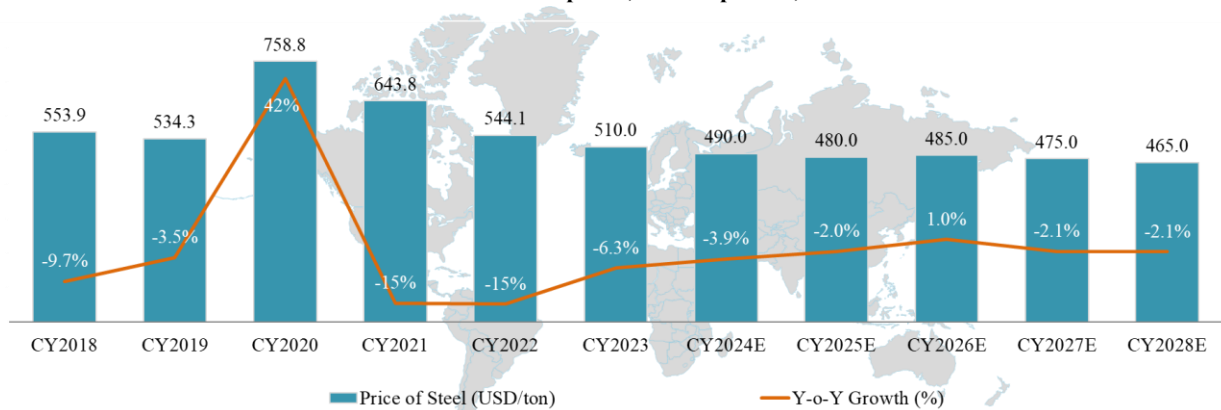
7.4 Global Future Pricing Trend of Steel

The global steel market has been stabilising after significant price fluctuations in recent years. Prices are expected to fall to USD 465.0 per ton by CY2029E, down from USD 554.3 per ton in CY2019. China, the

leading steel producer with a 54% share of global production, saw prices peak at USD 758.8 per ton in CY2021 due to COVID-19-related supply chain disruptions and policy changes. The market has since declined, although prices surged again to USD 643.8 per ton in CY2022 due to strong demand and the Russia-Ukraine conflict. Lower domestic demand in China, combined with increased exports and a global economic slowdown, has driven prices down, with this trend expected to continue until CY2029E.

Steel typically accounts for **60-70% of the total production cost** of Solar Module Mounting Structures (MMS) and solar trackers, making it the most significant cost component. This percentage can vary depending on several factors, including the design complexity of the system (fixed vs. tracker-based structures), the type of steel used (such as galvanized or structural steel), fluctuations in raw material prices, and the geographical sourcing of steel, which influences transportation and logistics costs. As a result, managing steel procurement effectively is crucial for optimizing overall production costs in these systems.

Exhibit 7.3: Global hot rolled steel prices, in USD per ton, CY2019 - CY2029E



Source: Trading Economics, Frost & Sullivan Analysis

Market Correction: The global metal market, including zinc, aluminium, and magnesium, experiences cycles of highs and lows. A fall in prices of these raw materials post-CY2023 can potentially reduce the cost of the coatings themselves.

Technological Advancements: The steel industry is constantly innovating. New, more efficient methods for applying G90 and ZAM coatings in the coming years will potentially lead to lower production costs.

Increased Competition: The pre-galvanized steel market can expect to see a rise in competition from new players or alternative materials. This increased competition will drive down prices for both the base steel and the coatings.

7.5 Introduction to the global component market used in solar plant

The global solar power industry has experienced phenomenal growth, driven by a focus on clean energy. This market encompasses companies that provide the essential support structure for solar farms, ensuring optimal panel positioning for maximum sunlight capture throughout the day.

This market caters to diverse needs with a range of components. Fixed-tilt structures, the most common option, utilise prefabricated piles, beams, and rails for a cost-effective solution. Adjustable-tilt structures offer greater flexibility in regions with seasonal sunlight variations. Single-axis trackers represent a more advanced option, allowing panels to follow the sun's east-west movement. Double-axis trackers are the most sophisticated solution, constantly adjusting on both horizontal and vertical axes to maximize solar capture efficiency. Each component, from piles to torque tubes (a key element in single-axis trackers), plays a vital role in the structural integrity and performance of a solar farm.

7.6 Leading suppliers of solar tracking and mounting products globally

Exhibit 7.4: Global Solar tracking and mounting products manufacturers

COMPANY NAME	LOCATION	FOCUS	CAPACITY	PRODUCTS
Clenergy Technologies	Melbourne, Australia (Founded) Xiamen, China (Manufacturing HQ)	Manufacturing, EPC, Developer	8 GW/annum	Products: • Ground Mount system, Tracker system, Rooftop, Carports, Balcony Solar Systems • Inverters, Energy Storage Systems • Accreditation Services • After-Sales support
Schletter Group	Krichdorf, Germany (Founded) China (Manufacturing)	Manufacturing, Developer	>55 GWp installations	Products: • Fixed-tilt system, Tracker system, Rooftop, Carports, Agri-PV vertical systems, accessories • Assessment and Training, Supervision and Reporting, Advice and Support
Hangzhou Huading New Energy Co. Ltd.	Hangzhou, China	Manufacturing, EPC	6 GW/annum	Products: • Ground and Roof Mounting System, Tracker System, Carport, BIPV, Balcony Solar Bracket
OMCO Solar	Ohio, USA	Manufacturing	10 GW+ /annum	Products: • Tubes, Fixed-Tilt and Tracker Mounting structures, Purlins • Prototyping Services, Technical Training and Support
APA Solar Racking	Ohio, USA	Manufacturing	NA	Products: • Fixed-Tilt and Tracking Mounting Systems • Foundation Systems • Installation support and Training
Caracal Engineering	Johannesburg, South Africa	Manufacturing, Construction, Testing	NA	Products: • Ground-Mount and Rooftop Mounting Systems, Single-axis tracker System, Carports
Sunlock	Melbourne, Australia	Manufacturing, Inspections	NA	Products: • Rooftop and Ground-Mount Systems, Components

7.7 Solar tracking and mounting products of interest

A. Module Mounting Assembly (stamped and fabricated products)

Solar Module Mounting Structures (MMS): Solar Module Mounting Structures are critical components in solar photovoltaic (PV) systems, designed to securely hold solar panels in place, ensuring their optimal

alignment and performance. These assemblies are engineered to provide stability, durability, and adaptability to various installation environments, including rooftops, ground-mounted systems, and tracking systems. Karamtara Engineering Ltd is one of the largest automated Solar MMS manufacturers in India, in terms of installed capacity (100,500 MTPA (~5.6 GW)) in the six months ended September 30, 2024. In Fiscal 2024 and the six months ended September 30, 2024, the Company produced an aggregate of 37,587 MTPA (~2.1 GW) and 28,597 MTPA (~1.6 GW) of Solar MMS respectively

Control Mount Unit (CMU): The Control Mount plays a critical role in the solar tracker's nervous system. It is the secure enclosure that houses the electrical controls, the brain of the tracker operation. This vital component protects the electrical components from the elements and ensures their reliable operation. Control mounts are crafted from sheet metal, and their manufacturing process relies primarily on stamping techniques.

Pile: Piles are typically rolled products made from hot-rolled or cold-rolled steel in shapes like H-beams or tubular sections, offering strength for deep anchoring in soft or uneven terrains.

Post Couplers: These are smaller, intricate components that typically require stamping to achieve the desired shape and precision.

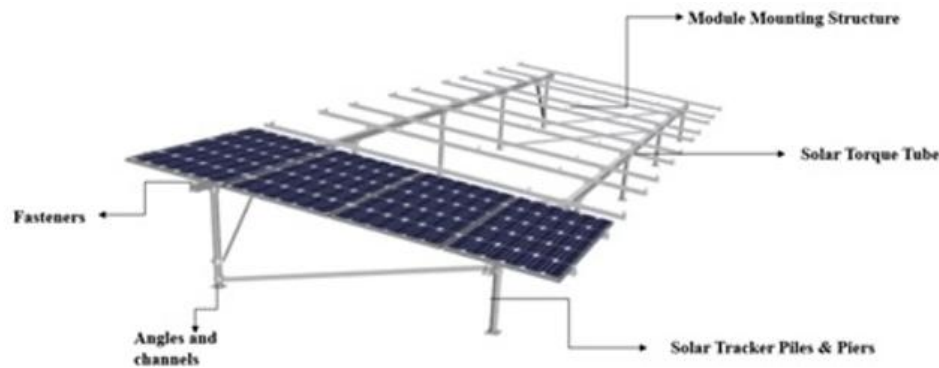
90-Degree Hat Purlins: Hat purlins often involve stamping, especially for creating angles and bends efficiently.

B. Rolled Products

Torque Tube: Torque tubes are a structural element that connect multiple solar panels and provide the necessary rigidity and structural integrity to the solar array, ensuring that the panels stay in optimal orientation. Accordingly, panels are located on the front side of URA/MMR while the back side would be secured with the torque tube. Karamtara Engineering Ltd is one of the largest manufacturers of fully automated solar torque tubes, with an installed capacity of 93,600 MTPA (~2.6 GW) as of September 30, 2024.

Torque Tube Assembly: This refers to the complete torque tube system, including the tube itself, bearings, and connecting components. It forms the core of the tracker's rotational mechanism. Karamtara Engineering Ltd is one of the largest manufacturers of fully automated solar torque tubes in India in terms of installed capacity (93,600 MTPA (~2.6 GW)) as of September 30, 2024. The company manufactures a full range of solar torque tubes, including circular, square, rectangular, hexagonal, and octagonal hollow sections, among others. In Fiscal 2024 and the six months ended September 30, 2024, Karamtara Engineering Ltd manufactured an aggregate of (37,272 MTPA (~1.0 GW)) and (20,905 MTPA (~0.6 GW)) of torque tubes, respectively.

Piers: Piers are often stamped or fabricated products, such as steel plates or precast concrete structures, designed to distribute loads over a broader surface area. The choice between piles and piers depends on site-specific conditions, with piles suited for deeper penetration and piers ideal for stable or rocky surfaces. Both are essential for ensuring the durability and reliability of solar PV systems



Z-Posts: These structural elements are usually roll-formed to achieve the Z-shaped cross-section, ensuring consistent shape and strength.

Karamtara Engineering Ltd has one of the largest integrated solar tracker piles and piers manufacturing facilities in India in terms of installed capacity as of September 30, 2024. The Company has an entire range of wide flange steel tracker piers, steel tracker piles with a fungible capacity of (180,600 MTPA (~5.0 GW)) (which includes 60,600 MTPA of transmission line tower capacity) as of September 30, 2024.

7.8 Estimated size of the solar tracking and fixed tilt components market (Global and India)

The global solar tracking and mounting products and fixed-tilt structural components market has grown significantly from CY2018 to CY2028E. The fixed-tilt market increased from USD 12,592 million in CY2018 to USD 25,651 million in FY2024 and is estimated to decrease to USD 17,682 million by CY2028E.

Exhibit 7.5: Structural components market, fixed-tilt, Global and India, in USD million, CY2018 – CY2028E

Country / Region	CY2018	CY2019	CY2020	CY2021	CY2022	CY2023	CY2024E	CY2025E	CY2026E	CY2027E	CY2028E
Global	12,592	12,314	14,130	14,160	16,170	25,651	24,095	22,223	21,049	19,803	17,682
India	587	502	388	906	710	819	995	1,130	1,188	1,399	1,373
USA	728	613	708	559	320	223	172	127	143	78	0
KSA	0	0	0	0	0	0	0	0	0	0	0
Europe	521	775	626	597	556	367	268	192	215	120	0

Source: Stakeholder interaction, Frost & Sullivan Analysis

After a high growth rate of 15.3% CAGR from CY2018 to CY2023, the market is expected to slow to a (7.2%) CAGR from CY2023 to CY2028E. The USA's market will decline as solar trackers replace fixed-tilt systems, and Saudi Arabia has fully transitioned to trackers. As of 31st March 2024, Karamtara Engineering Ltd held an approximately 4.4% share of the overall domestic market for fixed tilt solar components, equating to a domestic market of approximately USD 36 million within a total fixed tilt components market valued at approximately USD 819 million.

Exhibit 7.6: Structural components market, tracker, Global and India, in USD million, CY2018 – CY2028E

Country / Region	CY2018	CY2019	CY2020	CY2021	CY2022	CY2023	CY2024E	CY2025E	CY2026E	CY2027E	CY2028E
Global	5,659	6,811	9,931	12,364	17,377	33,040	38,617	43,967	48,753	55,720	64,092
India	225	230	208	591	580	810	1,227	1,580	2,116	3,068	3,429
USA	1,743	2,082	3,382	4,651	4,560	6,536	8,702	9,846	11,100	12,202	13,206
KSA	0.0	6.2	71.1	6.8	0.2	449	2,015	4,280	6,541	9,202	10,590
Europe	1,147	2,419	2,752	4,569	7,281	9,927	12,525	13,674	15,355	17,400	21,115

Source: Stakeholder interaction, Frost & Sullivan Analysis

In contrast, the solar tracking and mounting product market surged from USD 5,659 million in CY2018 to USD 33,040 million in CY2023. It is projected to reach USD 64,092 million by CY2028E. Market has grown at a CAGR of 42.3% in between CY2018 and CY2023 and expected to grow at CAGR of 14.2% in between CY2023 to CY2028E.

In the USA, the solar tracker market expanded from USD 1,743 million in CY2018 to USD 6,536 million in CY2023 and is projected to reach USD 13,206 million by CY2028E and doubling from USD 4,560 million in CY2022 to USD 8,702 million in CY2024E due to increased solar PV capacity. The solar tracker market has grown at a CAGR of 30.3% in between CY2018 and CY2023 and expected to grow at CAGR of 15.1% in between CY2023 to CY2028E. In Saudi Arabia, the solar tracker market grew from USD 6.2 million in CY2019 to USD 449 million in CY2023, with an expected rise to USD 10,590 million by CY2028E. Market has grown at a CAGR of 191.2% in between CY2019 and CY2023 and expected to grow at CAGR of 88.2% in between CY2023 to CY2028E.

