Crisil
Intelligence

Industry report on infrastructure and utilities sectors

Adani Enterprises Limited

June 2026

by S&P Global

Crisil
Intelligence

Contents

Module 1: Global and Indian macro economy

India to outpace major economies next fiscal

Before the war, the global economy was performing better than expected, laying the groundwork for upward revisions to forecasts.

The global economy has, to date, withstood a series of shocks, this time a military conflict engulfing the West Asia since the end of February is testing this resilience. This is the latest culmination in a series of events that have been reshaping international relations and raising geopolitical tensions markedly across all regions in recent years.

For calendar year 2026, the International Monetary Fund (IMF) has projected the global economy to grow at 3.1%, from 3.4% in 2025.

The United States (US) economy is projected to expand 2.3% in 2026 with growth supported by fiscal policy and the lagged impact of monetary policy rate cuts in 2025, even as the rise in trade barriers since April 2025 continues to weigh on the level of activity.

The euro area's growth is expected to moderate to 1.1% in 2026 from 1.4% in 2025. The slowdown reflects the impact of the West Asia conflict, which adds to the persistent drag from the higher energy prices since Russia-Ukraine conflict. The outlook is further constrained by the real appreciation of the euro relative to currencies of countries exporting similar products. The positive effects of planned increases in defense spending are expected to emerge only gradually over the coming years.

The United Kingdom's (UK) GDP growth is projected to slow to 0.8% in 2026 from 1.3% in 2025. The slowdown is attributed to the impact of the war in West Asia and a slower pace of monetary easing.

Japan's GDP growth is projected to slow at 0.7% in 2026 from 1.2% in 2025. The outlook is supported by fiscal stimulus package announced by the new government, stronger domestic-demand-driven carryover from 2025, and government measures aimed at limiting effects of higher energy prices. These factors are expected to be partly offset by weaker external demand and the broader economic effects of the West Asia conflict.

China's GDP growth is projected at 4.4% in 2026, lower from 5.0% in 2025. This marks a revision upward relative to the October 2025 outlook, reflecting the US tariff rates on Chinese goods and domestic stimulus measures, which are expected to help offset the adverse effects of West Asia conflict.

India's growth rate too is expected to slow to 6.6% in fiscal 2027 from 7.6% in fiscal 2026 because of higher crude oil and other commodity prices, softer global growth amid the conflict and forecasts of a below-normal monsoon.

Table 1: India expected to emerge relatively stronger amid the global uncertainties

On-year (%)	CY19	CY20	CY21	CY22	CY23	CY24	CY25	CY26P
World	3.0	-2.7	6.6	3.8	3.5	3.3	3.4	3.1
Advanced economies	1.9	-3.9	6.0	3.0	1.7	1.8	1.9	1.8
- Euro area	1.6	-6.0	6.4	3.6	0.4	0.9	1.4	1.1
- US	2.6	-2.1	6.2	2.5	2.9	2.8	2.1	2.3
- UK	1.6	-10.3	8.6	4.8	0.4	1.1	1.3	0.8
- Japan	-0.4	-4.2	2.7	1.0	1.2	-0.2	1.2	0.7
Emerging and developing economies	3.8	-1.8	7.0	4.3	4.7	4.3	4.4	3.9
- China	6.1	2.3	8.6	3.1	5.4	5.0	5.0	4.4

On-year (%)	CY19	CY20	CY21	CY22	CY23	CY24	CY25	CY26P
- India*^	3.9	-5.8	9.7	7.6	7.2	7.1	7.6	6.6

**India numbers are on a fiscal year basis (April-March), with calendar year 2026 corresponding to fiscal 2027; other countries are on a calendar year basis. Estimates for India as per the Ministro of Statistics and Plan Implementation (MOSPI) and Crisil Intelligence; E – estimated; P – projected; Euro area includes Germany, France, Italy and Spain*

Source: IMF World Economic Outlook, April 2026; Crisil Intelligence

Conflict weighs on global inflation

The effects of the conflict are also weighing in on the global inflation. As per IMF World Economic Outlook 2026, the global headline inflation is projected to rise to 4.4% in 2026 from 4.1% in 2025. The main drivers are expected to be higher energy prices, supply chain disruptions, and pressure on inflationary expectations, with the impact expected to be more pronounced in commodity-importing and more vulnerable economies.

The inflation in the US is projected to rise to 3.2% in 2026 from 2.7% in 2025. Although the US is relatively less exposed as a net energy exporter, it is still expected to face upward pressure from higher global energy prices and broader commodity-market spillover linked to the conflict.

Similarly, the inflation in the euro area is expected to rise to 2.6% in 2026 from 2.1% in 2025 mainly driven by higher energy prices and supply chain disruptions associated with the West Asia conflict.

The inflation in UK on the other hand is expected to ease to 3.2% in 2026 from 3.4% in 2025. The decline mainly reflects the fading impact of earlier one-off changes in regulated prices.

Japan too is expected to witness upside in inflation with IMF forecast projected at 2.6% in 2026 from 2.3% in 2025. However, the pass-through to consumers is expected to partly contained by government measures.

China's inflation is expected at 1.2% in 2026 from 0% in 2025 owing to low base.

The inflation in India is expected to rise sharply to an average of 5.1% in fiscal 2027 from 2.0% in fiscal 2026, mainly due to a low base and broader price pressures across key segments. Upside risks stem from a possible pass-through of higher global crude oil prices, rising input and logistics costs linked to the West Asia conflict and a weaker rupee, and potential food inflation from below-normal rainfall associated with El Niño conditions.

Table 2: Inflation movement across key economies

On-year (%)	CY22	CY23	CY24	CY25	CY26P
Advanced economies					
Euro area	8.4	5.4	2.4	2.1	2.6
US	8.0	4.1	3.0	2.7	3.2
UK	9.1	7.3	2.5	3.4	3.2
- Germany	8.7	6.0	2.5	2.3	2.7
Japan	2.5	3.3	2.7	3.2	2.2
Emerging markets and developing economies					
China	2.0	0.2	0.2	0.0	1.2
India	6.7	5.4	4.6	2.0	5.1

E – estimated; P – projected

Note: The above table is on calendar year basis; for India, data is based on fiscal year, with fiscal 2027 shown in 2026. Inflation for India is Crisil Intelligence outlook.

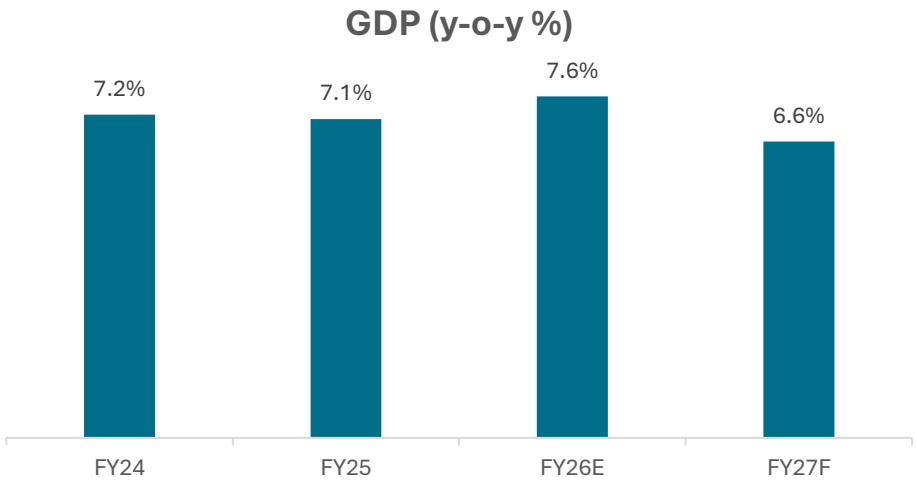
Source: IMF World Outlook, April 2026, Crisil Intelligence for India

Domestic drivers to boost India's growth

India's real gross domestic product (GDP) is projected to grow at 6.6% on-year in fiscal 2027 from 7.6% in fiscal 2026 because of higher crude oil and other commodity prices, softer global growth amid the West Asia conflict and forecasts of a below-normal monsoon.

Input cost pressures from the spike in crude oil and gas prices will weigh on growth. Global supply chain disruptions and the reduced availability of gas and other inputs will add to the pressure. The manufacturing sector, which is heavily dependent on imported inputs, is particularly vulnerable.

Figure 1: India's economy expected to grow at 6.6% in fiscal 2027



Note: F stands for forecast.
Source: NSO, Crisil Intelligence

A new GDP series ups the relevance and measurability quotient

A new national accounts series has been released with 2022-23 as the base year, superseding the 2011-12 series. The revised series incorporates new segments and administrative data sets, alongside methodological improvements such as double deflation in manufacturing wherever possible and the use of granular price data for deflators.

- The new series pegs GDP growth for fiscal 2026 at 7.6%, up from the 7.4% in the first advance estimate (FAE) based on the old series, and 7.1% in fiscal 2025. The new series underlines private consumption as the driver of growth in fiscal 2026, while the FAE under the older series called out fixed investments. Growth for the last fiscal has also been raised significantly from 6.5% in the old series.
- For fiscal 2024-26, real GDP growth stands at 7.3% under the new series, compared with 7.7% under the old series, led by broad-based downward revisions across private final consumption expenditure, gross fixed capital formation and government consumption. On the supply side, agriculture and services sectors have seen downward revisions in growth, but the manufacturing sector has seen significant upward revision of growth to 11.2% from 8.2% as double deflation has improved the real manufacturing estimates.
- The size of the economy, measured by nominal GDP, is smaller at Rs 345 lakh crore, compared with Rs 357 lakh crore under the old series for fiscal 2026. In US dollar terms, India is slightly below a $4 trillion economy.

Over fiscals 2022 to 2026, the Indian economy has outperformed its global counterparts. Going forward as well, the Indian economy will remain strong and would continue to be one of the fastest-growing economies.

In per capita terms, India's net national income at constant prices expanded 7.7% in fiscal 2026.

Table 3: Per capita NNI

Per-capita NNI	FY26 (PE) (Rs '000)		Growth of NNI per capita at current prices (%)											
	Current prices	Constant prices	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26
	208	193	11.5	9.5	9.4	10.6	9.9	9.3	5.1	-3.9	18.6	12.1	10.6	9.2	7.7

Note: P – projected. (^) Per-capita NNI as per second advance estimates of Annual GDP for FY 2025-26; Source: Ministry of Statistics and Program Implementation (MoSPI), International Monetary Fund (IMF), Crisil Intelligence

The Indian economy has performed far better than expected in fiscal 2026, driven by a stronger-than-expected surge in domestic demand and a softer-than-expected impact of India's exports given the frontloading of shipments to the US in the first four months ahead of higher tariffs coming into effect.