Exhibit 7.7: Torque Tube market, Global and India, in USD million, CY2018 – CY2028E

Country / Region	CY2018	CY2019	CY2020	CY2021	CY2022	CY2023	CY2024E	CY2025E	CY2026E	CY2027E	CY2028E
Global	428	584	802	1,099	1,520	2,619	3,140	3,549	4,155	4,729	5,494
India	21	23	23	75	90	108	160	206	278	411	469
USA	148	181	293	394	428	676	895	1,009	1,134	1,260	1,382
KSA	0	1	7	1	0	58	262	534	854	1,155	1,413
Europe	141	306	359	545	922	1,394	1,717	1,849	2,074	2,349	2,862

Source: Stakeholder interaction, Frost & Sullivan Analysis

The global torque tube market has grown significantly from CY2018 to CY2028E. The market increased from USD 428 million in CY2018 to an estimated USD 5,494 million by CY2028E. After a high growth rate of 43.6% CAGR from CY2018 to CY2023, the market is expected to slow to a 16.0% CAGR from CY2023 to CY2028E.

The global piles and piers market has grown significantly from CY2018 to CY2028E. The market increased from USD 530 million in CY2018 to an estimated USD 10,426 million by CY2028E. After a high growth rate of 52.8% CAGR from CY2018 to CY2023, the market is expected to slow to a 18.8% CAGR from CY2023 to CY2028E. The growth of piles and piers is fueled by the rapid expansion of utility-scale solar PV projects and the increasing adoption of solar trackers, which require robust foundations for stability and efficiency. As solar installations expand into diverse terrains, piles and piers offer adaptability for varying soil conditions, including soft, rocky, or uneven ground.

Exhibit 7.8: Piles and Piers market, Global and India, in USD million, CY2018 – CY2028E

Country / Region	CY2018	CY2019	CY2020	CY2021	CY2022	CY2023	CY2024E	CY2025E	CY2026E	CY2027E	CY2028E
Global	530	730	1,140	1,516	2,351	4,405	5,334	6,252	7,431	8,687	10,426
India	24	27	27	80	88	120	185	250	344	524	616
USA	125	169	295	430	469	660	895	1,059	1,226	1,416	1,614
KSA	0	1	6	1	0	47	224	481	794	1,119	1,426
Europe	127	305	387	636	1,083	1,457	1,840	2,080	2,402	2,829	3,511

Source: Stakeholder interaction, Frost & Sullivan Analysis

Additionally, technological advancements in foundation systems and the global push toward renewable energy, supported by government incentives and decarbonization goals, are driving the demand for these essential components.

7.9 Introduction to the structural component market in India

In India's rapidly expanding solar power sector, solar tracking and mounting products are essential for optimizing panel positioning and maximizing sunlight capture. Key types include rooftop mounts, which secure panels to buildings, and ground mounts, which support large solar farms with options for fixed-tilt or single-axis tracking systems. Carport and shed mounts offer both shade and energy generation, while floating mounts enable solar panels on water bodies. Material choice is critical, balancing cost, durability, and availability. Galvanized steel is favored for its strength, lightweight nature, and corrosion resistance, with durability 1.5 to 2.5 times greater than standard steel. Aluminum provides a rustproof but more costly alternative, while high-tensile steel is suited for large projects due to its strength-to-weight ratio. Concrete is often used for foundations in ground-mounted systems.

India's "Make in India" initiative supports domestic manufacturing of solar components, enhancing quality control and reducing costs. As solar ambitions grow, advancements are expected in materials, automation, and technologies such as self-cleaning systems. Solar tracking and mounting products account for about 20% of the total cost of a solar project, highlighting their significance in the sector's development.

7.10 Leading manufacturers of these components in India

India's solar power sector is undergoing significant expansion, fueled by ambitious renewable energy goals and its abundant sunlight resources. However, a critical but often unseen element underpins these solar panel arrays: the ecosystem for solar tracking and mounting products used for tracker systems and the structural components used for fixed-tilt systems. These companies provide the essential foundation for solar plants, ensuring optimal panel positioning to maximize sunlight capture throughout the day.

Exhibit 7.9: Indian Solar tracking and mounting/ Structural component manufacturers

COMPANY NAME	FOCUS	CAPACITY/ SUPPLY	ABOUT AND PRODUCT INFORMATION
Karamtara Engineering Ltd.	Tracker and Fixed tilt	Solar Module Mounting Structures – 100,500 MTPA (~5.6 GW), tracker / transmission tower components – 274,200 MTPA (7.6 GW), Structural steel profiles – 168,000 MTPA, 258,000 MTPA Galvanizing capacity	Karamtara Engineering Ltd offers a wide range of products across multiple sectors, including solar energy solutions like fixed-tilt structures and tracker components, lattice towers for power transmission, fasteners for solar, wind, transmission, and automotive industries, as well as OHTL hardware fittings and accessories for power transmission and distribution. These offerings cater to global clients, ensuring reliability and innovation in renewable energy and infrastructure solutions
PMEA Solar Tech Solutions Ltd	Tracker and Fixed tilt	Module Mounting Assembly – 16 GW Rolled Products – 6 GW	Solar tracking and mounting products for: • Tracker Strategy: • Fixed-tilt structural components Special Processes and Machinery: • Sheet Metal Fabrication, Robotic and Seam Welding, Conveyorized Powder Coating, Stamping • Dedicated press line for MMA Rails and extra heavy MMA products • Spot Welding SPMs, Bending SPMs, Drilling SPMs, Bend Saw

Purshotam Profiles Pvt. Ltd.	Tracker and Fixed tilt	15 GW/ annum	The Company is a registered/recognized vendor for many reputed Solar EPC players/ developers that supply Solar Module Mounting Structures, Tracker Structures, cable trays, and walkways. Products: • Solar Module Mounting Structure • Tubes
KP Green Engineering Ltd	Transmission line towers, lattice towers, Solar tracker and Module Mounting Structures	Dabhasa Unit: 53,000 MTPA, Kural Unit: 39,000 MTPA, Por Unit: 14,500 MTPA Matar Unit: 2,94,000 MTPA	KP Green Engineering Ltd. provides comprehensive solutions for renewable and infrastructural requirements, specializing in engineering and steel structure manufacturing. With state-of-the-art manufacturing facilities, KP Green Engineering offers a wide range of products including transmission towers, wind lattice towers, solar MMS structures, and highway crash barriers.
Premier Energies Ltd	Solar cells and Modules	4.13 GW Solar Module 2.00 GW Solar Cell	Premier Energies Ltd. manufactures solar PV modules, solar cells, and solar panels for utility-scale projects, rooftop installations, and off-grid applications. The company focuses on solar energy solutions.
Waaree Energies Ltd	Solar Modules, Solar Inverter	12.5 GW Solar Module	Waaree Energies Ltd was founded in 1990, with headquarters in Mumbai, India. Waaree has India's largest aggregate installed capacity of 12 GW as of June 30, 2024 at its plants in Chikhli, Surat, Tumb, and Nandigram in Gujarat

Karamtara Engineering Ltd is the largest manufacturer in India in terms of installed capacity to manufacture major products in the solar energy (~13.2 GW) and transmission sectors, including Solar Module Mounting Structures – 60,000 MTPA (~3.3 GW) & 100,500 MTPA (~5.6 GW), tracker components – 240,600 MTPA (~ 6.7 GW) & 274,200 MTPA (~7.6 GW), and Structural steel profiles – 168,000 MTPA & 168,000 MTPA in FY2024 and in the six months ended September 30, 2024 respectively. The tracker component capacity is also fungible to transmission line towers. As of September 30, 2024, Karamtara Engineering's manufacturing facilities boasted an aggregate installed capacity of 567,000 MTPA (excluding galvanizing facility). This positions Karamtara Engineering as the largest and a leading manufacturer in India for solar mounting structures and tracker components combined, in terms of installed capacity in FY2024 and during the six months ended September 30, 2024. In addition, the Company is one of the few product manufacturers to operate in-house galvanizing facilities, which is also the largest installed capacity in the solar energy sector in India with a capacity of 258,000 MTPA as of September 30, 2024. This makes Karamtara Engineering Ltd the largest integrated manufacturer in terms of installed capacity in India for solar mounting structures and tracker components in FY2024 and the six months ended September 30, 2024.

Karamtara Engineering also has a wide geographical footprint with a global delivery model, with exports to over 50 countries as of September 30, 2024, across North America, Europe, Asia, Africa, Australia, and Latin America. Karamtara Engineering Ltd. has a strong base of international customers including Independent Power Producers (“IPPs”), Original Equipment Manufacturers (“OEMs”) and Engineering Procurement and Construction (“EPC”) companies. Further, the Company also serves 6 of the top 15 EPC companies in the United States in terms of installed capacity totalling to approximately 76 GW. The

Company is also approved supplier and critical partner to many of the leading solar energy companies in the world, as of September 30, 2024.

7.11 Estimated size of the solar tracking and mounting products market in India

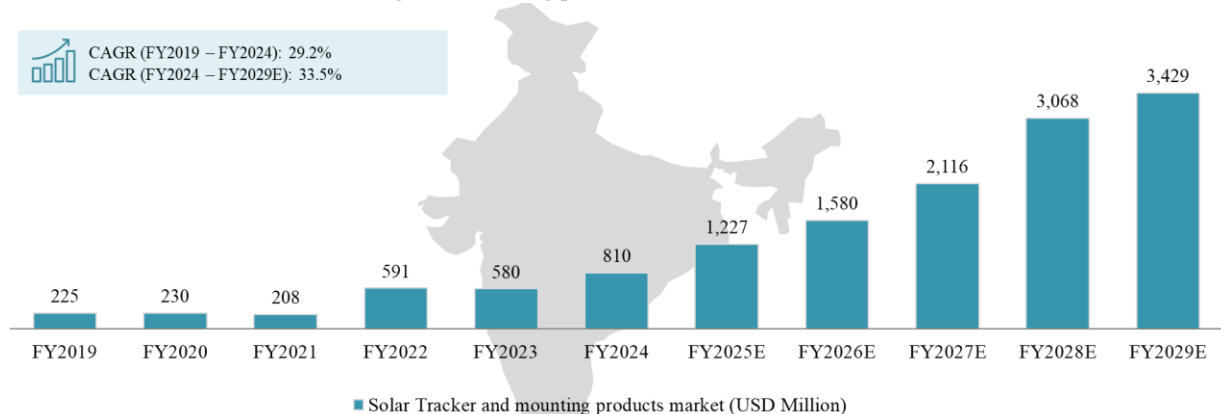
A. Solar tracker and mounting products market size

India's market for solar tracking and mounting products used in tracker systems exhibits a distinct trend. The market initially demonstrated an upward trend from USD 225 million in FY2019 to USD 810 million in FY2024 growing at a CAGR of 29.2%.

This positive trend is expected to continue, with projections estimating the market to reach USD 3,429 million by FY2029E growing at a CAGR of 33.5%. Additionally, the share of these solar tracking and mounting products as a percentage of the overall solar tracker market has risen from 22% in FY2019 to 23% in FY2024 and is projected to reach 25% by FY2029E, further strengthening the sector's significance.

This growth indicates India's increasing investment and demand for tracker systems in its energy infrastructure. Trackers optimize energy production by following the sun's path, and their use appears to be gaining traction in the Indian market.

Exhibit 7.10: Annual solar tracking and mounting products market, India, in USD million, FY2019 – FY2029E



Source: Stakeholder interactions, Frost & Sullivan Analysis

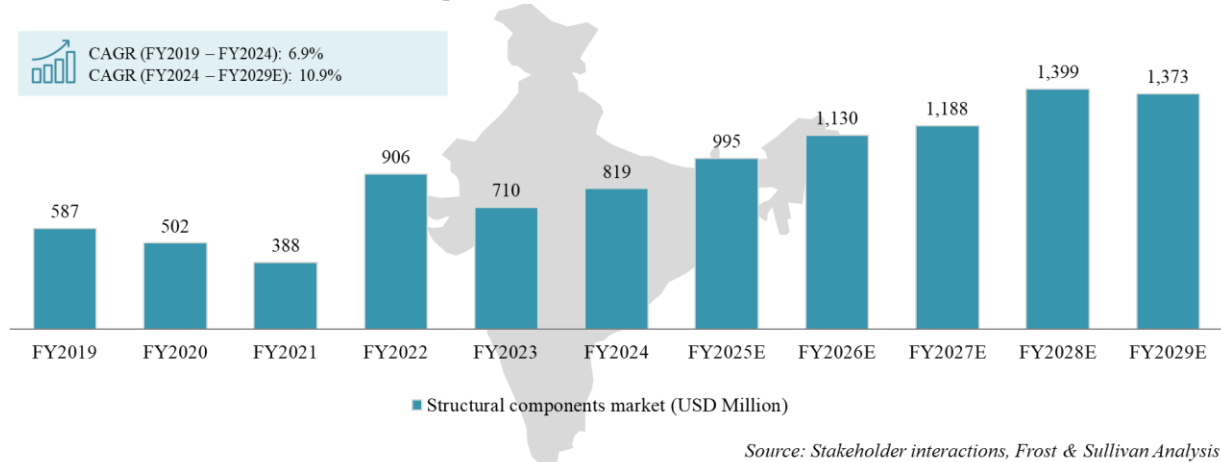
The market is experiencing growth, potentially driven by several qualitative factors. Trackers can significantly boost energy production compared to fixed-tilt systems, making them attractive in regions with lower sunlight or limited land. Advancements in tracker technology reduce costs and improve durability, while automation and tracking accuracy further optimise energy capture. Additionally, government support for trackers and a focus on renewable energy goals encourages wider adoption as the solar industry prioritizes maximizing output and grid integration. These factors combined contribute to the rise in demand for solar tracking and mounting products used in solar plants.

B. Structural component market size for fixed tilt

India's market for fixed-tilt solar structural components, which grew from USD 587 million in FY2019 to USD 819 million by FY2024, is projected to reach USD 1,373 million by FY2029E. Market has grown at a CAGR of 6.9% in between FY2019 to FY2024 and expected to grow at a CAGR of 10.9% in between FY2024 and FY2029. Despite this growth, adoption is expected to decline as tracker systems gain popularity. However, the fixed-tilt structural component market's share of the overall fixed-tilt market is increasing, rising from 18% in FY2019 to 19% in FY2024, and is anticipated to reach 20% by FY2029E. Trackers offer dynamic adjustments to follow the sun, significantly increasing energy capture compared to

fixed-tilt systems. This enhances power generation, particularly in regions with variable sunlight. Advancements in tracker technology, such as reduced component costs and improved durability, make them a financially viable and reliable option, despite higher initial investments.

Exhibit 7.11: Annual structural components market, fixed tilt, India, in USD million, FY2019 – FY2029E

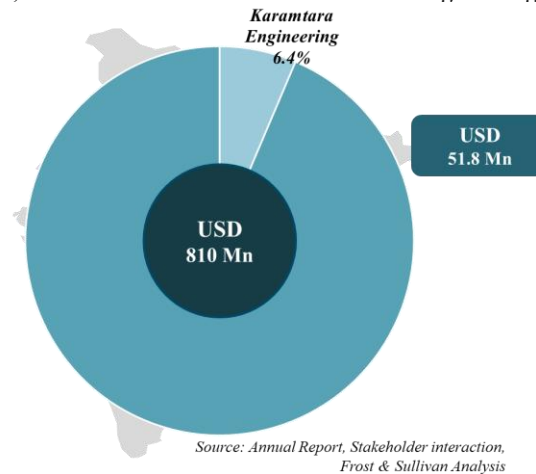


Government policies and renewable energy targets also influence this shift. Supportive initiatives and subsidies for trackers encourage their adoption over fixed-tilt systems. As India aims to meet its clean energy goals, trackers' enhanced efficiency and grid integration benefits make them a strategic choice for maximizing solar energy output.

7.12 Market Share Estimates

Karamtara Engineering Ltd achieved revenue from Operations of approx. INR 24,251 million in FY2024, reflecting its strong market position. As of 31st March 2024, Karamtara Engineering Ltd held an approximately 6.4% share of the overall domestic market for solar tracking products used in solar trackers, equating to a market of approximately USD 51.8 million within a total solar tracking components market valued at approximately USD 810 million. Notably, as of FY2024, Karamtara Engineering Ltd has a significant presence in its current range of solar tracking products both stamped and rolled products in India. As of September 30, 2024, Karamtara Engineering Ltd ranks among the leading manufacturers in the solar tracking and mounting products sector in India, with an annual installed capacity of ~374,700 MTPA (~13.2 GW). Karamtara Engineering Ltd has a wide geographical footprint with a global delivery model, exporting to over 50 countries as of September 30, 2024. These include regions such as North America, Europe, Asia, Africa, Australia, and Latin America. Karamtara Engineering serves 6 of the top 15 EPC companies in the United States in terms of installed capacity. Together, these companies represent a combined installed capacity of over 250 GW.

Exhibit 7.12: Solar tracking products, domestic market share of Karamtara Engineering Ltd, in USD million FY2024



In addition to the growing global demand for increased solar capacity installations and their presence in export markets like KSA, Karamtara Engineering Ltd is expected to gain from various international policies and incentives, notably, the Kingdom of Saudi Arabia is promoting the setting up of facilities that will help achieve the net-zero targets by 2030. These include various incentives such as leasing of land with infrastructure at concessional rates, debt funding at competitive rates, relaxations in employment rules for local employees in Saudi Arabia, availability of power at concessional rates, certain capital subsidies and approval/permit to import semi-finished materials as raw materials. The Kingdom of Saudi Arabia is witnessing an increased demand for renewable product and the gap in supplies provide industry players with significant growth opportunities.

7.13 Growth drivers and market restraints

India's solar power sector is rapidly growing, driven by ambitious renewable energy targets, abundant sunshine, and a focus on clean energy. Behind this growth is the critical ecosystem of solar components, including trackers and fixed-tilt systems, which optimize panel positioning for maximum energy capture.

A. The Key Drivers

- **Government Targets:** India's renewable energy goals, supported by policies like production-linked incentives (PLIs), drive demand for solar tracking and mounting products.
- **Cost Competitiveness:** Innovations in materials and manufacturing efficiency reduce costs, supported by the "Make in India" initiative, promoting domestic manufacturing.
- **Technological Advancements:** New materials and technologies, such as lighter, high-strength materials and self-cleaning coatings, improve performance, durability, and reduce maintenance.

B. Navigating Challenges: The Restraints

- **Land Acquisition:** Securing large land parcels and navigating permitting processes hinder solar project development. Streamlining these procedures is key.
- **Financing Challenges:** High upfront costs and limited financing options are significant barriers. Improved access to competitive financing and risk mitigation tools is crucial for market growth.

7.14 Factors driving the growth of the exports business of solar tracking and mounting products from India

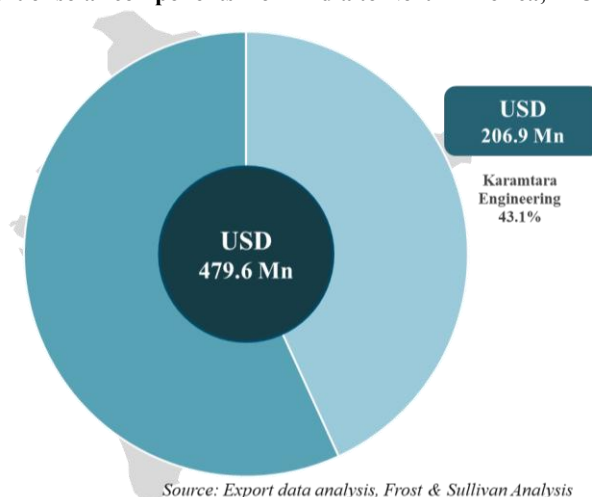
Ambitious climate goals and a growing focus on clean energy security are driving significant investments in renewable technologies, particularly solar power. This surge in demand creates fertile ground for export opportunities in countries with established solar manufacturing ecosystems. However, government policies play a crucial role in shaping the export competitiveness of these nations. The specific international policies that are propelling export growth in four key markets such as India, USA, Europe and KSA (Kingdom of Saudi Arabia) include:

A. India

- **Production-Linked Incentives (PLIs):** India's government has implemented a game-changing policy – Production-Linked Incentives (PLIs) for solar module manufacturing. These PLIs offer financial assistance to domestic manufacturers based on their production capacity. This incentivizes companies to scale up production, fostering a robust domestic manufacturing base and enhancing India's export competitiveness in solar components.
- **Free Trade Agreements (FTAs):** India's recent Free Trade Agreements (FTAs) with countries including United Arab Emirates (UAE) offer significant benefits for solar component exporters. These FTAs often involve tariff reductions or elimination, making Indian exports more price-attractive in foreign markets.
- **Quality Improvements:** Indian manufacturers are focusing on enhancing the quality and reliability of their solar tracking and mounting products as many countries now accept Make-in-India products. This would make them more competitive in the international market, where buyers seek cost-effective yet high-quality products.
- **Sync with Domestic Demand:** India's rapidly growing domestic solar market is creating a strong foundation for its manufacturing capabilities. As domestic demand rises, Indian manufacturers can leverage this capacity and expertise to cater to international markets as well.
- **Global Renewable Energy Focus:** The worldwide push towards renewable energy is generating a surge in demand for solar components. Indian manufacturers can strategically position themselves to capitalize on this growing market opportunity.

In FY2024, the total export of solar components from India to North America, including Mexico, Nicaragua, Canada, and the United States, amounted to USD 479.6 million. Of this, Karamtara Engineering Ltd contributed USD 206.9 million, representing a significant market share of 43.1% making Karamtara Engineering Ltd one of the largest exporters of solar products from India to North America in FY2024. This highlights Karamtara Engineering Ltd's prominent role in supporting the solar energy sector in North America through its robust export capabilities.

Exhibit 7.13: Total export of solar components from India to North America, in USD Mn, FY2024



B. USA

- **Cost Competitiveness + Quality Assurance:** Indian manufacturers can cater to a specific segment in the US market by offering cost-effective components that meet rigorous US quality standards. This is an attractive opportunity, as developers seek to balance project budgets with long-term durability.
- **Focus on Innovation:** Potential collaboration between Indian and US companies can foster innovation in component design or manufacturing processes. This could lead to the development of new, cost-efficient, and high-performance solar tracking and mounting products specifically targeted for the US market.

C. Europe

- **Demand for Renewable Energy in the EU:** The EU's commitment to achieving net-zero emissions by 2050 has significantly increased investments in solar energy projects. Growing adoption of utility-scale solar installations and decentralized solar systems drives the demand for supporting equipment like trackers and mounting structures.
- **Focus on Sustainability and Recycling in the EU:** Indian exporters emphasize recyclable materials and eco-friendly manufacturing processes to align with EU sustainability norms, making their products more attractive.

D. KSA

- **National Renewable Energy Program (NREP):** KSA's NREP drives large-scale investments in solar power, creating high demand for solar components. Exporters with established capabilities can capitalize on this growing market.
- **Economic Diversification:** KSA's push for economic diversification includes developing a strong domestic renewable energy sector. Countries skilled in technology transfer and joint ventures can seize opportunities to enter the KSA market and support its renewable energy objectives.

7.15 Threats and challenges to Karamtara Engineering Ltd and its products and services

A. Challenges specific to Karamtara Engineering Ltd

- **Export and Regulatory Risks:** Karamtara Engineering Ltd's strong focus on the U.S. market exposes the Company to potential regulatory impacts, including trade policies, tariffs, and compliance with U.S. regulations, which could affect its export operations.
- **Raw Material Cost Fluctuations:** Managing the cost of raw materials, which can be volatile, remains a key challenge. These fluctuations can impact profit margins and overall cost management.
- **Technological Advancements:** Keeping pace with rapid technological developments in the solar industry is essential for staying competitive. Falling behind in technology could result in a loss of market share.
- **Supply Chain Reliability:** Ensuring a consistent and reliable supply of raw materials and components is crucial to maintaining production efficiency and avoiding disruptions that could impact project timelines.
- **Customized Solutions:** Meeting the diverse needs of solar project developers by offering tailored solutions is critical for maintaining a competitive edge in the market.

B. Challenges specific to the End user industry

- **Fluctuations in Solar Panel Prices:** Changes in solar panel prices can directly affect the overall cost and attractiveness of solar projects, influencing demand for solar tracking and mounting products.
- **Impact of Government Policies:** Government policies, including subsidies and regulations, play a significant role in the viability of solar projects. Any changes in these policies can impact the demand for solar tracker components.
- **Grid Integration Challenges:** Integrating large-scale solar power into existing power grids often involves technical and regulatory hurdles. These challenges can slow down the deployment of solar trackers and affect market demand.

8. TUBULAR TOWERS TUBULAR TOWERS FOR WIND ENERGY

8.1 Regulatory and Policy Framework

8.1.1 Key Government Policies and Incentives in Key Countries

Wind energy is a significant renewable energy source globally, with wind turbine towers playing a crucial role in harnessing this energy. This wind turbine is placed on a tower to capture wind energy at an altitude. These towers are of different types such as Lattice, Tubular and Hybrid. Among the different types of towers, tubular towers are the prominent ones due to its structural advantages and efficiency. Tubular towers are made of steel and serve as the structural support for wind turbine's rotor and nacelle. The height of tubular tower is critical in harnessing more energy from wind, specifically at altitudes with less turbulence.

Policies and Incentives Supporting Wind Energy in India

India has the 4th highest wind installed capacity in the world, with a manufacturing base of about 15000MW as of March 2023. The country has set up an ambitious target of reaching 140GW of wind energy capacity by March 2032. This is possible through supportive policies and incentives that promote investments in innovative tower technology, domestic manufacturing of wind turbines, high standards and quality assurance of manufacturing that will pave way for efficient energy production.

Government is promoting wind power sector through private sector investment, with attractive policies and incentives including Accelerated Depreciation Benefit, Concessional Custom Duty exemption on specific components of wind electric generators and Generation Based Incentive (GBI) for projects commissioned

before 31 March 2017. MNRE has increased tenders for round-the-clock (RTC), hybrid and peak power supply projects. In October 2023, National Thermal Power Corporation (NTPC) floated a wind solar hybrid pan India tender for 1200 MW, with a “greenshoe option” of additional capacity of up to 600 MW.

In addition to the above mentioned fiscal and incentives, MNRE¹ has devised the following steps to promote installation of wind capacity in the country:

- Declaration of trajectory for Wind Renewable Purchase Obligation upto the year 2030.
- Waiver of Inter State Transmission System (ISTS) charges for inter-state wind power projects commissioned by 30th June 2025
- Issued Guidelines for Tariff Based Competitive Bidding Process for Procurement of Power from Grid Connected Wind Power Projects with an objective to provide a framework for procurement of wind power through a transparent process of bidding including standardization of the process and defining of roles and responsibilities of various stakeholders. These Guidelines aim to enable the Distribution Licensees to procure wind power at competitive rates in a cost-effective manner.
- Technical support including wind resource assessment and identification of potential sites through the National Institute of Wind Energy.

Policies and Incentives Supporting Wind Energy in the U.S

The United States has developed a comprehensive framework of policies and incentives to promote wind energy, reflecting a commitment to renewable energy sources. The country has detailed policies and incentives at both Federal and State level to promote renewable energy. A detailed policy guidelines are also available to promote adoption among states and the process in place allows faster implementation. Thus, there is a competition among states to promote renewable energy in the form of solar or wind power. Presence of many large wind tower and turbine manufacturers based out of the U.S, ensures these policies are well utilized in the country. As policies, regulations and incentives are at multiple levels, an overview of all the key policies and incentives currently in place applicable at suitable level are listed below as a table.