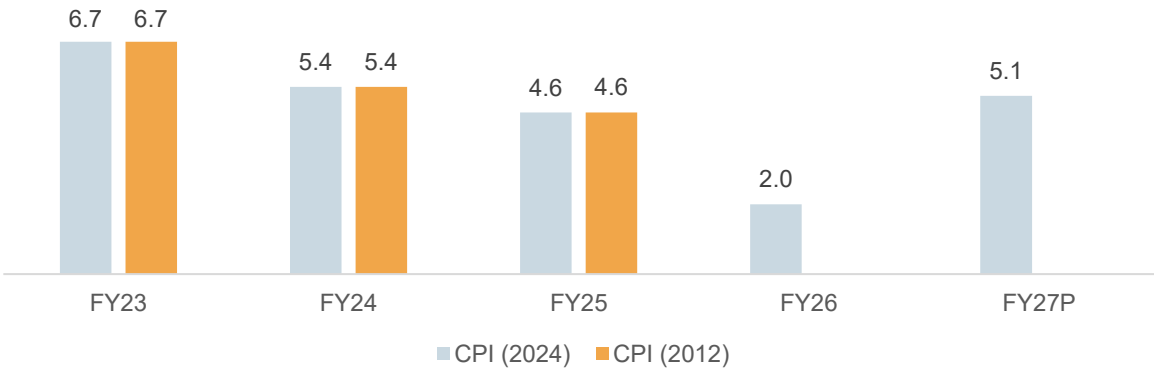
The economy is expected to maintain its growth momentum, driven by a combination of domestic factors. The government's efforts to boost private consumption, invest in infrastructure and promote economic growth will be crucial in sustaining the growth trajectory. Although government capex is expected to remain a key enabler, the continued emphasis on fiscal consolidation implies investment prospects will hinge on sustained revival in private capex.

Retail inflation projected at 5.1% in fiscal 2027

Inflation based on the revised Consumer Price Index (CPI) series, with 2024 as the base year, rose to 3.4% in March 2026 from 3.2% in February 2026, driven by upticks in both food and fuel inflation. While food inflation rose on a low base, the increase in fuel was driven by the increase in domestic cooking fuel prices.

Crisil Intelligence expects inflation based on the Consumer Price Index (CPI) to average 5.1% in fiscal 2027 from 2.0% in fiscal 2026, driven by a low-base effect and expectations of broadening price pressures across major segments. Expected below-normal rainfall amid the likely El Niño conditions during the southwest monsoon season can hurt agricultural production and exert pressure on food inflation, which is normalizing from its lows.

Figure 2: Inflation projected to rise 5.1% in fiscal 2027



Note: P = Projected, Source: Crisil Intelligence

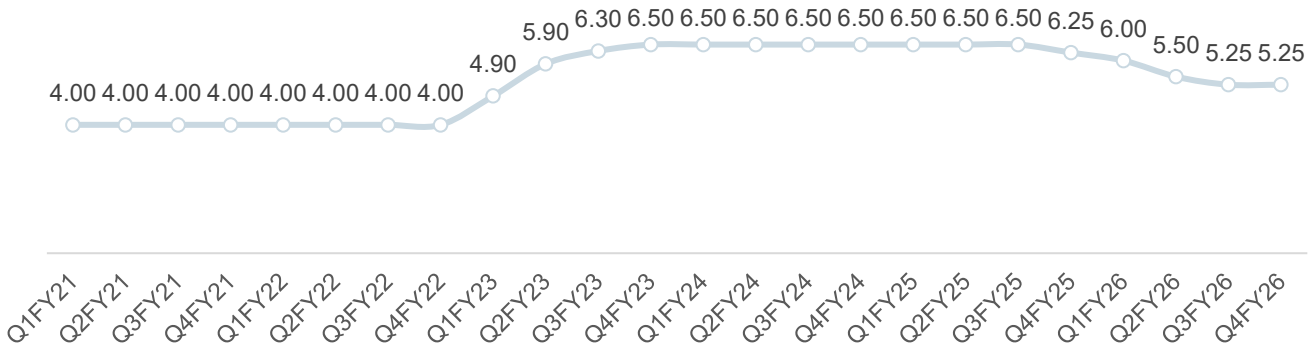
Policy rate remains unchanged in April 2026

In April 2026, the MPC kept policy unchanged at 5.25% and maintained its neutral stance allowing itself flexibility on future monetary policy actions.

The Fed, too, chose to pause its rate-cutting cycle in April 2026.

Crisil expected the MPC to maintain status quo on policy rate and monetary policy stance.

Figure 3: Repo rate in India (%)



Source: RBI, Crisil Intelligence

Table 4: Outlook for FY27

Macro parameters	FY25	FY26	FY27F	Rationale for outlook
Real GDP growth (on-year %)	7.1	7.6	6.6	Growth will be slow down by higher crude oil and other commodity prices, softer global growth amid the conflict and forecasts of a below-normal monsoon. Higher inflation on account of the disruptions to agricultural production and higher commodity prices will constrain household budgets and restrain private consumption.
CPI inflation (on-year %)	4.6	2.0	5.1	Inflation is set to risedriven by a low-base effect and expectations of broadening price pressures across major segments. A sharp rise in the cost of energy and other inputs, as well as trade and transportation, is expected to be passed by producers to consumers, raising core inflation
10-year government security yield (March average %)	6.7	6.7	7.0	A prolonged conflict will increase pressure on government finances through higher petroleum and fertiliser subsidies, even as a slowdown in domestic growth will impact tax collection. Rising yields in advanced economies are likely to keep foreign capital flows into the debt segment volatile, with a bias towards outflows.
Current account balance (% of GDP)	-0.6	-0.8	-2.2	Higher oil prices are expected to exert greater pressure on India's CAD. Goods exports are expected to be hit by global trade disruption and weakening global demand.
Exchange rate (March average, Rs/$)	84.6	92.8	93.5	India's external vulnerability has increased due to the conflict. A widening CAD will mean higher demand for the dollar, while elevated global uncertainty may lead to foreign capital outflows from emerging markets, including India, putting pressure on the rupee.

Source: NSO, RBI, Budget documents, Ministry of Finance, Crisil

Government's capex thrust to continue this fiscal

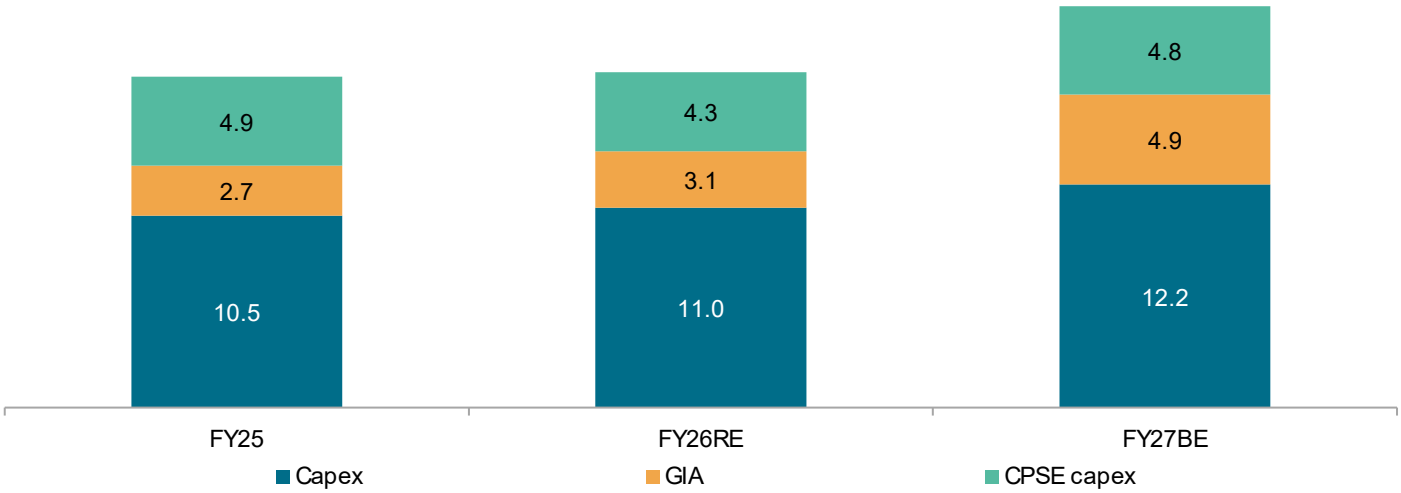
The Centre has been the bulwark of investments over the past five fiscals, building infrastructure for long-term economic growth. After rapidly increasing capex in the years following the pandemic, the government is now aiming to maintain its share in GDP.

But for economy to durably grow at a rapid pace, the investment-to-GDP ratio needs to rise further. This is where the private sector needs to step in.

In this context, the Union Budget has retained the public investment momentum while ushering in process reforms that can encourage private capex over time.

Central government capex for fiscal 2027 is budgeted at Rs 12.2 trillion, up 11.5% from Rs 11 trillion in fiscal 2026 (revised estimates).

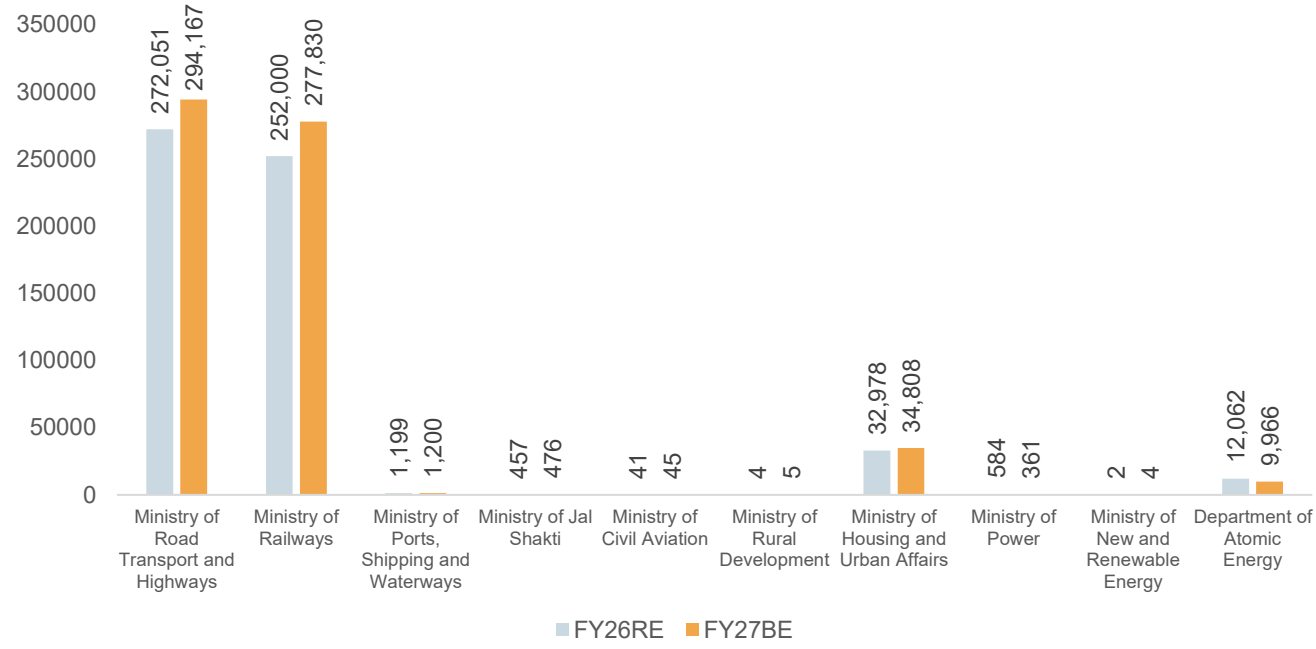
Figure 4: Allocations for capex components (Rs lakh crore)



Note: GIA refers to grants-in-aid for creation of capital assets
Source: Budget documents, CEIC, Crisil

The Ministry of Road Transport and Highways received the highest capex allocation (Rs 2.9 lakh crore), followed by the Ministry of Railways (Rs 2.8 lakh crore), rising 8.1% (vs -4.7%) and 10.3% (vs 0%), respectively, for the next fiscal, reflecting commitment to create infrastructure. The two ministries will cumulatively have a 46.3% share in the capex for next fiscal.