Exhibit 8.1: Policies and Incentives Supporting Wind Energy – Federal and State Incentives, The U.S, CY2018 – CY2024

Federal Incentives		State Incentives	
Production Tax Credit (PTC)	Tax credit of \$0.015 to \$0.017 per kilowatt-hour (kWh) of electricity produced from wind energy for the first ten years of operation; indexed for inflation	Renewable Portfolio Standards (RPS)	Require utilities to obtain a certain percentage of energy from renewable sources
Investment Tax Credit (ITC)	Allows investors to deduct a percentage of the investment cost from their federal taxes	State Financial Incentives	The Database of State Incentives for Renewables & Efficiency (DSIRE) provides detailed information on the policies, as each state offers additional financial incentives such as grants, rebates and tax exemptions.
Inflation Reduction Act (IRA)	Enacted in 2022, introducing bonus tax credits for projects that meet specific criteria such as located in economically disadvantaged areas or those utilizing domestic materials		
Renewable Energy Production Incentive (REPI)	Provides payments to municipal utilities and cooperatives that produce electricity from renewable sources including wind.		

Source: Office of Energy Efficiency & Renewable Energy- U.S Department of Energy; Frost & Sullivan Analysis

Policies and Incentives Supporting Wind Energy in the Kingdom of Saudi Arabia

The Kingdom of Saudi Arabia is actively pursuing wind energy development as part of its broader renewable energy strategy under the Vision 2030 initiative. The key policies and incentives supporting wind energy in the Kingdom are listed below:

¹ Source: Ministry of New and Renewable Energy - <https://mnre.gov.in/wind-overview/>

National Renewable Energy Program (NREP)

- Vision 2030 Goals – KSA has set a goal of generating 50% of its electricity from renewable sources by 2030, with a target of 40 GW from wind energy⁵.
- Power Purchase Agreements (PPA) - The Saudi Power Procurement Company has signed significant PPAs for major wind projects, such as the 600 MW Al-Ghat Wind Project and the 500 MW Wa'ad Alshamal Wind Project, which were awarded after competitive bidding processes. These agreements are crucial for securing investment and ensuring market stability.

Financial Incentives

- King Salman Renewable Energy Initiative – This initiative encourages private sector investment in wind sector through supportive legal and regulatory framework. It aims to facilitate public-private partnerships and promote local manufacturing of renewable technologies.
- Competitive Bidding Process - The NREP utilizes a competitive bidding process that has led to record-low costs for wind energy production, such as the recent achievement of 1.56558 cents/kWh² for the Al-Ghat project, making it one of the lowest globally.

Policies and Incentives Supporting Wind Energy in Europe

European region is a pioneer in harnessing renewable energy. It has robust framework of policies and incentive to promote wind energy as this as a part of its commitment to renewable energy and climate goals. The region has implemented detailed policies and directives, and financial initiatives across countries.

In addition to European directives and incentives, many countries are reforming their permitting processes to accelerate project approvals, as a part of local regional reforms. For instance, Germany and France have seen a significant increase in permits granted due to recent regulatory changes aimed at simplifying procedures. European Union is active in coming up supportive policies and regulations that helps member countries meet its NetZero targets. Additionally, these policies and incentives are frequently evaluated, and necessary amendments are also initiated to promote renewable energy and wind power effectively. European Union (EU) has imposed Carbon Border Adjustment Mechanism (CBAM), which is a border tax for carbon emission tariff levied on carbon-intensive goods such as steel, cement, aluminum, petrochemical, and ammonia, imported into the EU, effective from 1st January 2026.

The heavy industries will be the first set of companies to be affected when this is effective from 2026. One way of addressing this tariff is through increasing the share of renewable energy-based electricity in these production facilities. When the share of renewable energy-based electricity increases, the carbon emissions from these units reduces considerably, which makes it eligible to exempt from the tariff proposed by the CBAM legislation. Thus, CBAM is indirectly promoting renewable energy, specifically wind energy installations promoted by the private participation by the heavy industries from the countries that export into the EU.

²<https://www.moenergy.gov.sa/en/MediaCenter/News/Pages/Saudi-Arabia-sets-new-record-low-cost-for-wind-power.aspx>

Exhibit 8.2: Policies and Incentives Supporting Wind Energy – Directives and Incentives, Europe, CY2018 – CY2024

European Policies and Directives		Financial Incentives	
Renewable Energy Directive (RED II)	Revised in 2023, this directive sets a target of 42.5% renewable energy share in the EU's overall energy consumption by 2030. Member States must develop National Energy and Climate Plans (NECPs) to outline their contributions to these targets	European Union Innovation Fund	Funding has been doubled to €1.4 billion (USD 1.49 billion) under the EU Innovation Fund to support clean tech manufacturing and deployment of wind energy technologies
European Green Deal	Aims for the EU to become climate-neutral by 2050	Investment from European Investment Bank (EIB)	The EIB is increasing its investments in wind energy projects, focusing on both individual wind farms and manufacturing capabilities, which is crucial for boosting local supply chains
Wind Power Package	Launched in 2023, aims to address bottlenecks for wind energy installations. This includes measures to streamline permitting processes, enhance auction designs for wind projects, and increase funding for clean tech manufacturing.		
Renewable Energy Production Incentive (REPI)	Provides payments to municipal utilities and cooperatives that produce electricity from renewable sources including wind.		

Source: European Parliamentary Research Service; Frost & Sullivan Analysis

Implications of CBAM on Exports from India

The CBAM is expected to impose tariffs ranging from 20% to 35% on select imports into the EU starting January 1, 2026. This could lead to substantial increases in export costs for Indian goods, particularly in carbon-intensive sectors, which could reduce their competitiveness in the EU market. Approximately 38%³ of India's steel exports and 27% of aluminum exports are directed towards the EU. The introduction of CBAM could result in significant revenue losses, estimated between \$1 billion to \$1.7 billion for the steel and aluminum sectors alone. With nearly 17% of India's total exports going to the EU, any significant reduction in trade due to CBAM could adversely affect India's overall trade balance and economic growth prospects.

By investing in cleaner production technologies and improving energy efficiency, Indian industries can lower their carbon footprints and potentially reduce compliance costs under CBAM. Encouraging industries to adopt cleaner production methods can help lower carbon emissions and potentially reduce compliance costs under CBAM. Investments in renewable energy sources, such as solar and wind power, are crucial for achieving this goal.

8.1.2 Specific Regulations Promoting Domestic Manufacturing

India has implemented several regulations and initiatives to promote the domestic manufacturing of tubular wind towers, reflecting its commitment to expanding renewable energy capacity. This led to nearly 70%-80% of indigenization, with unit size of machines increasing up to 5.2 MW. The current annual production capacity of wind turbines is about 15000MW⁴. The key components of these supportive regulations are:

Customs and Financial Incentives

- **Concessional Custom Duty Exemption⁵** - The Indian government provides a concessional customs duty exemption on certain components essential for manufacturing wind electric generators. This exemption aims to lower the cost of imported materials that cannot be produced domestically, thus encouraging local production. Additionally, strong local manufacturing is also promoting exports to nearby countries of Bangladesh, Sri Lanka, Nepal and other Asian countries including Philippines,
- **Extended Customs Duty Benefits** – Ministry of Finance has issued Notification No. 02/2023-Customs dated 01.02.2023 providing concessional customs duty benefits for domestic manufacturing have been extended until March 31, 2025, for components included in the Revised List of Models &

³ Ministry of Company Affairs

⁴ Source: Ministry of New and Renewable Energy, Government of India - <https://mnre.gov.in/wind-manufacturing/>

⁵ Source: Indian Wind Energy Association - <http://www.inwea.org/wind-energy-in-india/wind-power-policy/>

Manufacturers (RLMM). This list consists of certified wind turbine models eligible for installation in India. This is beneficial for manufacturers to handle pricing pressure of the product.

- **Interest Subvention for MSMEs** - To support micro, small, and medium enterprises (MSMEs) in participating in wind projects, the industry has proposed interest subventions. This is critical as many MSMEs face challenges due to low tariffs and high project costs.

Minimum Local Content Mandate

- There is a requirement for a minimum local content of 60% in wind turbine components including tubular towers, aimed at fostering domestic manufacturing and reducing reliance on imports

Certification and Quality Assurance

- **Revised List of Models & Manufacturers (RLMM)** – This is the list of type and quality certified wind turbine models eligible for installation in India, as per the Guidelines for Development of Onshore Wind Power Projects issued by the Ministry vide F. No. 66/183/2016-WE dated 22 October 2016. that mandates manufacturers have its wind turbine models certified according to international standards. This includes mandatory type certification from accredited bodies, ensuring that all major components are manufactured within India.

8.2 Technological Trends and Advancements

8.2.1 Overview of Technological Innovations in Tubular Tower Designs and Materials

Tubular wind towers have witnessed significant technological innovations in its design and materials aimed

Exhibit 8.3: Technological Innovations in Tubular Tower Design and Materials , India, FY2019 - FY2024

Innovations	Type	Details
Material Innovations	Steel and Hybrid Towers	This innovation uses concrete for lower sections and steel for upper sections, reducing steel dependency and overall cost.
	High Strength Steel (HSS)	Critical innovation enabling thinner walls for towers without compromising strength. This material results in lighter structure that are easier to transport and erect, thus reducing the overall project costs
	Sustainable Steel	When towers are built with recycled secondary steel and the trend of planned measures in using the materials with an end-of-life disassembly are gaining momentum.
Design Innovation	Modular Construction	Sections prefabricated towers are transported and assembled on-site. This reduces construction time, transportation cost and maintenance cost
	Alternative Cross-Sections	Polygonal cross section providing buckling resistance and material efficiency with less steel requirement for the same integrity.
	Soft-Tower Configuration	Allows dynamic responses to wind loads by optimizing the eigen frequency of the tower to avoid resonant vibrations with rotor speeds, engineers can reduce fatigue stresses on the structure, leading to longer service life and reduced maintenance costs

Source: Frost & Sullivan Analysis

at enhancing efficiency, reducing costs and addressing environmental concerns. Some of the most remarkable innovations are classified as material innovations, design innovations, dynamic performance optimization, and sustainability focused.

8.2.2 Trends Adopted in Tower Height and Materials Used

The wind energy sector is experiencing significant trends in tower height and material usage, particularly between high-tensile (HT) steel and mild steel (MS) in tubular wind towers. These trends are driven by the need for improved efficiency, cost-effectiveness, and structural integrity in harnessing wind energy.

Increasing Hub Heights - Taller wind turbine towers could access stronger and less turbulent wind resources at greater heights. Research indicates that moving from a hub height of 80 meters to 110 meters

can increase annual average wind speeds by 0.5 to 1.0 m/s, translating into significant capacity factor improvements of approximately 2% to 4%.

As such, towers are now commonly reaching heights of 100 meters and beyond, with some designs approaching 160 meters. However, the cost of constructing taller towers remains a challenge, necessitating innovations in design and materials to reduce expenses.

Comparing Material Usage in HT Steel and Mild Steel

HT steel has superior tensile strength and so can withstand higher loads, making it suitable for taller towers and the overall requirement of HT steel is less compared with mild steel to achieve the same structural integrity. Additionally, HT offers high corrosion resistance compared with MS, which needs to be coated, thus increasing maintenance cost. So, HT steel has a competitive edge over mild steel in taller towers.

Exhibit 8.4: Trends in Tower Height and Materials Used – Comparison of HT Steel and Mild Steel, Global, CY2024

Material	Strength	Weight	Cost	Best Use Case
High-Tensile Steel (HT)	High	Light Weight	Potentially Lower per Unit Strength	Towers Over 100m; Suited for Hybrid Designs
Mild Steel (MS)	Moderate	Heavier, More Material Needed for Tall Towers	Generally Lower Initial Cost	Towers up to 80m; Suited for Conventional Designs

Source: Frost & Sullivan Analysis

The future of wind tower design is likely to see continued innovation in both height and materials:

- **Hybrid Structures:** The combination of HT steel with concrete bases is expected to gain traction as developers seek to maximize efficiency while minimizing costs.
- **Sustainable Practices:** There is a growing focus on sustainable materials and practices within the industry, which may influence future material choices beyond traditional options like HT and MS.

In summary, the trends in wind tower height reflect a strategic move toward maximizing energy capture from higher altitudes, while the choice between high-tensile and mild steel will depend on factors such as structural requirements, cost considerations, and advancements in construction technology.

8.3 Competitive Landscape and Key Participants

8.3.1 Major Manufacturers and Suppliers of Tubular Towers in Key Countries

Exhibit 8.5: Competitive Landscape and Key Participants – Tubular Tower Manufacturers and Suppliers, Countries in Focus, CY2024

COMPANY NAME	LOCATION	FOCUS	YEAR OF INCORPORATION	PRODUCTS
Arcosa Wind Towers Inc	Dallas, Texas, U.S	Manufacturing	Over 12,000 towers since 2000	• Structural Wind Towers
Broadwind Towers Inc	Abilene, Texas, U.S	Manufacturing	1924	• Tubular Steel Towers

Marmen Energy Co	Brandon, South Dakota, U.S	Manufacturing	2002	• Customized Tubular Towers
Vestas Wind Systems A/S	Global (U.S, India, and Europe)	Manufacturing	1945	• Tubular, lattice and hybrid towers
Inox Wind Ltd	Ahmedabad, Gujarat, India	Manufacturing	2009	• Tubular Towers and Blades
Cu-Built Engineers Pvt Ltd	Pune, Maharashtra, India	Manufacturing	1995 (2011 – Wind Towers).	• Tubular Tower • 350+ tubular towers since 2011
Wind World (India) Ltd	Mumbai, Maharashtra, India	Manufacturing	1994	• Tubular Steel Towers • Concrete Towers
GE Vernova (Formerly GE Renewable Energy)	Global	Manufacturing	2015 (GE Renewable Energy) 2024 (GE Vernova)	• Tubular Steel Tower
Nordex SE	Europe & Global (Germany, Brazil, India, Mexico and Spain)	Manufacturing	1985	• Wind Turbines and • Tubular Steel Towers with hub heights of 112 meters, 142 and 162 meters
EMEK SA	Greece	Manufacturing	1965 (2000- Wind Towers)	• Customized Tubular Steel Towers

8.3.2 Analysis of Competitive Dynamics

The competitive dynamics between local and international tubular wind tower manufacturers in India are characterized by a blend of innovation, strategic positioning, and responsiveness to market demands. While international players bring advanced technologies and global experience, local manufacturers capitalize on cost advantages and tailored solutions to maintain competitiveness in this rapidly evolving sector.