Figure 5: Capex focused on infrastructure creation (Rs crore)



Source: Budget documents, Crisil Intelligence

These sectors act as catalysts for growth in the related industrial sectors as well. For instance, according to a study by the National Institute of Public Finance and Policy, every rupee allocated to capex has a multiplier effect of 4.8 on the economy compared with 0.96 for revenue expenditure.

Apart from the government's support for investments in the economy through its infrastructure spending, the push for consumption demand through tax concessions should incentivise the private sector to step up investments.

Contribution of key sectors to gross value added

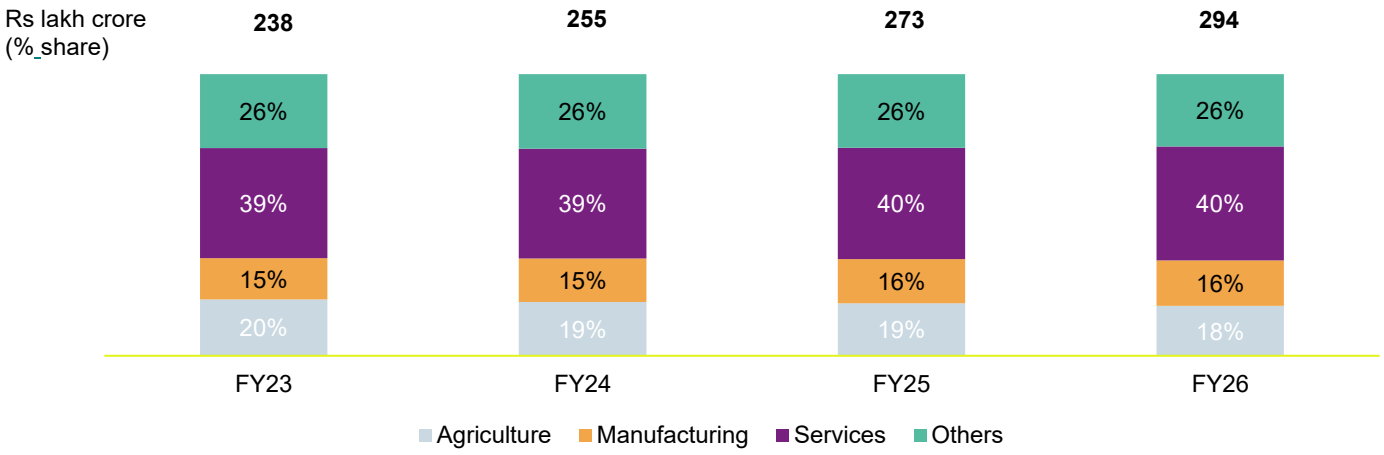
India's gross value added (GVA) has grown consistently over the years, except in fiscal 2021, when it was affected by the pandemic-induced lockdown. The services sector is a significant contributor, with growth in services exports, which account for half of the country's overall exports, has outpaced economic growth.

The manufacturing sector has contributed to the resilient performance of the economy in three consecutive financial years after rebasing. The sector attained double-digit growth rates of 13% and 12%, respectively, in fiscals 2024 and 2026.

The growth in manufacturing GVA is attributable to government initiatives such as the Atmanirbhar Bharat campaign, Make in India and the Production Linked Incentive (PLI) scheme. While the share of industry in GVA averages 15%, a large percentage of the PLI capex that is yet to be commissioned is expected to boost the share of both manufacturing and exports.

Agriculture GVA clocked a CAGR of 3.08% between fiscals 2023 and 2026, driven by the subsidy support to farmers and other government initiatives such as the Pradhan Mantri Krishi Sinchayee Yojana, Dhan Dhaanya Krishi Yojana etc. Normal monsoon, government schemes and favourable agricultural commodity prices over the past two fiscals have aided the growth.

Figure 6: Contribution of key sectors (industry, agriculture and services) to GVA



Source: MoSPI, Crisil Intelligence; 2024-2025 numbers are second revised estimates, and 2025-2026 numbers are second advance estimate

Private consumption is holding up in fiscal 2027

With a share of more than 56% in the GDP, private consumption remains the key driver of the economy. The positive effects on private consumption from fiscal support, including income tax cuts, rationalisation of goods and services tax (GST) rates and unconditional cash transfers by states, are expected to support consumption demand in fiscal 2027. Some moderation in consumption growth is expected towards the latter part of fiscal 2027 as the one-time benefits of the tax cuts fade.

- **Tax relief measures to prop up consumption**: The rejig of income tax rates under the new tax regime will increase the disposable income of the middle class. The tax rebate limit has been raised to Rs 12 lakh from Rs 7 lakh, which will lead to tax savings of ~Rs 80,000 annually for an individual earning Rs 12 lakh. Tax slabs have also been revised, which will reduce the tax burden across income levels. These measures will durably support spending by the middle class beyond fiscal 2026 as well, though some of the increase in disposable income can also go towards savings and debt repayment.

- **Support to consumption via key flagship schemes continues**: Higher allocations for key infrastructure and employment-creating schemes such as the Pradhan Mantri Awas Yojana (1.4 times higher on-year on revised estimates), Pradhan Mantri Gram Sadak Yojana (up 0.7 times on revised estimates) should support incomes and consumption in fiscal 2027. These schemes primarily benefit lower-income households, which have a greater propensity to consume.

- **GST rate revision:** The revised GST, which came into effect on September 22, 2025, reduced the tax rates on mass consumption items, including automobiles and consumer durables such as air conditioners and televisions, and fast-moving consumer goods. This is expected to provide a boost to domestic consumption. The timing of the revision was also favourable given the prevailing global economic uncertainty and the onset of the festival and wedding seasons, when consumer spending typically rises. Lower GST rates are expected to translate into reduced prices across key categories such as FMCG, consumer durables and automobiles. In these segments, the benefit is likely to be passed on directly to consumers. However, in sectors such as construction, the extent of the impact will need to be monitored. Further, the GST anti-profiteering provisions could limit any significant improvement in margins, as companies will be required to pass on a substantial portion of the tax savings to consumers

- **Rate cuts:** The Monetary Policy Committee (MPC) of the Reserve Bank of India (RBI) maintained the policy stance and decided to keep the policy rates unchanged at 5.25% in April 2026. Lower interest rates are expected to support consumption as they are gradually transmitted to other interest rates (such as those on auto and housing loans), thereby lowering borrowing costs.

Regulatory and policy developments that could drive the private capex cycle

- **Government push for infrastructure development:** The National Infrastructure Pipeline (NIP) was launched with projected infrastructure investment of Rs 111 trillion ($1.5 trillion) over fiscals 2020-2025. Sectors like energy, roads, urban infrastructure and railways have received almost 80% of the funds under the NIP. The focused infrastructure initiative will boost the economy, generate better employment opportunities and drive competitiveness.

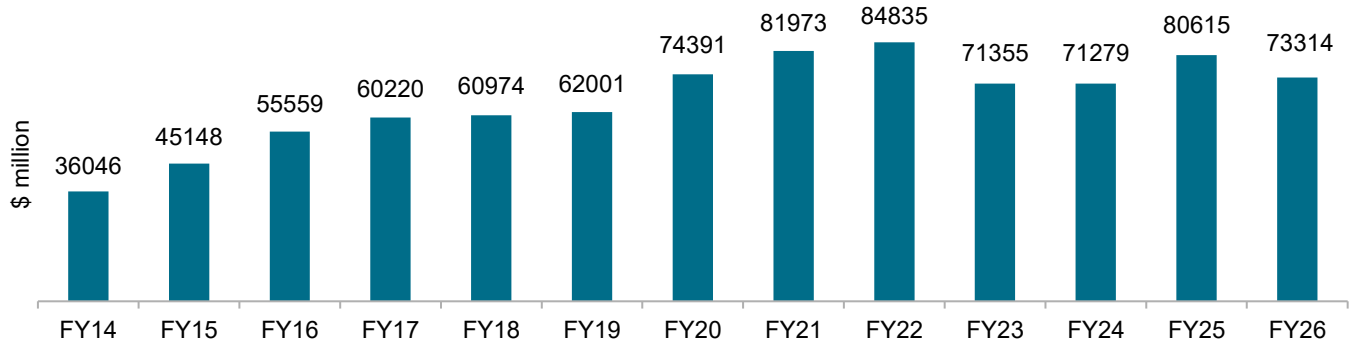
- **Private sector participation:** With government capex normalising, the private sector is expected to take the lead in furthering the investment momentum. The ability of private companies to invest is supported by their deleveraged balance sheets, healthy balance sheets of lenders and the turning of the interest rate cycle. However, the share of private investments in total fixed investment declined to 34.4% in fiscal 2024 from its peak of 41% in fiscal 2016, following a steady climb from ~33% in fiscal 2012. A revival in private capex will need to be accompanied by faster growth in machinery and equipment (or capacity addition) and intellectual property creation (or innovation).

- **PLI scheme:** As of December 31, 2025, the PLI scheme has demonstrated remarkable progress in bolstering India's manufacturing sector. With a total of 836 applications approved across 14 sectors, the scheme has attracted cumulative investments exceeding Rs 2.16 lakh crore, reflecting strong industry participation and confidence. Production and sales under the scheme have surpassed Rs 20.41 lakh crore, while cumulative exports have reached over Rs 8.3 lakh crore. Furthermore, the PLI scheme has generated over 14.39 lakh direct and indirect jobs, contributing significantly to employment creation. Incentive disbursements totalling Rs 28,748 crore as of the end of 2025. It is poised to drive significant growth in the manufacturing sector over the next two years, particularly in capital-intensive segments. Historically, these sectors have struggled with a substantial 20% cost disadvantage compared with Chinese imports. However, the scheme has yielded promising results in sectors such as mobile, telecom and pharmaceuticals

Foreign direct investment

India's gross foreign direct investment (FDI) inflows have reached $1 trillion since April 2000, bolstered by a 14% increase rise in FDI during fiscal 2025. FDI inflows increased steadily to $80.62 billion in fiscal 2025 from $36.05 billion in fiscal 2014. The total FDI inflow into India from April to December 2025 stood at $73.34 billion. This reflects India's growing appeal as a global investment destination, driven by a proactive policy framework, dynamic business environment and increasing focus on competitiveness. FDI has played an important role in India's development by providing substantial non-debt financial resources, fostering technology transfers and creating employment opportunities. Initiatives such as Make in India, outcome-oriented sectoral policies and GST have enhanced investor confidence.