Key Competitive Factors

- **Technological Innovation:** Local manufacturers like Suzlon Energy Ltd. leverage their R&D capabilities to innovate continuously, which helps them compete effectively against established international brands.
- **Manufacturing Capacity:** India hosts over 17⁷ wind turbine manufacturers with a combined annual production capacity exceeding 15,000MW. Local manufacturers often benefit from lower transportation costs and quicker turnaround times for domestic projects.

⁷ NITI Aayog Report on Domestic Manufacturing Capacity & Potential Cyber Security Challenges in the Wind Sector and Way Forward

- **Cost Competitiveness:** Local firms can often provide more cost-effective solutions due to lower labor costs and localized supply chains. This is crucial in a price-sensitive market like India.
- **Strategic Partnerships:** Collaborations between local firms and international companies can enhance technological transfer and improve product offerings, allowing both parties to leverage their strengths effectively.

8.4 Market Size and Demand Analysis

8.4.1 Market Size and Growth Projections in Key Countries of Interest

Tubular wind towers are in focus among the different types of towers. Wind towers account to nearly 65 – 75% of the turbine material cost, followed by fibreglass, plastic, or resin accounting to 10-15% along with metals such as iron, copper and aluminium accounts to 5-10%. Tubular wind towers are composed of steel and so the cost of manufacturing is largely influenced by steel pricing.

Tubular towers are favoured for their structural integrity, adaptability for various wind conditions, efficiency, durability and cost-effectiveness. So, it accounted for a significant portion of the market due to its suitability for both onshore and offshore projects. Increasing adoption of tubular wind towers ensures consistent growth globally during the forecast period. Demand for tubular towers is likely to witness a five year CAGR of 6.8% from CY2023 to CY2028E. This indicates a significant growth, when the market witnessed a historic five year growth of 4.9% from CY2018 to CY2023 globally, % where European region is a stabilized mature market, expected to grow at a five year CAGR of 5.5% from CY2023 to CY2028E of %. Germany, France and the U.K are leading in wind turbine installations in this region. This region witnessed a historic CAGR of 4.5% from CY2018 to CY 2023. Increasing offshore wind farm installation drives demand for tubular towers in this region. U.S, the country with technological innovation is likely to witness a five year CAGR of 7.2% from CY2023 to CY2028E. %.

Exhibit 8.6: Tubular Wind Tower Market, Value in USD Million, Global, CY2018 – CY2028E

Country / Region	CY2018	CY2019	CY2020	CY2021	CY2022	CY2023	CY2024E	CY2025E	CY2026E	CY2027E	CY2028E
Global	5,800	6,025	6,300	6,600	6,950	7,350	7,793	8,300	8,850	9,480	10,200
USA	935	980	1,028	1,085	1,149	1,220	1,300	1,390	1,490	1,600	1,730
Europe	2,115	2,200	2,295	2,400	2,516	2,640	2,780	2,930	3,090	3,260	3,445
India	846	904	968	1,040	1,120	1,200	1,284	1,376	1,476	1,588	1,712
KSA	47.5	51.7	56.4	61.6	67.7	74.5	82.4	91.3	101.5	113.0	126.0

Source: Stakeholder interactions, Frost & Sullivan Analysis

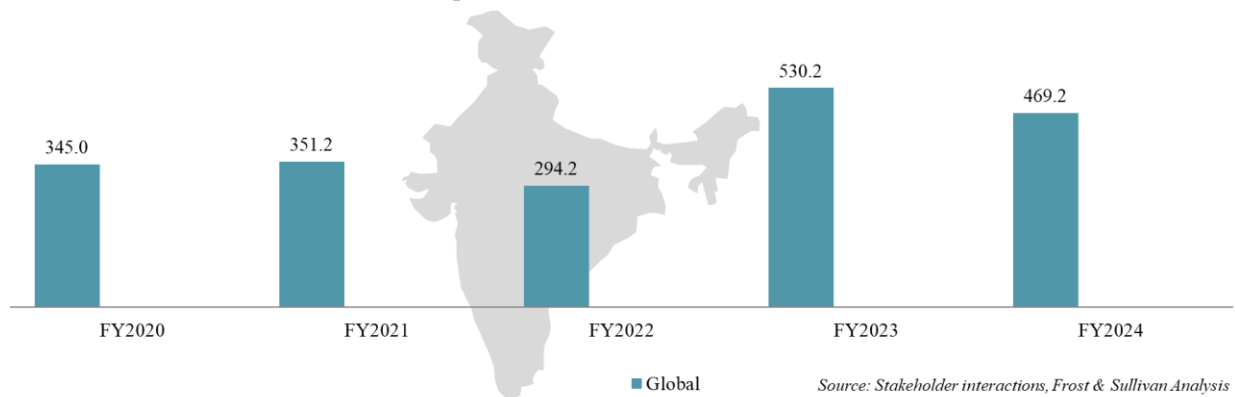
This is a significant growth from its historic CAGR of 5.5% from CY2018 to CY2023. Increasing focus on renewable energy and offshore wind farms drive growth for tubular towers. Demand for tubular wind tower is likely to continue during forecast period as a part of the broader trend towards renewable energy adoption and infrastructure development in the wind sector. India is the key growth engine in terms of volumes and manufacturing scale. The country is likely to grow at a five-year CAGR of 7.4% from CY2023 to CY2028E, as more projects are initiated every year to meet renewable energy targets. The country is continuing its steady growth from its historic CAGR of 7.2% from CY2018 to CY2023. The country is focusing on reducing costs and increasing efficiency, which increases the preference for tubular wind towers in India. Saudi Arabia is a niche, emerging market, likely to grow at a five year CAGR of 11.1% from CY2023 to CY2028E, %, as the Kingdom is expanding its presence in renewable energy sector. So, the Kingdom is

likely to witness significant growth during the forecast period, as this region grew at a historic CAGR of 9.4% from CY2018 to CY2023, which is less than its forecasted growth.

8.4.2 Export Analysis & Prospects from India

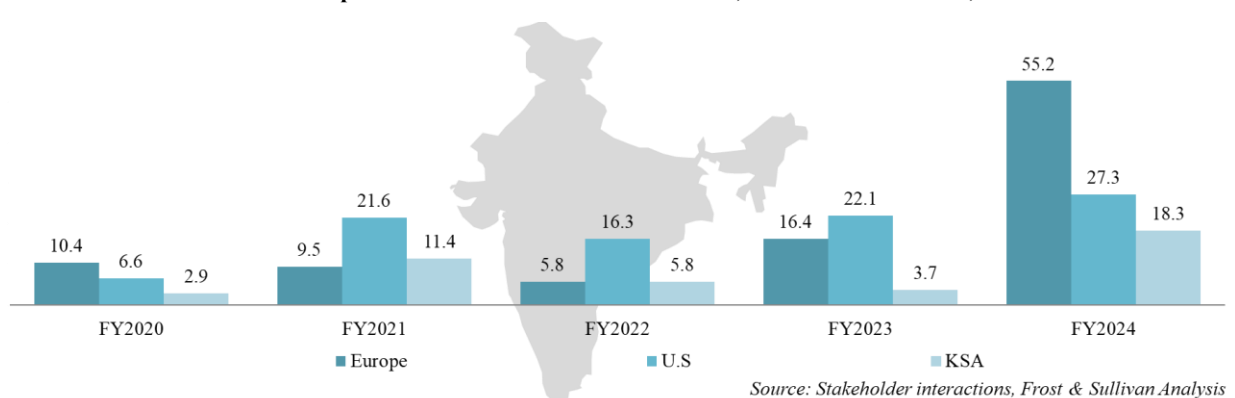
India is emerging to be an important country with strong manufacturing base supported by government policies and initiatives. India exported 102 shipments of turbine towers from the manufacturing base of 10 companies, indicating a robust demand for these towers at the international market. Indian companies are adapting to the global technological innovations such as using stress-reducing L-flanges in tubular steel towers enhancing structural integrity and ease of assembly.

Exhibit 8.7: Wind Tower Exports from India, Value in USD Million, FY2020 – FY2024



Offering technologically advanced products at competitive pricing compared with the pricing at Europe and the U.S creates constant demand for exports from India. Bangladesh, Australia, Saudi Arabia, Georgia, and Colombia are the top five countries that import wind towers from India. The other countries importing from India include Philippines, United Republic of Tanzania, the U.S, Nepal, Nigeria, Oman, United Arab Emirates and the like. Well established logistics and connected ports ease the process of exporting from India.

Exhibit 8.8: Wind Tower Exports from India to Countries in Focus, Value in USD Million, FY2020 – FY2024



8.5 Challenges and Growth Drivers

8.5.1 Key Drivers

Tubular steel wind towers are the most reliable ones for a tall wind turbine with heights above 80 meters. These towers are typically conical in shape, with the diameter of the tower decreasing as it rises. The tubular steel tower for a wind turbine requires perfectly bent steel that meets the specific requirements of wind tower. These advancements coupled with renewable targets set by individual countries and wind farm

expansions promote the demand for tubular wind towers globally. Individual drivers by key countries are captured as a table below:

Exhibit 8.9: Key Drivers for Tubular Wind Towers, India and Saudi Arabia, CY2024

	Key Drivers for India		Key Drivers for Saudi Arabia
Government Initiatives and Funding	Viability Gap Funding (VGF) is introduced to support offshore wind projects, in addition to Make in India, Customs Duty Benefits and other initiatives.	Renewable Energy Targets and Vision 2030	Saudi Arabia's Vision 2030 has ambitious goals with renewable energy capacity of 9.5GW by 2030 , with focus on wind power The Kingdom is embarking on a USD 1 Trillion investment plan that allocates approximately USD 235 Billion specifically for clean energy initiatives, including wind power.
Renewable Energy Capacity Goals	Ambitious targets with a commitment to achieve 500GW of non-fuel capacity by 2030.	Significant Investment in Clean Energy	A commitment of achieving net-zero emissions by 2060 and reducing carbon emissions significantly by 2030, the Kingdom is prioritizing wind power.
Increasing Energy Demand	Rapid urbanization and industrial growth demands high energy consumption, that needs to be supported by clean energy.	Environment Sustainability Goals	
Technological Advancement	Manufacturing of tubular towers at globally accepted technological innovations is building confidence for domestic manufacturing in India along with promoting exports.	Growing Energy Demand and Infrastructure Development	Rapid economic growth and urbanization in Saudi Arabia are driving increased demand for electricity, which is promoting demand for wind tower.

Source: Ministry of New & Renewable Energy-Govt of India; Saudi Arabia Ministry of Energy; Frost & Sullivan Analysis

Exhibit 8.10: Key Drivers for Tubular Wind Towers, the U.S and Europe, CY2024

	Key Drivers for the U.S		Key Drivers for Europe
Government Initiatives and Funding	Incentives such as Production Tax Credit (PTC) and Investment Tax Credit (ITC) drive demand for wind farms and tubular wind towers in the U.S	Renewable Energy Directive	Europe has robust regulatory frameworks and policies mandating wind farm installations, thus, driving tubular tower demand.
Renewable Energy Capacity Goals	The U.S pledged to triple its renewable energy capacity by 2030 , to reach 938 GW of renewable capacity, including 25GW of onshore farm by 2025.	Commitment to Climate Goals	Europe is at forefront of climate initiatives with ambitious targets to achieve carbon neutrality by 2050
Expanding Offshore Wind Projects	A notable trend of offshore wind farms along the U.S coastline require specialized tubular tower capable of withstanding harsh marine conditions, driving demand	Increasing Investment in Offshore Wind Projects	European countries are pioneers in offshore wind farm installations, and tubular towers are in demand to handle the harsh marine conditions.
Technological Advancement	U.S is pioneering in taller towers of above 100m with its technological innovations. The country has multiple manufacturing companies with advanced R&D infrastructure, leading technological innovation, driving better adoption of tubular towers.		

Source: Office of Energy Efficiency & Renewable Energy- U.S Department of Energy; European Parliamentary Research Service; Frost & Sullivan Analysis

8.5.2 Key Challenges

Tubular wind towers face few common challenges across all countries in its installation process. These challenges include:

- **Expertise in Transportation and logistics:** Tubular wind towers are used when the tower height is above 80 meters. In such cases, transportation of these towers needs special vehicles with expertise in transporting these structures. These may lead to a delay in transportation as not all logistic carriers are capable of this task.
- **Environmental Concerns:** Wind energy projects often face opposition due to concerns about environmental impacts, land, use and aesthetics. Additionally, not all locations suit wind farm installation and selecting the most suitable location which is environmentally safe for installation is a challenge by itself across all regions.
- **High Initial Capital Costs:** The upfront capital required for wind energy projects can be substantial, potentially deterring investment in any country for any participant. So, frequent installations and multiple participants venturing into wind farm installations are low.