Figure 7: Total FDI inflow



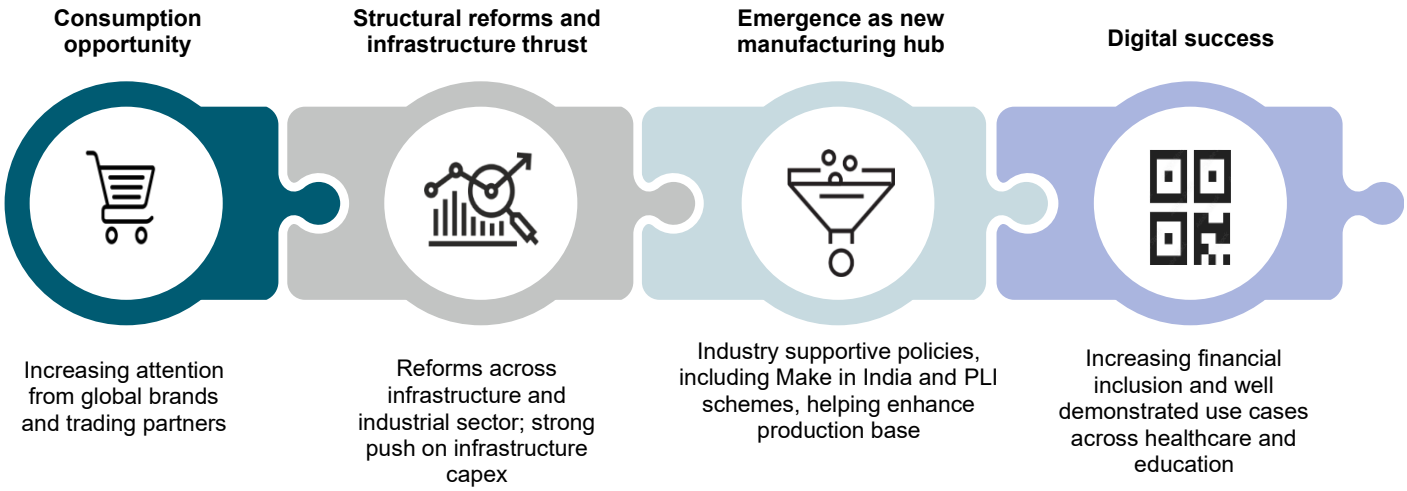
Note: Data for fiscal 2026 is up to December 2025

Source - DPIIT

Medium-to-long term growth drivers

Government initiatives on multiple fronts, encompassing digitalisation, financialization, export-oriented policies, manufacturing incentives, infrastructure development and a vast addressable market, are poised to propel the country's medium-term growth trajectory. Four key structural pillars, as highlighted below, are expected to underpin this growth. These pillars will play a crucial role in driving India's growth momentum as it navigates the complexities of a rapidly evolving global landscape.

Figure 8: Stronger fundamentals to support India's structural growth



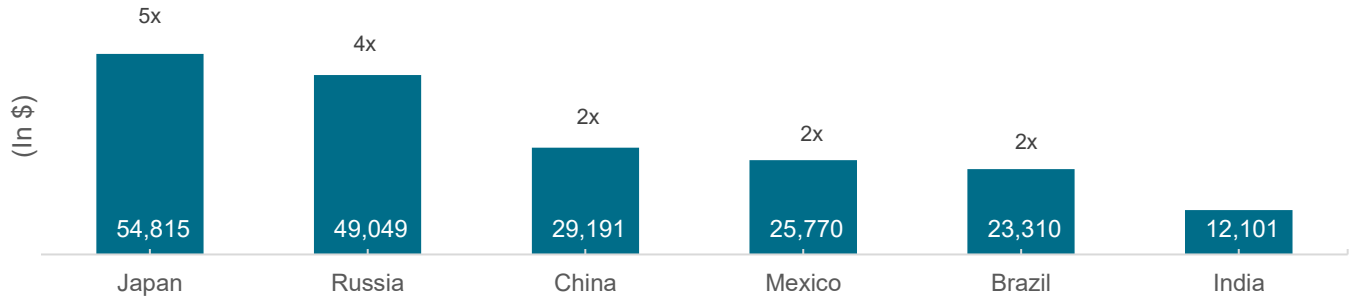
Source: Crisil Intelligence

Consumption opportunity: Reaping the demographic dividend

Per capita income comparison: With a population of over 1.4 billion, India surpassed China as the world's most populous country in 2023, accounting for more than 17% of the global population. India's largest states are comparable to entire countries in terms of population. For instance, Maharashtra, India's second most populous state, is comparable to Japan (over 122 million). Similarly, Karnataka and Gujarat are comparable to the UK and Thailand, respectively. India,

however, ranks lower in terms of nominal per capita income, which stands at ~$12,801. In comparison, China's and Japan's per capita incomes are 2x and 5x that of India's, respectively. This disparity underscores a significant opportunity that underpins the structural growth potential.

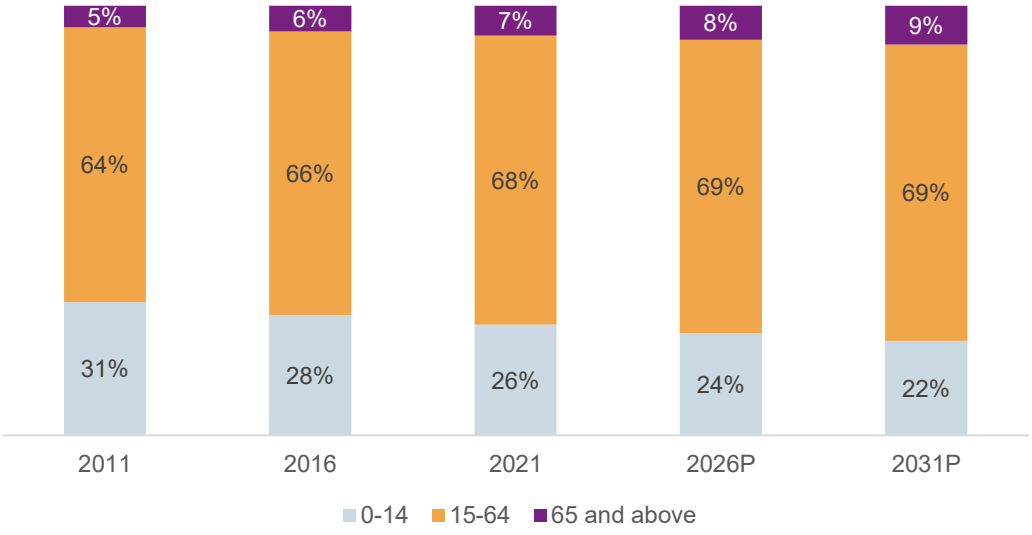
Figure 9: Per capita income comparison



Note: Numbers in the top box denote country specific per capita income compared to India; Source: IMF,2025

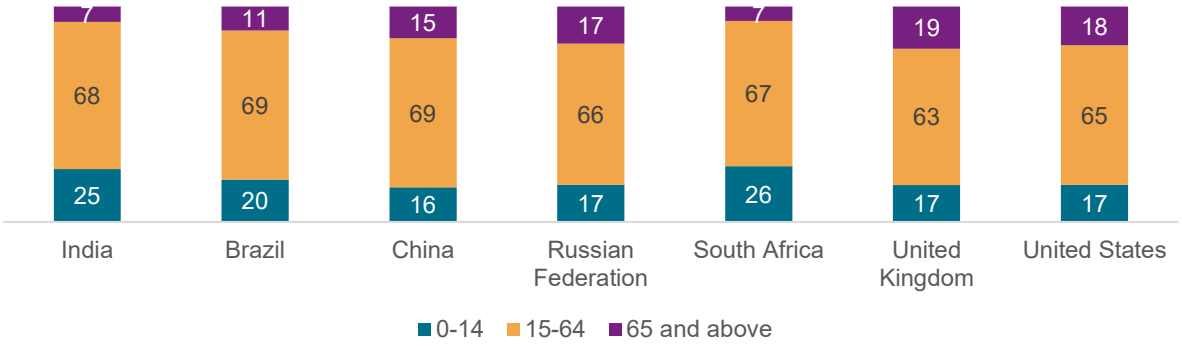
Consumption, contributing to more than 58% of the country's GDP, is growing rapidly as India has one of the world's largest youth population, the median age of which is 28 years, compared with China's 39 and Japan's 49. It is estimated that 68% of India's population falls between the ages of 15 and 64. A large share of the country's population falling in the working age group, rapid urbanisation and rising affluence will support consumption and economic growth.

Figure 10: India's demographic division by age groups



Source: World Bank: Population estimates and projections

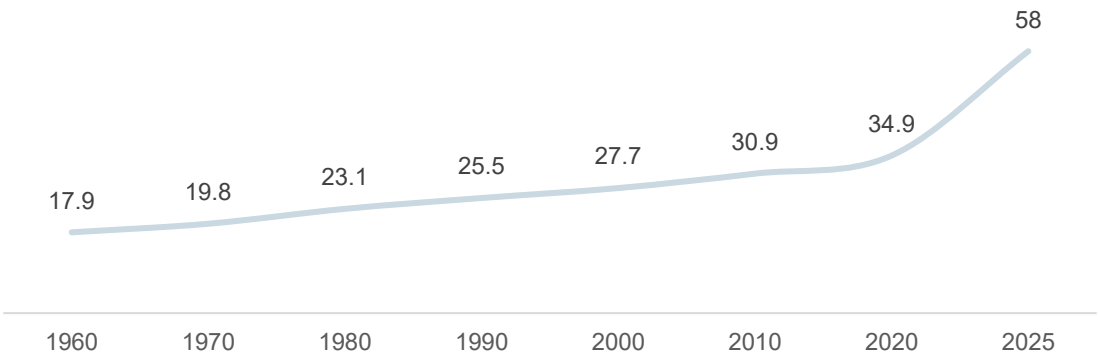
Figure 11: India's population in the 15-64 years bracket vs major economies (CY24)



Source: World Bank

- **Urbanisation**: Urbanisation, one of India's significant economic growth drivers, is expected to boost substantial investments in infrastructure development, which in turn, is likely to generate jobs, develop modern consumer services and increase the ability to mobilise savings. According to the 2025 revision of World Urbanization Prospects, the urban population in India was estimated at 58% in 2025

Figure 12: Urban population as a percentage of total population (%)



Note: E- estimated, P – projected, figures in percentage.
Source: Census 2011, World Urbanization Prospects: The 2025 Revision (UN)

- **Rising middle-income households to help sustain economic growth**

Middle-income households, annually earning Rs 0.2-1.0 million, have been increasing over the past decade and this trend would continue due to expansion in GDP and disposable incomes. Crisil Intelligence estimates India had 103 million middle-income households in fiscal 2022 and the number is likely to surge to 181 million by fiscal 2030.

Key government initiatives, such as the Skill India Mission, aim to create and implement comprehensive skill development training programmes to bridge the gap between industry demand and skill requirements, catalysing the transition from low-income to middle-income group.

The Make in India initiative targets the creation of a global design and manufacturing hub, with a focus on developing a robust manufacturing sector, elevating the country's economic trajectory and generating employment opportunities. The initiative aims to make India self-reliant.

Such initiatives have had a profound impact on the micro, small and medium enterprises (MSME) sector, enhancing employability and providing support to the middle class. MSMEs, the backbone of the economy, account for ~30% of the GDP and 46% of the exports, and generate employment for 250 million people.