Exhibit 8.11: Key Challenges for Tubular Wind Towers, Countries of Focus, CY2024

India	Saudi Arabia	The U.S	Europe
▪ Infrastructural Constraints ▪ Financial Challenges ▪ Competition from Other Renewable Sources ▪ Cyclonic Activity on the Eastern Coast	▪ Logistical and Transportation Issues ▪ Limited Local Manufacturing Capacity ▪ High Initial Investment Cost in an Emerging Market	▪ Competition from Alternative Wind Tower Designs ▪ Crane Availability and Installation Challenges	▪ Economic Uncertainty in the Europe ▪ Competition from Alternative Wind Tower Designs

Source: Frost & Sullivan Research & Analysis

9. OTHER BUSINESS SEGMENTS

9.1 Lattice Tower for Transmission Line

9.1.1 Regional Analysis in Key Focus Countries

Overview of Lattice Towers for Transmission Lines

Lattice towers are a prominent type of transmission tower widely used in electrical power distribution. Their design consists of an open framework made from intersecting metal sections, which provides them with a high strength-to-weight ratio, making them particularly suitable for supporting heavy power lines over long distances.

Characteristics of Lattice Towers:

- **Structural Design** – Lattice towers feature a triangular or square cross-section, which enhances their stability and allows for efficient load distribution. This design minimizes the amount of material needed while maximizing strength, making them cost-effective for extensive power transmission networks
- **Height and Configuration** – Lattice towers range from 50 to 150 feet (approximately 16 to 45 meters) in height depending on the voltage requirements and terrain.
- **Material** – Most lattice towers are constructed from galvanized steel which provides durability and resistance to environmental factors.

Types of Lattice Towers are:

- **Suspension Towers** – Used primarily in straight sections of transmission lines with minimal angle deviation (up to 10 degrees). They support the wires but do not change the direction of the line.
- **Strain Towers** – These are designed for areas where the transmission line changes direction significantly (beyond 10 degrees). Strain towers are larger and heavier than suspension towers as they need to handle the tension load imposed by the wires
- **Self-Supporting Vs Guyed Towers** – Lattice towers can be self-supporting, relying on their structure alone for stability, or guyed, which use external cables (guy wires) anchored to the ground for additional support. Guyed towers are often employed in locations with limited space or challenging terrain.

Lattice towers are predominantly used for high-voltage transmission lines due to their ability to span long distances without significant structural support. These towers offer cost-effectiveness, wind resistance (the open framework allows wind to pass through, reducing the wind load on the structure compared to solid towers) and versatility to be adapted for various voltage levels and environmental conditions, making them

suitable for diverse geographical locations. Lattice towers play a crucial role in modern electrical infrastructure by efficiently supporting high-voltage power lines across vast distances. Their unique design and structural properties make them a preferred choice in the construction of transmission networks worldwide. Understanding their characteristics and applications helps appreciate their importance in delivering electricity reliably and efficiently.

Market Size and Growth of Lattice Towers for Transmission Lines

The market for lattice towers used in transmission lines is part of the broader transmission tower market, which is experiencing significant growth. The lattice tower for transmission line market is valued at USD 3,670.0 Million at 2023, CY2023, which is expected to reach USD 5,250.0 Million in 2028, CY2028.

Exhibit 9.1: Lattice Tower Transmission Line, Market Value in USD Million, Global, CY2018 – CY2028E

Country/Region	CY2018	CY2019	CY2020	CY2021	CY2022	CY2023	CY2024E	CY2025E	CY2026E	CY2027E	CY2028E
Global	3,010.0	3,110.0	3,220.0	3,350.0	3,500.0	3,670.0	3,870.0	4,100.0	4,400.0	4,800.0	5,250.0
USA	731.4	755.7	782.5	814.1	850.5	896.8	950.9	1012.9	1093.0	1198.8	1318.3
Europe	692.0	715.3	740.6	770.5	805.0	844.1	890.1	934.8	990.0	1070.4	1155.0
India	361.2	373.2	386.4	402.0	420.0	440.4	472.1	508.4	554.4	614.4	682.5
KSA	48.2	49.8	51.5	53.6	56.0	58.7	62.7	67.2	73.0	80.6	89.3

Source: Stakeholder interactions, Frost & Sullivan Analysis

The overall global market is expected to witness a five-year CAGR of 7.4%, from CY2023 to CY2028E, while the growth at the key countries varies depending on the regional factors. The market witnessed historic five-year CAGR of 4.0% from CY2018 to CY2023. Among the regions, India is likely to witness highest five-year CAGR of 9.2% from CY2023 to CY2028E, followed by Saudi Arabia at a CAGR of 8.7% from CY2023 to CY2028E, being the two important regions with high infrastructure spending towards renewables and transmission lines. The U.S is the steady growth region, with strong replacement demand, likely to witness a five-year CAGR of 8.0% from CY2023 to CY2028E, followed by Europe at a futuristic CAGR of 6.5% from CY2023 to CY2028E. However, these regions have similar historic growth rate of 4% CAGR from CY2018 to CY2023.

9.1.2 Growth Drivers

Key growth drivers contributing to global and regional growth includes:

- **Increasing Demand for Electricity:** Rapid urbanization and industrialization are leading to heightened electricity needs, necessitating the expansion of power transmission infrastructure. In developed countries of the U.S and Europe demand is driven from both new and replacement demand from upgrading existing infrastructure.
- **Integration of Renewable Energy:** The shift towards renewable energy sources like wind and solar is prompting investments in new transmission lines and towers to connect generation sites to the grid.
- **Government Initiatives:** Many governments are investing in modernizing their power transmission networks, which includes upgrading existing infrastructure and integrating smart grid technologies

Asia Pacific is expected to be a significant contributor to market growth, driven by expanding economies and increasing energy demands, particularly in countries like China and India. In North America and Europe, efforts are focused on grid modernization and renewable energy integration, further supporting market expansion. The lattice tower segment within the transmission tower market is poised for robust

growth due to rising electricity demands, renewable energy integration, and substantial government investments in infrastructure development.

9.1.3 Key Suppliers/Manufacturers

Most of the companies offer lattice transmission towers that is capable of handling a voltage range of 66kV to 800kV, depending on the capacity. In addition to these global participants, Karamtara Engineering Ltd (KEL) is a noted participant from India, with an advanced manufacturing facility for lattice towers for transmission lines based in India. Karamtara Engineering Ltd specializes in manufacturing a wide range of transmission towers for power transmission. As of September 30, 2024, the company operates one of India's most advanced manufacturing facilities, featuring advanced automation and mechanization capabilities, including the latest CNC (Computer Numerical Control) machines. Initially, KEL was engaged in business of manufacturing of Transmission line tower (TLT) and served a major customer in India and exported the product to more than 25 of countries. Since 2016, adapting to the market demand, KEL has focus on renewable energy, KEL has scaled up the production of solar products in its TL manufacturing facility. Considering the upcoming power generation capacity, the evacuation of the power is equally growing. To capture the market, KEL is planning to restore its capacity by moving out solar manufacturing capacity in Tarapur. The Company has the capabilities to design, manufacture and supply transmission lines up to 1200 kV. The Company is also setting up capacity in KSA to capture the market in that region.

KEL is keen to restore its capacity of TLT is largely to meet the surge in demand in India. The country needs INR 4.25 trillion in power transmission infrastructure by 2027 to meet the power demand of 227 GW in that year. Based on National Electricity Plan transmission line infrastructure by 2027 needs to be 5,71,403 Km, from the exiting 4,56,716 Km as of 2022. This needs to further increase to 6,48,190 Km to support the power demand by 2032. Thus, TLT is a surging product in India to cope up with this infrastructure development.

Exhibit 9.2: Summary of Companies Offerings Offering s Lattice Tower for Transmission Line, Global, CY2024

COMPANY NAME	LOCATION	PRODUCTS
SAE Towers Holdings LLC	Houston, Texas, U.S	• Lattice Towers and Hardware Solutions
Utkarsh India Ltd	Kolkatta, West Bengal, India	• Power Grid Corporation Approved Lattice Towers for Transmission
Locweld Inc	Quebec, Canada	• Lattice Steel Transmission Tower Manufacturer
Shilpa Steel & Power Ltd	Kinhi, Maharashtra, India	• Lattice Steel Transmission Tower Manufacturer for Transmission Lines • Lattice Steel Tower Manufacturer for Wind Towers
Skipper Ltd	Kolkatta, West Bengal, India	• Lattice Steel Transmission Tower Manufacturer ranging from 66KV to 800KV.

The Company is also involved in exporting these lattice towers to other geographic region, as the plant capacity is significant compared with other manufacturers from India. As of September 2024, the Company supplied over half a e million metric tons of transmission towers and lattice structures to clients across geographic regions

9.2 Hot Rolled High Tensile (HT) and Mild Steel Structures

9.2.1 Usage of HR HT Steel and Mild Steel Structures for Captive Purpose

Hot Rolled High Tensile (HT) and Mild Steel (MS) are two widely used types of steel in construction and manufacturing. Each has distinct characteristics that make them suitable for various applications, particularly in structural engineering.

Mild Steel

- Mild steel, also known as low carbon steel, typically contains 0.05% to 0.25% carbon by weight, making it ductile and malleable.
- It is characterized by good weldability, machinability, and a high strength-to-weight ratio, which makes it ideal for structural applications.
- It has ultimate tensile strength in the ranges from 340 MPa to 580 MPa, depending on the specific grade, while the yield strength varies between 285 MPa to 370 MPa at a density of approximately 7850 kg/m³
- Mild steel is extensively used in construction for beams, columns, and other structural components due to its affordability and ease of fabrication. It is commonly found in building frameworks, bridges, fences, automotive parts.

Hot Rolled High Tensile (HT) Steel

- Hot rolled high tensile steel is produced by rolling steel at high temperatures, which enhances its strength and ductility. This type of steel typically contains higher carbon content than mild steel, often exceeding 0.25%, which contributes to its increased tensile strength.
- The mechanical properties of HT steel include ultimate tensile strength exceeds 500 MPa, making it suitable for heavy-duty applications with yield strength can reach values above 400 MPa, providing excellent load-bearing capabilities.
- HT steel is preferred in applications requiring higher strength and durability, such as heavy machinery, structural components in high-rise buildings, bridges and other infrastructure projects, automotive frames and components.

Exhibit 9.3: Hot Rolled High Tensile Steel & Mild Steel Structures for Captive Use, Value in Million Tonnes, CY2018 – CY2028E

Country/Region	CY2018	CY2019	CY2020	CY2021	CY2022	CY2023	CY2024E	CY2025E	CY2026E	CY2027E	CY2028E
Hot Rolled HT	89.3	93.1	95.6	98.4	101.5	105.0	108.9	113.1	118.0	123.2	129.2
Mild Steel	59.5	62.1	63.7	65.6	67.7	70.0	72.6	75.4	77.0	80.4	82.6

Source: Stakeholder interactions, Frost & Sullivan Analysis

HT Steel and Mild Steel for Captive Use: High Tensile steel has better suitability for transmission towers than mild steel and so the consumption growth of high tensile steel is higher than mild steel. Hot rolled high tensile steel witnessed a historic five-year CAGR of 3.3% from CY2018 to CY2023 is likely to witness a five-year CAGR of 4.2%, from CY2023 to CY2028E while mild steel is expected to witness a five year CAGR of 3.4% from CY2023 to CY2028E, with a historic CAGR of 3.3% from CY2018 to CY2023.

Product Offerings: Hot rolled high tensile steel products for captive use are primarily offered in various forms, including High Yield Strength Deformed (HYSD) bars and Corrosion Resistant Steel (CRS) bars, each tailored for specific applications in construction and infrastructure. HYSD bars are produced through a unique heating and cooling process that enhances their tensile strength and flexibility. While CRS bars incorporate corrosion-resistant elements like copper, chromium, and phosphorous making them suitable for

environments prone to corrosion. Hot rolled deformed steel bars are produced according to various international standards with different yield strengths.

Exhibit 9.4: Summary of Product Offerings of HT and Mild Steel for Captive Use, Global, CY2024

PRODUCT OFFERINGS	TYPES AND FEATURES	COMMON APPLICATIONS
HYSD Bars	• Fe 415 (Tor 40) • Fe 500 (Tor 50) • Flexible, corrosion-resistant, high tensile strength	• Suitable for general construction offering higher strength, ideal for more demanding applications.
CRS Bars	• CRS Fe 500 • CRS Fe 500 D • Corrosion resistance and high ductility	• Suitable for coastal structures, bridges as it provide longevity for structures exposed to harsh weather conditions.
Deformed Steel Bars	• HRB335 - ≥ 335MPa • HRB400 - ≥ 400MPa • HRB500 - ≥ 500MPa • Various grades of yield strengths	• General construction, where they are available in various diameters of 6mm to 32mm and length between 6m to 12m.

These offerings cater to the needs of construction companies seeking reliable materials for structural integrity and longevity in their projects.

9.3 Fasteners for Solar, Wind & Transmission Segment

9.3.1 Market Overview and Demand for Fasteners in Solar Segments

Fasteners for solar panels are usually made of stainless steel for its corrosion resistance and strength, while zinc-nickel or hot-dip galvanization are the widely used coatings to provide additional protection against environmental factors. Fasteners are used in both rooftop and ground-mounted solar installations across residential, commercial, and utility-scale projects. They play a vital role in mounting systems that support the weight of solar panels while resisting wind forces.

The demand for specialized fasteners that can endure harsh conditions is increasing, leading manufacturers to innovate with new materials and designs. There is a growing trend towards integrated supply chain solutions that streamline procurement and distribution processes for fasteners in solar projects.

Fasteners for Solar Market

The fasteners market for solar panels is a critical component of the renewable energy sector, driven by the need for reliable and durable installation solutions. It is essential for ensuring the stability and longevity of solar panel installations. Fasteners must withstand various environmental conditions, including extreme temperatures, humidity, and mechanical loads, over a lifespan of 20 to 25 years. Types of fasteners include:

- **Screws** – Self- self-drilling and self-tapping screws commonly used for securing panels to mounting structures. These screws usually are coated with corrosion resistance paints.
- **Bolts and Nuts** – Various types such as hex bolts, anchor bolts, and lock nuts are used to secure structural components.
- **Washers** – Flat, lock and sealing washers are utilized to enhance the integrity of connections.

Exhibit 9.5: Fastners Demand for Solar Panel Installations, Market Value in USD Million, Global, CY2018 – CY2028E

Country/Region	CY2018	CY2019	CY2020	CY2021	CY2022	CY2023	CY2024E	CY2025E	CY2026E	CY2027E	CY2028E
Global	1,000.0	1,060.0	1,090.0	1,125.0	1,200.0	1,290.0	1,390.0	1,505.0	1,635.0	1,780.0	1,940.0
USA	180.0	190.8	196.2	202.5	216.0	232.2	251.6	273.9	299.2	327.5	358.9
Europe	230.0	243.8	250.7	258.8	276.0	296.7	319.7	346.2	367.9	391.6	417.1
India	156.0	165.4	170.0	175.5	187.2	201.2	216.8	234.8	259.3	286.9	317.8
KSA	8.0	8.5	8.7	9.0	9.6	10.3	11.3	12.3	13.6	15.0	16.5

Source: Stakeholder interactions, Frost & Sullivan Analysis

North America and Europe are leading markets due to strong investments in renewable energy infrastructure. So, the U.S is likely to witness a five-year CAGR of 9.1% from CY2023 to CY2028E, while the more mature European market is expected to register a five-year CAGR of 7.0% from CY2023 to CY2028E. The Asia Pacific region is expected to experience significant growth driven by government initiatives supporting solar energy adoption. Hence, India is likely to register a five-year CAGR of 9.6% from CY2023 to CY2028E, which is much above than the global CAGR of 8.5% from CY2023 to CY2028E. However, KSA is expected to witness highest growth rate of 9.8% CAGR from CY2023 to CY2028E driven by strong push towards solar installations. All these regions witnessed a historic growth rates of around 5.2% CAGR from CY2018 to CY2023.

Fasteners for solar panels are usually made of stainless steel for its corrosion resistance and strength, while zinc-nickel or hot-dip galvanization are the widely used coatings to provide additional protection against environmental factors. Fasteners are used in both rooftop and ground-mounted solar installations across residential, commercial, and utility-scale projects. They play a vital role in mounting systems that support the weight of solar panels while resisting wind forces.

The fasteners market for solar panels is evolving with advancements in materials technology and an increasing focus on sustainability. As the demand for solar energy continues to rise globally, the need for high-quality fasteners that ensure reliable installations will remain a priority within the industry.

9.3.2 Market Overview and Demand for Fasteners in Wind Segments

The fasteners market for wind turbine installations is experiencing significant growth, driven by the expanding wind energy sector and the increasing demand for renewable energy solutions. The wind energy fasteners market is expected to witness substantial CAGR of 8.6% from CY2023 to CY2028. This growth is closely tied to the overall expansion of the wind power industry, which is rapidly gaining traction as a sustainable energy source. Fasteners used in wind turbine includes:

- Bolts – Essential for securing various components such as tower sections, rotor blades, and nacelles.
- Nuts and Washers – Used in conjunction with bolts to ensure secure connections.
- Specialized Hardware – Includes items designed to withstand extreme weather conditions and mechanical stresses typical in wind turbine environments.

Fasteners are predominantly made from materials like stainless steel due to its corrosion resistance, which is crucial given that turbines are often located in harsh environments, including coastal areas. Coatings such as hot-dip galvanization are also common to enhance durability.

Exhibit 9.6: Fasteners Demand for Wind Turbine Installations, Market Value in USD Million, Global, CY2018 – CY2028E

Country/Region	CY2018	CY2019	CY2020	CY2021	CY2022	CY2023	CY2024E	CY2025E	CY2026E	CY2027E	CY2028E
Global	725.0	760.0	785.0	815.0	860.1	915.0	980.0	1,060.0	1,150.0	1,260.0	1,385.0
USA	110.9	116.3	120.1	124.7	131.6	140.0	150.0	164.0	178.9	197.1	217.8
Europe	152.3	159.6	164.9	171.2	180.6	192.2	205.8	222.6	235.8	258.3	277.0
India	124.0	130.0	134.2	139.4	147.1	156.5	170.4	187.3	206.5	229.8	256.6
KSA	5.8	6.1	6.3	6.5	6.9	7.3	7.8	8.6	9.4	10.5	11.6

Source: Stakeholder interactions, Frost & Sullivan Analysis

Fasteners for wind turbine installations witnessed a five-year CAGR of 4.8% from CY2018 to CY2023. However, this market is likely to witness strong growth in India and KSA, which is expected to growth at a CAGR of 10.4% and 9.7% respective from CY2023 to CY2028E. The U.S follows next which could witness 9.2% CAGR from CY2023 to CY2028E, while Europe, which is a mature market is likely to grow at 7.6% from CY2023 to CY2028E.

9.3.3 Growth Drivers

- **Renewable Energy Transition** - The global shift towards renewable energy sources is a primary driver for the wind power sector. Governments worldwide are implementing policies to reduce carbon emissions, leading to increased investments in wind farms.
- **Infrastructure Development** – As new wind farms are constructed and existing ones undergo maintenance or upgrades, the demand for reliable fastening solutions rises significantly. This includes both initial installation and ongoing maintenance needs.
- **Technological Advancements** – Innovations in fastener design and materials are enhancing performance and safety standards within the industry. Manufacturers are focusing on developing products that can endure specific challenges faced by wind turbines, such as vibrations and severe weather conditions.

There is considerable potential for growth in emerging markets where wind energy capacities are being developed. Countries investing in renewable energy infrastructure present opportunities for fastener demand. Additionally, increasing emphasis on safety and structural integrity in wind turbine installations is driving demand for high-quality fasteners that meet stringent regulatory standards.

9.3.4 Market Overview and Demand for Fasteners in Transmission Line Segments

The market for fasteners in transmission line segments is integral to the infrastructure supporting electrical transmission systems. The global fasteners market of the transmission line segment was valued at approximately USD 3,030.0 Million in CY2023, and is projected to reach USD 4,350.2 Million by 2028. CY2023 to CY2028, growing at a compound annual growth rate (CAGR) of 7.5% from 2023 to 2028. CY2023 to CY2028. This market witnessed a historic growth rate of 4.3% from CY2018 to CY2023, and is likely to witness strong surge in growth in the regions of India, KSA and the U.S. These three regions are likely to register growth higher than that of global CAGR at 9.2%, 8.8% and 8.1% respectively from CY2023 to CY2028E, while European region is likely to register a growth rate of 6.2% from CY2023 to CY2028E. The types of fasteners used in transmission line segments include:

- **Bolts** - Such as double arming bolts, U-bolts, and square head bolts that secure various components of transmission towers.
- **Nuts and Washers** – Essential for ensuring tight connections and stability.

- Eye Bolts: Used for connecting hardware on overhead lines.
- Thimble Eye Bolts: Often employed in securing cables and wires.

Fasteners are primarily made from carbon steel, often hot-dip galvanized to enhance corrosion resistance, which is critical given the outdoor environments they operate in. The choice of materials ensures durability against weather elements and mechanical stresses.

Exhibit 9.7: Fasteners Demand for Transmission Line, Market Value in USD Million, Global, CY2018 – CY2028E

Country/Region	CY2018	CY2019	CY2020	CY2021	CY2022	CY2023	CY2024E	CY2025E	CY2026E	CY2027E	CY2028E
Global	2,455.0	2,570.0	2,640.3	2,720.4	2,860.1	3,030.2	3,225.3	3,454.8	3,715.2	4,015.1	4,350.2
USA	419.8	439.5	451.4	465.1	489.1	518.1	554.5	597.4	645.9	701.8	764.5
Europe	515.6	539.7	554.4	571.2	600.6	636.3	670.8	708.3	754.1	803.0	861.3
India	405.1	424.1	435.6	448.8	471.9	500.0	541.0	589.1	643.6	706.6	777.6
KSA	19.6	20.6	21.1	21.8	22.9	24.5	26.4	28.7	31.2	34.1	37.4

Source: Stakeholder interactions, Frost & Sullivan Analysis

9.3.5 Growth Drivers

- **Infrastructure Development:** The increasing need for reliable electricity supply is driving substantial investments in transmission line infrastructure. Governments and private sectors are focusing on upgrading existing networks and building new ones to improve energy distribution efficiency.
- **Renewable Energy Expansion:** As the global shift towards renewable energy sources accelerates, there is a growing demand for robust transmission systems capable of handling electricity generated from wind, solar, and other renewable sources. This shift necessitates the installation of new transmission lines and the maintenance of existing ones.
- **Regulatory Compliance:** Stringent safety regulations regarding electrical installations are pushing manufacturers to produce high-quality fasteners that meet specific performance standards. This includes ensuring that fasteners can withstand extreme environmental conditions and mechanical loads.

Asia Pacific region is witnessing rapid growth driven by countries like China and India, which are heavily investing in expanding their electrical transmission networks to support urbanization and industrial growth. The increasing demand for reliable power supply is propelling the need for high-quality fasteners. Similarly, Countries within Europe are also investing significantly in upgrading their infrastructure to meet renewable energy targets, further driving demand for specialized fastening solutions in transmission line applications.

Product Offerings in the Fasteners

The offerings of fasteners for transmission line segments are diverse, catering to the specific needs of power transmission infrastructure. Some of the prominent product offerings include:

- **Huck Bolts** – Designed for structural integrity in steel lattice towers supporting high-voltage transmission lines.
- **Foundation Bolts** – Essential for anchoring structures in various construction projects.
- **Heavy Hex Structural Bolts** – Available in sizes from M10 to M48, compliant with ASTM A325 and A490 specifications, suitable for high-temperature applications.
- **HSFG (High Strength Friction Grip) Bolt Assemblies** – Engineered for high-stress structural connections, ensuring load distribution and resistance to vibration.

- Square Head Bolts – Partially threaded with a shoulder, offering durability for various applications.
- Hex Bolts and Nuts – Standard fasteners used in various applications.
- Flange Bolts & Nuts
- Shear Studs
- Plain/Pack Washers
- Spring Washers
- Socket Head Cap Screws/Bolt.
- U Bolts

Most fasteners are made from carbon steel, often hot-dip galvanized to enhance corrosion resistance, crucial for outdoor applications in harsh environments. The company offerings are manufactured according to international standards (ANSI, BS, GB) to ensure quality and reliability.

The fasteners market for transmission line segments is poised for substantial growth as infrastructure development and renewable energy initiatives gain momentum globally. With a focus on safety, durability, and compliance with stringent regulations, manufacturers are likely to innovate continuously to meet the evolving needs of the industry. This presents significant opportunities for both established players and new entrants looking to capitalize on the expanding market.

9.4 Overhead Transmission Line (OHTL) Hardware Fittings and Accessories

9.4.1 Market Overview of OHTL Hardware Fittings and Accessories

The market for overhead transmission line hardware fittings and accessories is integral to the infrastructure of electrical power distribution. The overhead transmission line market is projected to grow significantly, with estimates indicating a five-year CAGR of approximately 5.0% from CY2023 to CY2028 from 2023 to 2028. These fittings are typically made from materials like aluminum, steel, and composite materials, chosen for their strength, durability, and resistance to environmental factors. Key Components of Fittings and Accessories include:

- Insulators – Essential for supporting conductors and preventing electrical leakage.
- Clamps and Connectors – Used to secure conductors to towers and poles.
- Brackets and Mounting Hardware – Facilitate the attachment of various components to support structures.
- Crossarms – Provide lateral support for conductors on transmission poles.
- Grounding Equipment – Ensures safety by preventing electrical surges.

Key Trends

- **Smart Grid Technologies** – The integration of digital monitoring and control systems into transmission infrastructure is becoming more prevalent. This trend enhances operational efficiency and reliability, driving demand for advanced hardware fittings that can accommodate these technologies.
- **Sustainability Initiatives** – There is a growing emphasis on sustainable practices within the energy sector, leading to increased investments in environmentally friendly materials and technologies for overhead transmission lines.

- **Regulatory Support** – Government policies promoting electrification and renewable energy projects are creating a favorable environment for market growth. These policies often include incentives for upgrading existing infrastructure or building new lines.

The fittings are typically made from materials like aluminum, steel, and composite materials, chosen for their strength, durability, and resistance to environmental factors.

9.4.2 Market Size and Growth Rate

The market for overhead transmission line hardware fittings and accessories is poised for substantial growth, supported by ongoing investments in power infrastructure and the integration of renewable energy sources. As utilities seek to enhance their networks' reliability and efficiency, the demand for high-quality fittings will continue to rise, presenting opportunities for manufacturers in this sector.

Exhibit 9.8: Fasteners Demand for Transmission Line, Market Value in USD Million, Global, CY2018 – CY2028E

Country/Region	CY2018	CY2019	CY2020	CY2021	CY2022	CY2023	CY2024E	CY2025E	CY2026E	CY2027E	CY2028E
Global	370.0	380.0	387.0	395.0	407.0	420.0	435.0	455.0	478.0	505.0	535.0
Europe	92.5	95.0	96.8	98.8	101.8	105.0	108.8	112.8	117.1	122.7	128.4
KSA	3.55	3.65	3.72	3.79	3.91	4.03	4.23	4.46	4.7	5.01	5.33

Source: Stakeholder interactions, Frost & Sullivan Analysis

The overhead transmission line hardware fittings and accessories market is poised for substantial growth, supported by ongoing investments in power infrastructure and the integration of renewable energy sources. As utilities seek to enhance their networks' reliability and efficiency, the demand for high-quality fittings will continue to rise, presenting significant opportunities for manufacturers in this sector. This market witnessed a growth of 2.6% from CY2028 to CY2023, while the market is expected to surge ahead registering 5.0% CAGR from CY2023 to CY2028E, while Saudi Arabia, though a niche market is likely to grow at a much faster pace than the mature European market.