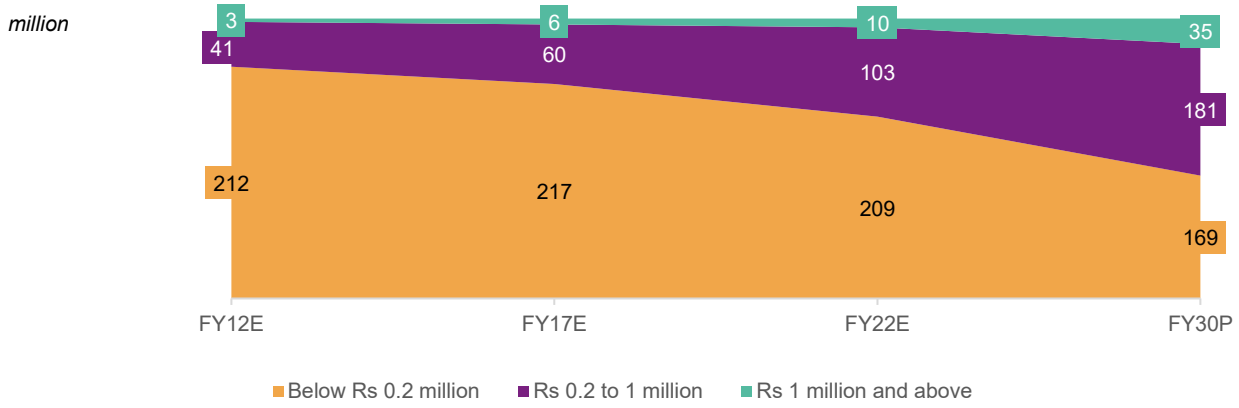
Financial inclusion has improved significantly in the country with the share of bank account holders increasing to 89% in fiscal 2025 from 78% in fiscal 2021 and 35% in fiscal 2014 (Source: Global Findex Database). The increase can largely be attributed to the government's efforts to promote financial inclusion and the proliferation of supporting institutions. As a result, more citizens have access to formal financial services, enabling them to participate in the organised economy and improve their economic prospects. Many households that have transitioned to the middle-income bracket from the low-income bracket in the past few years are likely to be from semi-urban and rural areas.

According to the National Sample Survey (NSS) 76th round (2018), 83.3% of households resided in pucca dwellings, compared with 74.6% in the NSS 69th round (2012).

Crisil Intelligence believes that the personal income tax changes made in the budget for fiscal 2026, including exemption from direct tax, for individuals earning less than Rs 1.2 million per annum, will boost the purchasing power of the middle-class population, leading to a rise in their contribution to economic growth.

Crisil Intelligence believes that improvement in literacy levels (from 73 in 2011 to 80.9 in 2024), better access to information and awareness, increase in the availability of basic facilities and improvement in road infrastructure (the length of India's roadways has risen to 6.7 million km in 2024 from 3.4 million km in 2001) have increased the aspirations of the middle-income households, which is likely to translate into higher demand for financial products and opportunities for financial services providers.

Figure 13: Middle-income households to log a CAGR of 9% over fiscal 2012-30



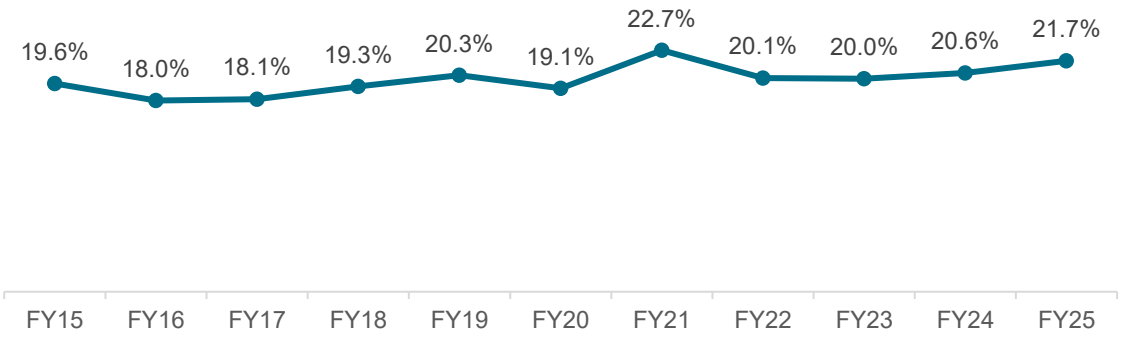
Note: E: Estimated, P: Projected
Source: National Council of Applied Economic Research, Crisil Intelligence

- **Rising affluence:** India's affluence has increased over the past decade, driven by rapid economic growth, urbanisation and expanding middle class, boosting disposable incomes, consumer spending and appetite for credit. This is reflected in the growth of the credit card market, where the value rose to Rs 21.7 trillion in fiscal 2026 from Rs

9.72 trillion in fiscal 2022, a CAGR of 22%. The growth was driven largely by online spending that accounted for nearly half of all credit card transactions. The expansion is expected to continue, led by higher adoption of digital payments, expansion of e-commerce and the rising aspirations of the burgeoning middle class.

- **Savings in India:** Household savings (as a percentage of GDP) increased to 22.69% in fiscal 2021 from 19.13% in fiscal 2020. However, savings moderated to 21.7% in fiscal 2025 on account of a faster rate of borrowing than saving since the pandemic; significant retail credit push by lenders; an increased willingness among individuals to borrow, particularly the younger demographic; and enhanced access to lenders, facilitated by technological advancement. Crisil Intelligence expects India to remain a high-savings economy on account of its higher gross domestic savings (GDS) rate compared with the global average.

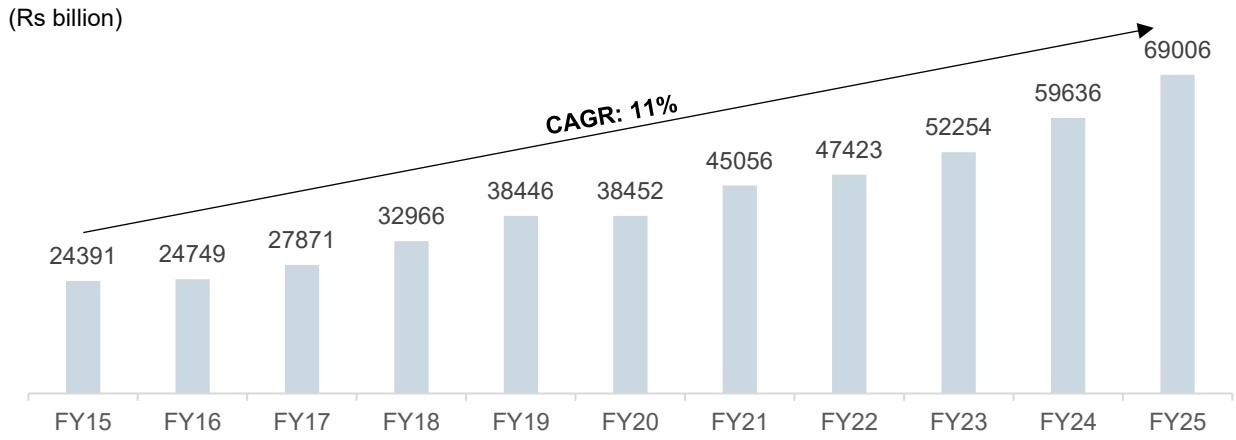
Figure 14: Household savings as a percentage of GDP moderated in fiscals 2023 and 2024



Note: Fiscal 2025 figures are first revised estimates

Source: MOSPI's second advance estimate for fiscal 2026, NSO, Crisil Intelligence

Figure 15: Growth in household savings



The data is for the financial year ending March 31.

Source: MOSPI, Crisil Intelligence

In fiscal 2027, Crisil expects GDP growth to slow to 6.6% from 7.6% in fiscal 2026 because of higher crude oil and other commodity prices, and softer global growth amid the conflict and forecasts of a below-normal monsoon. Input cost

pressures from the spike in crude oil and gas prices will weigh on growth. Global supply chain disruptions and the reduced availability of gas and other inputs will add to the pressure. The manufacturing sector, which is heavily dependent on imported inputs, is particularly vulnerable. Below-normal rainfall amid the onset of El Niño conditions is expected to impact agricultural production. Inflation based on the Consumer Price Index (CPI) to average 5.1% in fiscal 2027 from 2.0% in fiscal 2026, driven by a low-base effect and expectations of broadening price pressures across major segments. The benchmark 10-year G-sec yield to average 7.0% by March 2027 from 6.7% in March 2026, driven by increased pressure on government finances in fiscal 2027, tighter global financial conditions, volatile foreign capital flows and pressures on domestic liquidity. Current account deficit (CAD) rose to 2.2% of GDP in fiscal 2027 from an estimated 0.8% last fiscal. Higher oil prices are expected to exert greater pressure on India's CAD. Oil, as a commodity, remains the biggest source of India's overall goods trade deficit (36% in fiscal 2026). It is noteworthy that India's oil trade deficit was trending higher in the past two fiscals even when crude oil prices were falling. This fiscal, with crude oil prices rising, the pressure on oil trade deficit will increase. Elevated gas and fertilizer prices will put further pressure on the import bill. The rupee to average 93.5 dollars in March 2027 compared with 92.8 in March 2026 amid high volatility. India's external vulnerability has increased due to the conflict. A widening CAD will mean higher demand for the dollar, while elevated global uncertainty may lead to foreign capital outflows from emerging markets, including India, putting pressure on the rupee.

Module 2: Mining services, commercial mining and integrated resource management

Mining – non coal mining

Overview of the structure of the mining industry – non-coal

India is well-endowed with natural resources, particularly minerals, which serve as raw materials for many industries, paving the way for rapid industrialization and infrastructural development. The mineral and mining industry of India is a key economic driver as well as an enabler for the country. While the mining industry accounts for ~2% of India's GDP, it has far-reaching impacts. Not only does it create a significant amount of employment in relatively backward states in eastern and central India, but it also sustains behemoth industries such as steel, cement, and aluminium.

India's overall mining industry can be classified into two segments: coal and non-coal. While coal continues to account for over 50% of India's mine production, other minerals have also seen significant growth over the past few years.

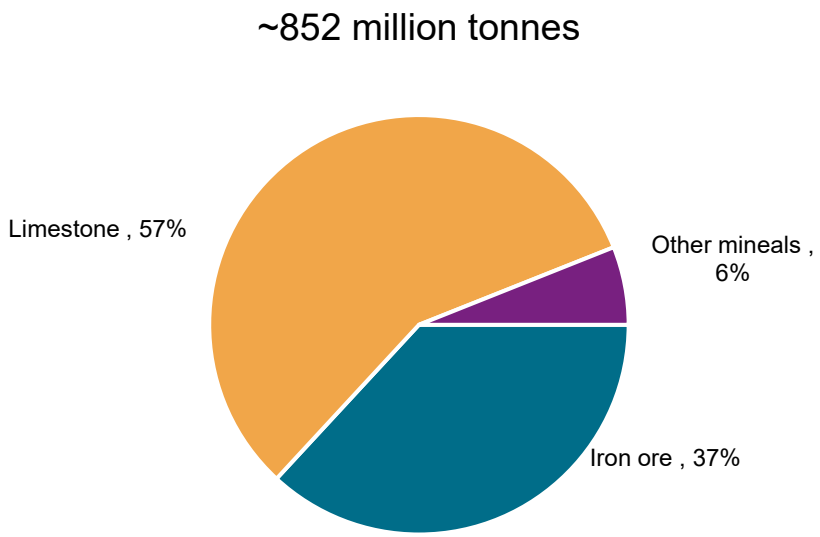
The non-coal sector is largely dominated by two minerals – iron ore and limestone, the key inputs to the steel and cement industries, accounting for around 94% of the non-coal mineral output in fiscal 2026 by volume. The remaining 6% is largely led by bauxite, copper concentrate, zinc and lead concentrate, and manganese ore.

The total number of operating mines for major minerals (non-coal) in India is estimated at 1,206 (as of fiscal 2024), which has decreased from 1,319 in fiscal 2022 due to the closure of smaller and older mines. Among the states, Madhya Pradesh has the highest number of mines, followed by Gujarat, Karnataka, Andhra Pradesh, Rajasthan, Odisha, Chhattisgarh, Maharashtra, Tamil Nadu, Telangana, and Jharkhand.

Overview of India's non-coal mining sector

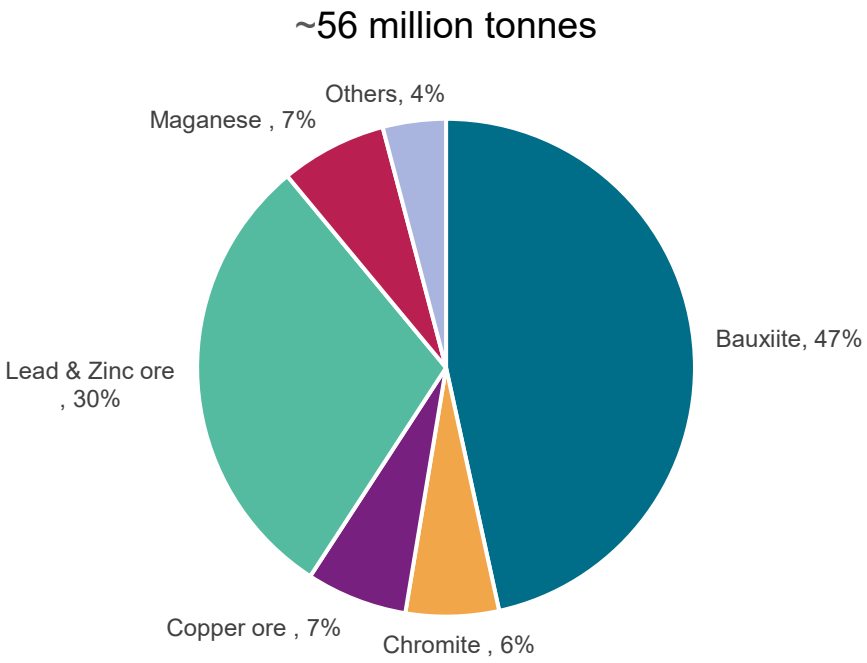
Minerals are valuable natural resources. They constitute the vital raw materials for many basic industries and are a major resource for development. The Indian mining sector (non-coal) makes a significant contribution towards the economy, with the total value of major mineral production (excluding atomic, fuel minerals, and minor minerals) during fiscal 2025 estimated at Rs 1.5 trillion. While metallic minerals account for ~43% of the total volume of mineral production, non-metallic minerals (including minor minerals) account for the remaining 57%.

Figure 16: India's total mineral production in fiscal 2026



Source: Ministry of Mines, Crisil Intelligence

Figure 17: Share of other key minerals in fiscal 2026

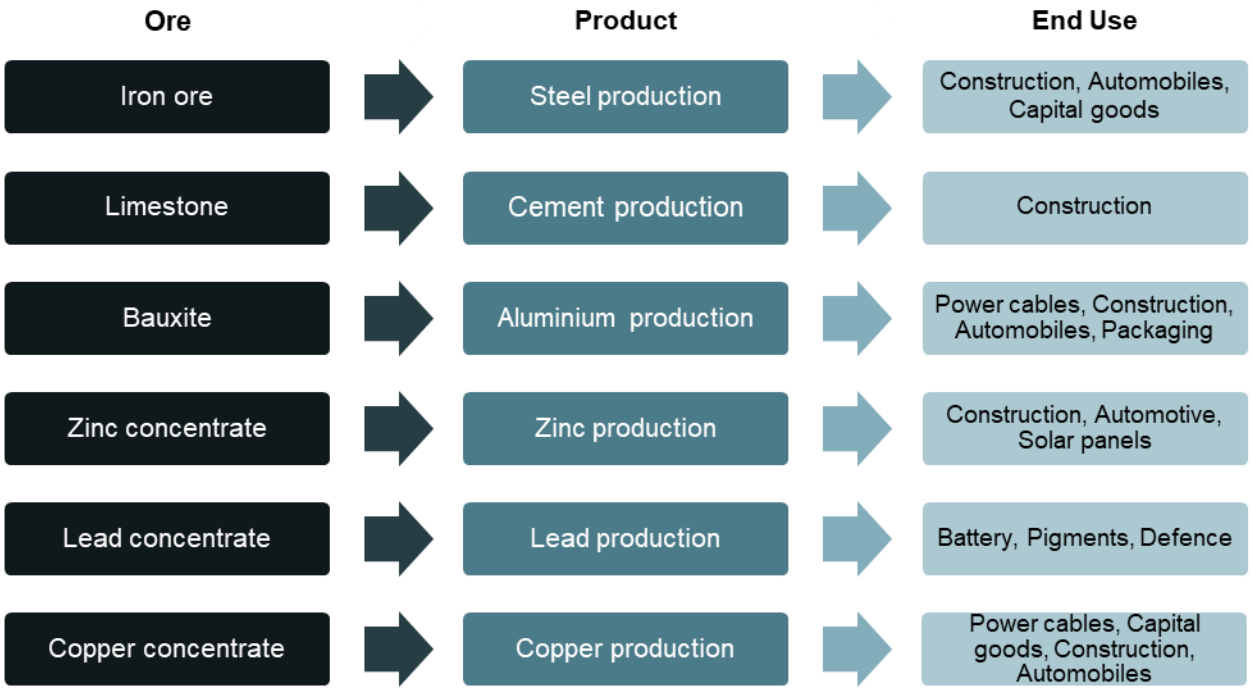


Source: Ministry of Mines, Crisil Intelligence

Assessment of key demand drivers of India's non-coal mining sector

While overall economic development remains the key driver for the Indian mining sector, each of the different minerals has its own downstream uses. For example, consumer durables and automobiles are key consumers of aluminium, which drives demand for bauxite; however, the same has no impact on limestone, which is primarily used in the manufacture of cement.

Figure 18: Key end users for the mining industry



Source: Crisil Intelligence

Pricing regime overview of the iron ore sector

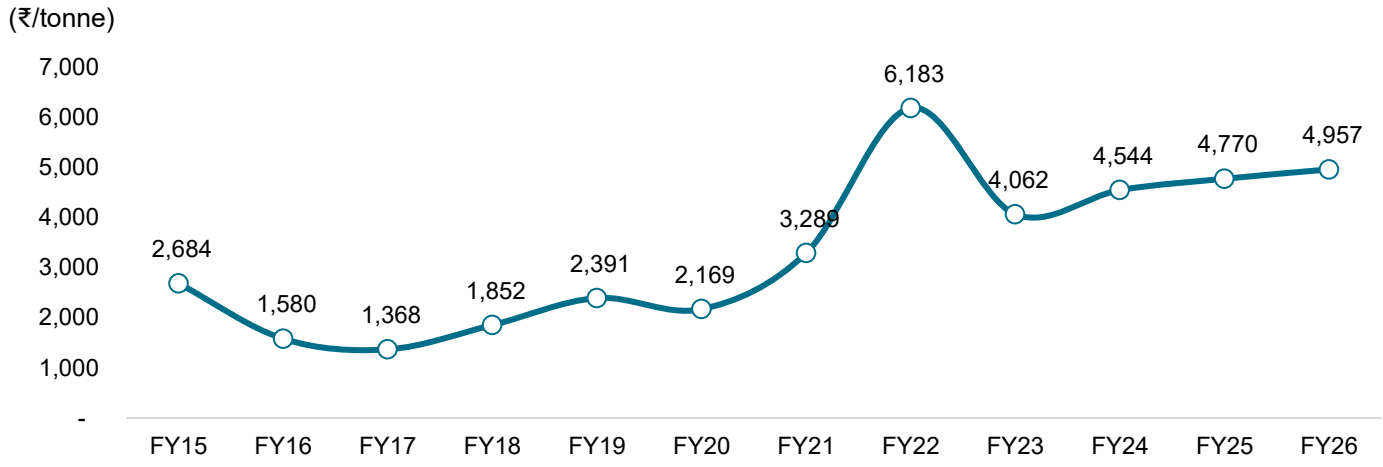
The iron ore sector in India is deregulated. The Government of India has no direct role in fixing the prices of iron ore. The merchant miners and steel producers with captive mines are allowed to price their products based on regional demand-supply dynamics, as well as the quality and grade of the ore.

However, the Indian Bureau of Mines (IBM) releases iron ore prices across grades, based on which the iron ore producers (merchant or captive) contribute towards a District Mineral Fund (DMF), National Mineral Exploration Trust (NMET), royalty and bid premiums (as determined for mines acquired post-MMDR Amendment Act, 2015). The IBM arrives at the iron ore prices based on the pricing of the top 10 non-captive producers. There have also been discussions about setting up a National Mineral Index to help realize the actual market price of iron ore, which has yet to materialise.

India is a key exporter of iron ore, and domestic prices are not at parity with the landed cost of imports, as in the case of steel. However, domestic iron ore prices move in line with global prices. Elevated global prices open up opportunities for exports, leading to lower availability in the domestic market and thus driving prices upwards.

Recently, India's Ministry of Mines (the central government body that frames mining policy and rules) has amended the Minerals Concession Rules through the Third Amendment Rules, 2026, notified on 10 April 2026, to introduce a formal pricing framework for low-grade iron ore; specifically Banded Haematite Quartzite (BHQ) and Banded Haematite Jasper (BHJ), with Fe below 45%. Under the new approach, the Average Sale Price (ASP); a government-used reference price that influences royalty and other levies, for ore with 35% ≤ Fe < 45% is set at 75% of the ASP of 45%–51% Fe ore, while ore with Fe < 35% is set at 50% of that benchmark. The ministry's rationale is that low-grade ore previously lacked distinct pricing, making beneficiation (processing to upgrade ore quality) less viable despite improved technology, contributing to wastage and under-utilisation. The change aims to support mineral conservation, reduce pressure on high-grade deposits, and improve feedstock availability for steelmakers by bringing sub-threshold resources into the supply chain. Before the present amendment in the rules, there was no methodology to publish ASP of Haematite Iron Ore having Fe content below 45% including for BHQ and BHJ. Thus, the ASP published for lowest grade of Haematitic Iron above the threshold value, i.e., 45% to below 51% Fe grade, was taken as the ASP for these grades. The change is supply-focused and is relevant for miners operating near the cut-off grades, and for pellet capacity additions that are contingent on beneficiation economics.