9.4.3 Growth Drivers

The factors driving demand for electrical infrastructure will have an influence on transmission line, which directly drives demand for OHTL hardware fittings and accessories. These drivers include:

- **Infrastructure Development** – Increasing investments in power infrastructure, particularly in developing regions, are driving demand for overhead transmission line hardware. Governments are focusing on expanding and modernizing their electrical grids to improve reliability and efficiency.
- **Renewable Energy Integration** – The shift towards renewable energy sources such as wind and solar power necessitates robust transmission systems capable of handling variable loads. This trend is propelling the demand for high-quality fittings and accessories that can support new energy generation methods.
- **Urbanization and Industrial Growth** – As urban areas expand and industries grow, the demand for electricity surges, leading to increased requirements for efficient power transmission systems. This growth is particularly evident in regions like Asia-Pacific, where rapid industrialization is occurring.

9.4.4 Major Indian Manufacturers & Product Offerings Company Offerings

Exhibit 9.9: Major Indian Manufacturers & Product Offerings for Overhead Transmission Line Hardware Fittings and Accessories, Global, CY2024

COMPANY NAME	PRODUCT OFFERINGS
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Ventura Transmetals Pvt. Ltd	• Transmission Line Fittings • Conductor Accessories • Tower Accessories • Substation Clamps & Connectors
Aumni Transmission Industry Pvt Ltd	• Clamps, Connectors, and Insulator Fittings • Ground Wire Accessories • OHE Fittings
Karamtara Engineering Ltd	• Insulator String Fittings • Conductor Accessories • Extra High Voltage Equipment Equipment Fittings • Vibration Dumpers • Fittings and Accessories for Substations • Fittings for Distribution Line
Pankaj International	• Huck Bolts • Heavy Hex Structural Bolts • HSFG Bolt Assemblies
IAC Electricals Pvt. Ltd	• Clamps, Shackles, U-bolts, Clevises, Yoke Plates • Galvanized Components

10 OPERATIONAL AND FINANCIAL BENCHMARKING

9.1 Financial Benchmarking

**Exhibit 10.1(a): Key financial indicators of key competitors, value in INR Million, FY2022 – FY2024
(Revenue from operations, Revenue growth, EBITDA, EBITDA margin, PAT)**

Financial Indicators	Years	Karamtara Engineering Ltd.	PMEA Solar Tech Solutions Ltd	KP Green Engineering Ltd.	Premier Energies Ltd.	Waaree Energies Ltd.	Inox Wind Ltd.	Suzlon Energy Ltd.
Revenue from Operations INR Million	FY2022	12,448.09	5,585.37	777.02	7,428.71	28,542.65	6,246.23	65,199.50
	FY2023	16,003.07	8,007.90	1,142.09	14,285.34	67,508.73	7,330.45	59,468.40
	FY2024	24,251.50	15,002.04	3,490.49	31,437.93	1,13,976.09	17,432.35	64,968.40
Revenue from Operations Y-O-Y Growth in %	FY2022	19.00%	60.02%	101.23%	5.90%	46.14%	-12.11%	97.90%
	FY2023	28.56%	43.37%	46.98%	92.30%	136.52%	17.36%	-8.79%
	FY2024	51.54%	87.34%	205.62%	120.07%	68.83%	137.81%	9.25%
EBITDA INR Million	FY2022	1,298.05	589.28	94.27	295.76	1,109.46	-3,104.08	8,276.20
	FY2023	1,536.07	887.20	208.28	782.03	8,346.43	-2,644.62	8,082.30
	FY2024	2,629.28	2,093.87	512.46	4,778.00	15,744.23	2,686.38	9,966.30
EBITDA Margin in %	FY2022	10.43%	10.55%	12.13%	3.98%	3.89%	-49.70%	12.69%
	FY2023	9.60%	11.08%	18.24%	5.47%	12.36%	-36.08%	13.59%
	FY2024	10.84%	13.96%	14.68%	15.20%	13.81%	15.41%	15.34%
PAT INR Million	FY2022	126.46	448.20	43.89	-144.08	796.50	-4,826.14	-1,765.50
	FY2023	423.60	274.40	121.17	-133.36	5,002.77	-6,968.37	28,872.90
	FY2024	1,026.50	1,036.39	353.91	2,313.60	12,743.77	-507.84	6,603.50

Source: Annual Reports of Companies published in RoC, MCA; Frost & Sullivan Analyst

Exhibit 10.1(b): Key financial indicators of key competitors, value in INR Million, FY2022 – FY2024 (PAT margin, ROCE, ROE, Net working capital, Net debt to equity)

Financial Indicators	Years	Karamtara Engineering Ltd.	PMEA Solar Tech Solutions Ltd	KP Green Engineering Ltd	Premier Energies Ltd.	Waaree Energies Ltd.	Inox Wind Ltd.	Suzlon Energy Ltd.
PAT Margin in %	FY2022	1.01%	7.58%	5.60%	-1.88%	2.70%	-73.87%	-2.67%
	FY2023	2.65%	3.39%	10.56%	-0.91%	7.29%	-92.38%	48.20%
	FY2024	4.23%	6.81%	10.05%	7.30%	10.96%	-2.82%	10.05%
RoCE in %	FY2022	11.12%	18.31%	20.40%	0.28%	9.90%	-14.79%	18.81%
	FY2023	14.55%	16.60%	41.61%	2.45%	46.77%	-11.24%	19.37%
	FY2024	24.15%	31.38%	27.81%	23.61%	40.06%	4.17%	23.34%
RoE in %	FY2022	3.14%	50.91%	24.09%	-4.67%	20.42%	-30.70%	5.14%
	FY2023	9.85%	22.33%	45.64%	-3.31%	44.15%	-39.35%	-237.97%
	FY2024	20.45%	55.17%	23.64%	43.73%	43.01%	-2.98%	26.31%
Net debt to equity	FY2022	0.97	1.18	0.83	0.62	-0.44	0.82	-1.67
	FY2023	0.65	1.74	0.43	1.26	-0.81	1.25	1.40
	FY2024	0.84	1.55	-0.47	1.53	-0.86	1.88	-0.08
Fixed Asset Turnover Ratio	FY2022	2.75	5.56	4.83	1.58	5.05	0.49	8.43
	FY2023	3.19	7.54	5.83	2.45	6.81	0.48	8.54
	FY2024	4.26	11.66	13.13	2.64	9.92	1.17	9.00
Capacity Utilization	FY2022	43.45%	NA	NA	NA	NA	NA	NA
	FY2023	51.90%	NA	NA	NA	NA	NA	NA
	FY2024	67.91%	NA	NA	NA	NA	NA	NA

Source: Annual Reports of Companies published in RoC, MCA; Frost & Sullivan Analysis

In FY2024, Karamtara 's revenue from operations, EBITDA, PAT and ROCE were one of the highest among its solar energy industry peers in India. In addition, Karamtara Engineering Ltd ranked 4th in both revenue from operations and RoCE (Return on Capital Employed) and 5th in both EBITDA and PAT among its solar energy industry peers, reflecting its strong position in the market.

9.2 Operational Benchmarking

10.1.1 Karamtara Engineering Ltd.

Company Overview

- **Karamtara Engineering Ltd, founded in 1996, is a global leader in Engineering and Manufacturing, with a strong focus on Renewable Energy. Specializing in the Transmission and Distribution (T&D) sectors, the Company offers a diverse range of products, including solar and wind energy components, structural steel, and transmission line fittings. With ten manufacturing facilities across India, Italy, and soon Saudi Arabia, Karamtara Engineering Ltd is committed to driving sustainable energy solutions and making a positive impact through its Corporate Social Responsibility initiatives. Karamtara Engineering Ltd is one of the largest manufacturers of solar mounting structures and trackers in India, with a significant installed capacity of 567,000 MTPA as of September 30, 2024.**

Product Offerings

- Karamtara Engineering Ltd. manufactures a range of steel structures and components for solar PV mounting systems, catering to both fixed tilt and tracker applications. Their product lineup includes ground and rooftop solar Module Mounting Structures, H-beams, piers, steel piles, torque beams and tubes, transmission tower products (including lattice towers for transmission lines), as well as fasteners such as bolts, nuts, and washers.

Key Clients

- Gamechange Solar Services India Pvt Ltd
- Soltec Energías Renovables, S.L.U.
- Nextracker US
- M/S Al Babbain Power & Telecommunic
- Waaree Renewable Technologies Ltd

- Mahindra Susten Private Limited
- Elecnor Servicios Y Proyectos S.A.U.

10.1.2 PMEA Solar Tech Solutions Ltd.

Company Overview	• PMEA Solar Tech Solutions Limited is a company focused on manufacturing and supplying solar trackers and fixed tilt components. These products are integral to the installation and operation of solar energy systems. Strategically located near Mundra port, their Mundra facility enjoys a prime location for efficient logistics and distribution resulting in reduced turnaround times and cost savings.
Product Offerings	• The company makes solar tracking and mounting products and utilizes advanced processes and machinery. Their capabilities include sheet metal fabrication, robotic and seam welding, and conveyorized powder coating. They operate dedicated press lines for MMA Rails and extra heavy MMA products and employ spot welding, bending, and drilling SPMs (Special Purpose Machines), along with a bend saw
Key Clients	• Nextracker LLC • Sterling and Wilson

10.1.3 KP Green Engineering Ltd.

Company Overview	• KP Green Engineering Limited, formerly known as KP Buildcon Pvt. Ltd., serves as the parent company within the KP Group. The KP Group is recognized for its diverse portfolio and expertise in infrastructure development, engineering solutions, and green energy initiatives. Company has covered major market share of transmission industries, telecom industries, substation structure, isolator hybrid tower, solar industry (fixed type and tracker) among others
Product Offerings	• The company's product portfolio includes lattice towers structures, substation structures, solar Module Mounting Structures, cable trays, earthing strips, beam crash barriers.
Key Clients	• Airtel • ABB • BSNL • GMR • Lupin • SRF

10.1.4 Premier Energies Ltd.

Company Overview	• Founded in 1995, Premier Energies Ltd. is a leading integrated manufacturer of solar cells and modules. Supported by GEF Capital, a Washington, D.C.-based private equity investor, the company leverages cutting-edge technology to develop advanced photovoltaic products and solutions. Premier Energies Ltd. is recognized for its innovation and commitment to sustainable energy solutions.
Product Offerings	• Premier Energies Limited is a solar cell and panel manufacturer that offers a variety of products that includes integrated solar cells, monofacial and bifacial modules among others
Key Clients	• NTPS • Tata power solar • Panasonic • Luminous

10.1.5 Waaree Energies Ltd.

Company Overview	• Waaree Energies Limited (WEL), established in 1990, is India's largest solar PV module manufacturer. The company began its solar PV module manufacturing operations in 2007, aiming to deliver high-quality, cost-efficient, and sustainable energy solutions to diverse markets globally.
Product Offerings	• Waaree Energies Limited (WEL) stands as India's largest solar PV module manufacturer, with a total installed capacity of 12 GW. The company leverages advanced technologies, including N-type TOPCon, N-type HJT, and P-type PERC. Its versatile module offerings cater to various applications, such as ground-mounted utility-scale PV plants, rooftop installations, and floating PV systems.
Key Clients	• Adani • Aditya Birla • Cello • Mondelez • L&T • Sharada construction • Mumbai metro • MEDA

10.1.6 Inox Wind Ltd.

Company Overview	• Inox Wind Ltd, incorporated on March 6, 2020, focuses on wind energy generation and sales. The company also specializes in providing Erection, Procurement, and Commissioning (EPC) services for wind farms and holds strategic business interests in the renewable energy sector.
Product Offerings	• Inox Wind Ltd. has four manufacturing facilities in Gujarat, Himachal Pradesh, and Madhya Pradesh. Company produce blades, tubular towers, hubs, and nacelles. Their flagship product is the 2 MW DFIG. Inox Wind Ltd. is expanding its offerings to include crane services.
Key Clients	• Integrum Energy Infrastructure Ltd • Continuum Green Energy

10.1.7 Suzlon Energy Ltd.

Company Overview	• The Suzlon Group is a leading global provider of renewable energy solutions, transforming and innovating the way sustainable energy is harnessed worldwide. With a presence in 17 countries spanning Asia, Australia, Europe, Africa, and the Americas, Suzlon Energy Ltd. is driving the transition to a greener future through its expertise in renewable energy systems.
Product Offerings	• Suzlon Energy Ltd. provides comprehensive 360-degree solutions for wind energy projects. With over 13,060 wind turbines installed across six continents and 14 advanced manufacturing facilities in India, Suzlon Energy Ltd. has established itself as a symbol of innovation and competitive edge. Company's Wind Turbine Generators integrate cutting-edge technology across blades, nacelles, towers, and foundations, delivering reliability and sustainability. These WTGs boast a proven track record of helping customers achieve maximum returns on investment while advancing renewable energy adoption.
Key Clients	• NTPC • ITC • Reliance • Jindal Renewables • Adani Renewables • ACC • GAIL

Exhibit 10.2: Product offerings of leading players in India, renewable energy structures, transmission towers and fasteners

	Hardware fittings and accessories	Solar tracker piles and piers	Lattice tower for transmission lines	Structural steel profiles	Fabrication and Galvanizing	Solar MMS	Solar torque tubes	Z-posts	Post couplers	90-degree hat purlins	Fasteners	OHTL hardware fittings and accessories	PV module	Solar Cells	Tubular Tower for wind
Karamtara Engineering Ltd	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓ *
PMEA Solar Tech Solutions Ltd	✓				✓	✓	✓		✓	✓					
Purshotam Profiles Pvt. Ltd.				✓	✓	✓	✓			✓					
KP Green Engineering Ltd			✓	✓	✓	✓		✓		✓					✓

Source: Secondary research, Frost & Sullivan Analysts

*Note: The facility is being set up in Bhuj and is currently under construction.

Karamtara Engineering Ltd is one of the largest players in India in terms of number of product offerings in the solar sector as of September 30, 2024. In FY2024 and the six months ended September 30, 2024, the Company manufactured an aggregate of 121,776 MTPA (~3.4 GW) and 64,863 MTPA (~1.8 GW) of piers and piles, respectively.