Figure 19: Domestic iron ore prices (62-65% Fe fines)



Source: Ministry of Mines, Crisil Intelligence

Review and outlook of the mining industry — iron ore

Demand review and outlook

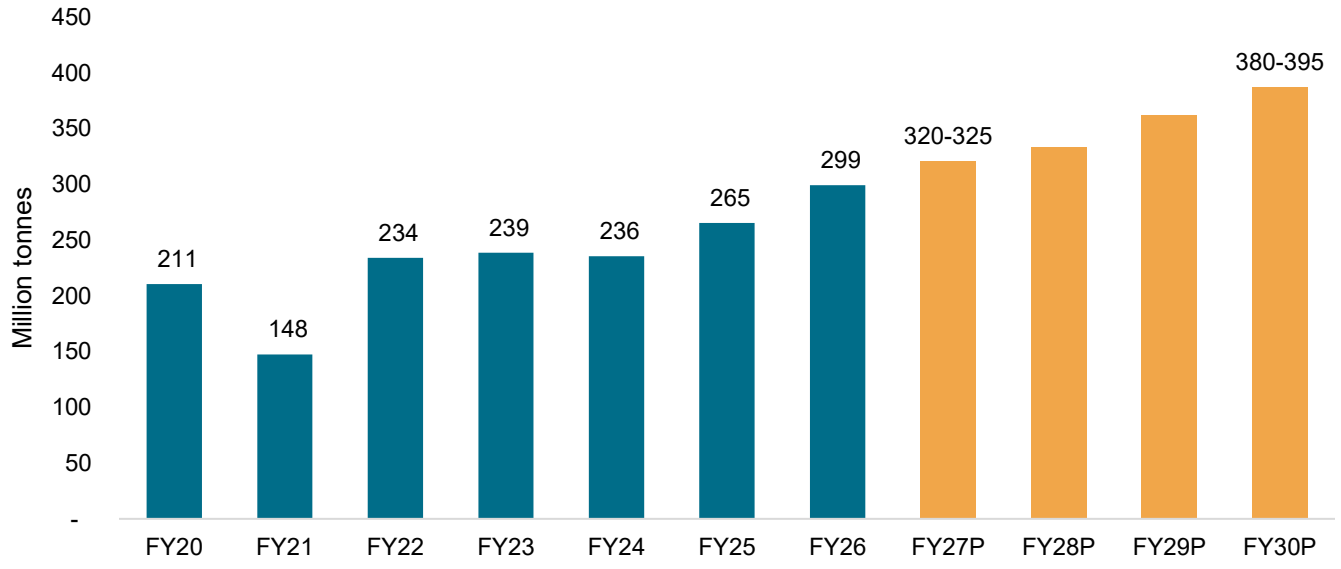
India's iron ore demand is driven by the domestic steel industry. The domestic consumption of iron ore has moved in line with domestic steel production over the years, given little change in scrap usage due to the lower availability of scrap in the domestic market.

India's apparent consumption of iron ore has grown at a healthy pace of ~15% between fiscals 2021 and 2026 to ~299 MT in fiscal 2026. The consumption of iron ore mirrors domestic crude steel production, which has also grown at a compound annual growth rate (CAGR) of ~10% between fiscals 2021 and 2026, from ~ 104 MT to ~169 MT.

India's iron ore demand is intrinsically linked to crude steel production, which has expanded materially since fiscal 2020. For the fiscal 2027, iron ore demand is expected to increase by 7-8% to 320-325 MT from 299 MT in fiscal 2026. The demand outlook for iron ore through fiscal 2030 is primarily driven by healthy crude production. However, this growth dynamics will vary over time due to higher scrap usage and palletisation. As a result, iron ore demand growth is likely to

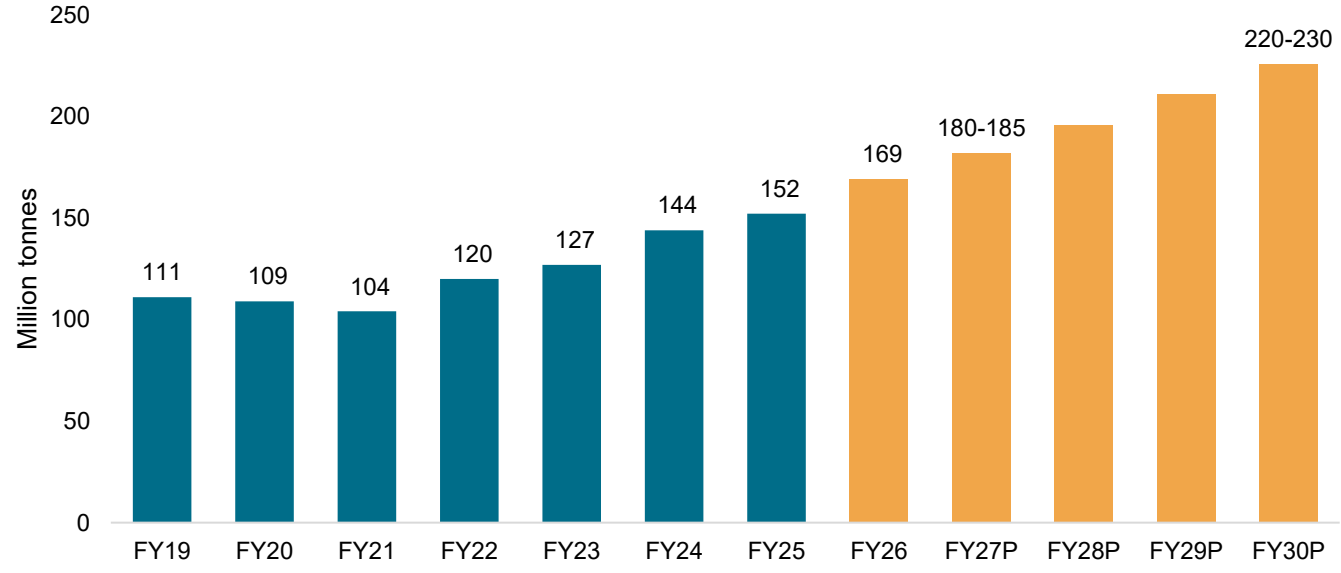
be positive but gradual, rather than linear with steel capacity expansion. For the fiscal year 2027, crude steel production is anticipated to rise by 8-9% year-over-year, driven by robust demand, as well as the ramping up of already added capacities. Although starting from a relatively low base, this growth is expected to lead to a slight increase in utilization rates and remain high at 81–83%. On the long term, crude steel production is expected to align with the domestic demand growth trajectory.

Figure 20: India iron ore apparent consumption, FY20-30 (MT)



Source: Ministry of Mines, Ministry of Commerce and Industry, Crisil Intelligence

Figure 21: India crude steel production, FY20-30 (MT)



Source: Crisil Intelligence, Joint Plant Committee (JPC) Ministry of Steel

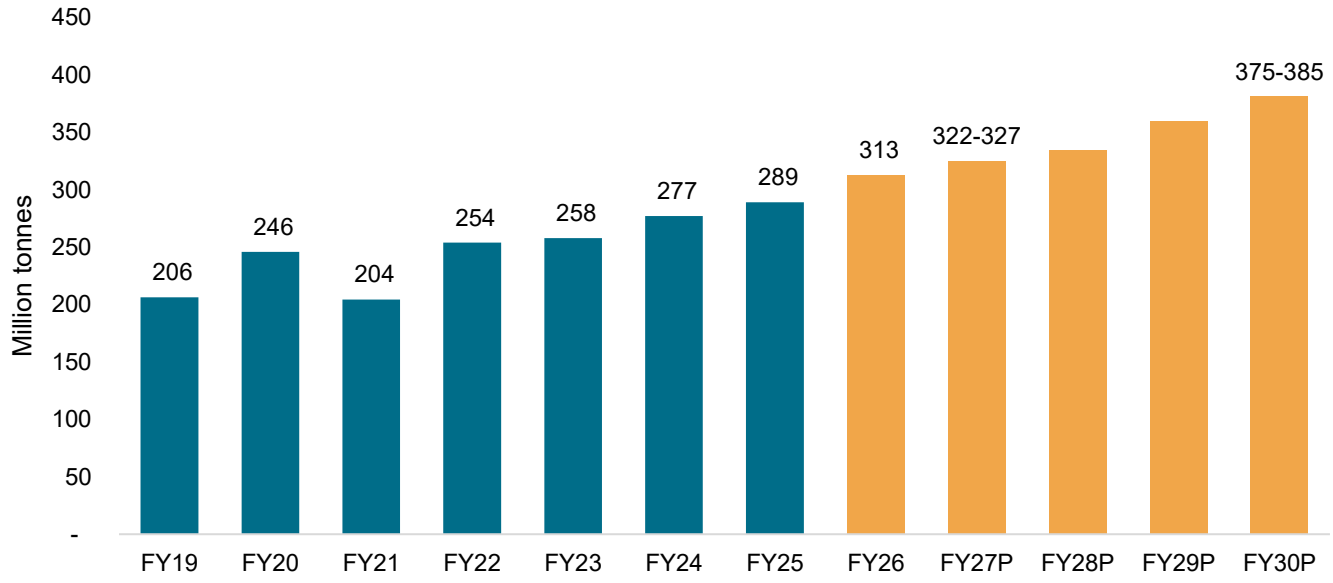
Supply review and outlook

Iron ore production in India has increased at a CAGR of ~9% between fiscals 2021 and 2026, to ~313 MT. While production has been strong over this period, it had witnessed a sharp decline between fiscals 2010 and 2013, owing to mining and export bans in Karnataka and Goa. In fact, production fell by over 35%, from 219 MT in fiscal 2010 to 137 MT in fiscal 2013. However, production started to increase in fiscal 2016, after the re-auction of existing mines and new auctions post-amendment of the MMDR Act. Mine operations became more efficient with large steelmakers taking over, leading to a pickup in production. However, production witnessed only marginal growth in fiscal 2023, as the export duty levied on pellets and low-grade iron ore curbed exports.

For the fiscal 2027, iron ore production is expected to increase by 4-5%. The iron ore output curve has witnessed a strong growth in fiscal 2026 despite extended monsoon and operational challenges in utilisation levels.

During fiscal 2026, iron ore production inched up by ~8% to approximately 313 MT compared to 289 MT in fiscal 2025. Over this same timeframe, Odisha continued to be the leading producer, accounting for approximately 50% of Indian iron ore production. However, Odisha's output is estimated to have witnessed a marginal decline of less than 1% in fiscal 2026. The premature onset of the monsoon season in the eastern region during the first two quarters of fiscal 2026 is the major reason for the lower output.

Figure 22: India iron ore production, FY20-30 (MT)



Source: Indian bureau of mines, Crisil Intelligence

Assessment of regulatory framework in the iron ore industry

Iron ore mining is a highly governed industry, affected by regulations such as export duty changes, mining and export bans. As a result, the sector's output has varied significantly over the years. Other major regulatory changes that have impacted the sector are the Mines and Minerals Development and Regulation (MMDR) Amendment Act, 2015, and subsequent amendments.

Export duty changes

In fiscal 2010, the export duty on iron ore lumps, pellets (10%) and fines (5%, irrespective of grade) was introduced to reduce raw material costs for the domestic steel industry. However, it was hiked to 20% across grades the following fiscal. In fiscal 2013, the export duty on iron ore lumps and fines was hiked to 30%, while that on iron ore pellets was decreased to 5%. In fiscals 2014 and 2015, the export duty on iron ore lumps and fines with a high-quality grade continued at 30%, while that on iron ore pellets continued at 5%. While the export duty on iron ore lumps and fines has remained at 30% since fiscal 2016, that on iron ore pellets was removed, thereby supporting pellet and low-grade ore exports. However, in May 2022, the government decided to hike the export duty on iron ore lumps and fines across grades to 50% from 30% and iron ore pellets to 45% from 0%, to bring elevated domestic steel prices under control. The same was amended again in November 2022, where duty was placed only on high-grade (>58% Fe) iron ore lumps and fines, leading to a pick-up in iron ore exports for below 58% Fe grade.

Export ban and production cap in Karnataka

Karnataka was the second-largest iron ore producer in India after Odisha, producing ~43 MT (20% share in total production) in fiscal 2010. There was an environmental impact, such as air and water pollution and infertile lands, from mining activities in nearby areas. There was also a delay in rehabilitating vegetation and fauna around the mining area. To curb these damages, the Supreme Court banned the export of iron ore from Karnataka and ordered a temporary ban on production in July 2011. After a year, it allowed 108 mines to restart production with a 30 MT annual production cap. Further, it directed miners to sell their iron ore to steel makers only through e-auction. However, due to several pending environmental clearances, only 25 mines were operational for 3-4 years.

In 2020, the Supreme Court increased the production cap to 35 MT from 30 MT. However, the export ban persisted in the state. In May 2022, the apex court passed a ruling to lift the export ban from Karnataka. Further, mines that were closed through previous rulings were allowed to operate. The court took into consideration the fact that Karnataka had remained a net importer, with steel mills resorting to purchasing iron from merchant players in Chhattisgarh and Odisha.

Goa mining ban

Goa was the third-largest iron ore-producing Indian state in fiscal 2010, after Odisha and Karnataka, with ~38 MT (17% share in total production). It accounted for more than half of India's total iron ore exports. In September 2012, the Supreme Court banned iron ore mining in Goa to curb illegal operations. It also cancelled mining leases amid multiple irregularities during mining auctions and banned exports. Thus, over fiscals 2014 to 2016, iron ore production from the state was nil.

In fiscal 2017, the court allowed the resumption of mining operations with a production cap of 20 MT. However, production was limited due to several pending environmental clearances for miners. In 2018, the court cancelled 88 mine leases that had been renewed in 2014 and 2015 prior to the implementation of the MMDR Amendment Act, 2015. Thus, there has been no production between fiscal 2019 and 2024.

Auction of mineral blocks resumed in Goa in fiscal 2023; till May 2025, 12 mining leases have been auctioned. In fiscal 2025, Goa produced 0.95 MT of iron ore. The production is expected to ramp up as more mines restart post-lease allocation. The state recently tweaked its e-auction policy for iron ore dump handling. The new revised policy empowers

the State Directorate of Mines and Geology (DMG) to re-auction iron ore mined prior to the mining ban and stored in dumps.

The DMG in Goa has initiated the process to publicly auction 10 iron ore mining dumps in 2025. These dumps contain an estimated quantity of ~22 MT iron ore. The 10 dumps are primarily located in South Goa, with one dump in Honda, North Goa. This will be the first phase of public auctions under the Goa iron ore mining dump handling policy 2023.

MMDR Amendment Act, 2015

The Act is aimed at bringing transparency to the mining industry and making the allocation process more transparent. Major changes made to the Act are as follows:

- Mine auction was made the only mode for mine allocation, and the auction was made completely online. This increased transparency significantly.
- Mine blocks can be given for a maximum lease period of 50-year lease to the successful bidder.
- Captive players were allowed to bid for mines previously held by non-captive players. However, captive players could not sell non-required iron ore production to external buyers.
- Captive players had the first right of refusal after the lease expired and could get a 15-year extension.
- To curb illegal mining, a penalty of up to Rs 0.5 million per hectare and five years of imprisonment was introduced in the Act.
- A composite prospecting lease (PL)-cum-mining lease (ML) licence was introduced for virgin blocks.

These reforms were beneficial for state governments since the states earned extra revenue through the auction process through bid premium, compared with only royalty earlier. The Act is aimed at bringing transparency to the mining industry and making the allocation process more transparent. Major changes made to the Act are as follows:

Mineral Laws (Amendment) Act, 2020

The MMDR Amendment Act, 2015, garnered a positive response from the mining industry. To make the auction process easier, further changes were introduced in 2020. Major changes include the following:

- The government abolished restrictions related to end use for captive and non-captive leases.
- A new composite licence (reconnaissance permit (RP)-cum PL-cum-ML) was introduced for virgin blocks.
- The central government directed state governments to auction mines with pre-embedded clearances to shorten the lead time before the start of mining operations. Here, state governments were made responsible for obtaining necessary clearances.

Following these changes, more captive players started taking part in the auctions, as restrictions related to the end use of production were removed.

MMDR Amendment Act, 2021

Post the amendments introduced in 2020, the government introduced new amendments in 2021 to improve the availability of high-grade iron ore for the Indian market:

- Captive mines were allowed to sell up to 50% of the production to external buyers.
- Statutory clearances remained valid even after the expiry of the lease. This promoted ease of doing business.
- The lessee who could not undertake mining operations could transfer the lease to the interested party without any additional charges, thus ensuring continuation of mine production.

These changes promoted ease of doing business and boosted mineral production.

MMDR Amendment Act, 2025

In August 2025, The Mines and Minerals Amendment Act, 2025, received a nod in the Indian parliament. The act brings forth several significant changes to India's mining sector by amending the existing Mines and Minerals (Development and Regulation) Act, 1957.

- A new definition for “mineral exchange” has been introduced. The mineral exchange (similar to the London Metal Exchange, or LME) will be an electronic trading platform where buyers and sellers can transact and enter into contracts for minerals, their concentrations, or processed forms (including metals and derivatives).
- The contribution to the National Mineral Exploration and Development Trust (NMEDT), formerly known as the National Mineral Exploration Trust (NMET), has increased to 3% of the royalty from 2% earlier.
- The amendment removes the sale limit for captive mines. Previously, captive mines, operated by a company primarily for their own consumption, were allowed to sell only up to 50% of the total mineral production in a year after meeting their end-use requirements. Additionally, the Bill empowers state governments to permit the sale of mineral dumps accumulated in leased areas up to a date specified by the central government and also allows lease holders to add new minerals to their existing leases with certain payment requirements.
- Lease holders may apply to the state government to add other minerals to their existing lease. Notably, the inclusion of critical and strategic minerals, such as lithium, graphite, nickel, cobalt, gold, and silver, will not incur any additional costs. However, for the inclusion of other minerals, lease holders will be required to pay an amount equivalent to the royalty for that mineral.

Commercial mining of iron ore

The commercial iron ore mining landscape in India is dominated by large public sector enterprises and government organisations such as the National Mineral Development Corporation (NMDC) and Odisha Mining Corporation (OMC), along with private players such as Lloyds Metals and Energy Limited, Rungta Mines Limited, Essel Mining & Industries Ltd (EMIL), and Serajuddin and Company etc.

Merchant miners used to account for ~70% of India’s iron ore till fiscal 2019. However, the removal of mine classification (captive/merchant) for re-auction has led to captive players gaining the lion’s share. Over, the past four years, the share of captive miners has gone up from ~30% to over 60%.

Reduction and removal of export duties on iron ore

Following the onset of the Russia-Ukraine conflict in early 2022, global energy and commodity prices witnessed a dramatic surge, fuelling what many described as a new commodity super cycle. This global shock sent prices for key steelmaking raw materials, especially coking coal, and finished steel to unprecedented levels.

This international trend directly translated to the Indian market, causing a sharp spike in domestic steel prices. The resulting high inflation created significant challenges for the Indian government, particularly for downstream user industries like construction and MSMEs that were struggling with crippling input costs. It was in this volatile environment of soaring domestic prices and the need to ensure local availability that the government stepped in, imposing significant export duties on steel and iron ore in May 2022 as a direct measure to cool the overheated market.

India was a key iron ore exporter in global markets, having exported over 26 MT of iron ore in fiscal 2022, constituting 10% of the total domestic production. The government had imposed export duties in May 2022 on iron ore to ensure its better availability in the domestic market, thus bringing prices lower.

While earlier the government had imposed an export duty on high-grade iron ore (58% Fe and higher) to curb exports, the export of low-grade ores, as well as iron ore pellets, continued. However, once both steel and iron ore prices corrected, the Indian government rolled back the export duty for pellets and low-grade ore (fines and lumps ≤58% Fe) and lowered the duty on high-grade ore (fines and lumps >58% Fe) to 30% from 50% earlier. The move helped scale up exports over the last four months of fiscal 2023. In fact, India exported close to 14 MT of iron ore from November 2022 to March 2023, after having exported only 7.3 MT over the first eight months of the fiscal.

In fiscal year 2024, iron-ore exports rebounded to 46 MT, but declined to 30 MT in fiscal 2025 as strengthening domestic demand for ore coincided with subdued global demand that depressed ore prices. During fiscal 2026, imports more than doubled, rising to approximately 12.27 MT from roughly 6.39 MT in fiscal 2025, while exports for that interval fell to about 25.68 MT, down from around 30.01 MT in fiscal 2025. Consequently, the trade balance is expected to shift toward net imports in the forthcoming fiscal years, driven primarily by robust domestic steel production that sustains strong demand for high-quality imported ore. Export volumes are projected to contract further as the Chinese market reduces its reliance on low-grade ore supplied by India, favoring higher-grade sources.

Table 5: Change in customs duty on iron ore exports

Material	HS code	Customs duty		
		Before May 2022 order	From 21st May 2022 to 19th November 2022	Post November 2022 order
Iron ore fines (> 58% Fe)	26011143, 26011149	30%	50%	30%
Iron ore fines (< 58% Fe)	26011141, 26011142	0%	50%	0%
Iron ore lumps (> 58% Fe)	26011129 26011131	30%	50%	30%
Iron ore lumps (< 58% Fe)	26011121 26011122	0%	50%	0%
Iron ore pellets	26011210	0%	45%	0%

Source: Department of Revenue - Ministry of Finance, Crisil intelligence

Profile of key iron ore commercial miners in India

NMDC

NMDC, a Navratna public sector enterprise under the Ministry of Steel, Government of India, is the largest iron ore producer in India. It owns and operates iron ore mines in Chhattisgarh and Karnataka. It also operates the only mechanised diamond mine in India at Panna, Madhya Pradesh.

NMDC produced ~53 MT of iron ore from three mechanised mining complexes (two in Chhattisgarh and one in Karnataka) in fiscal 2026, which supply ore in the form of lumps and fines for production to steel industries that use blast furnaces/DRIs. Sales reached to 53 MT in the same period.

In fiscal 2025, the company achieved production of 44.07 MT and sales of 44.4 MT, recording a drop from the previous fiscal where it recorded production of 45.02 MT and sales of 44.48 MT. The company is undertaking substantial capital expenditure projects to enhance its ore production, aiming to reach a production capacity to 100 MTPA by 2030 from the current installed capacity of 55 MTPA.

OMC

OMC was incorporated in 1956 as a JV between the Government of Odisha and Government of India. In 1961, it became a fully owned state PSU of the Government of Odisha. OMC is now the largest state PSU in India's mining sector. It is the fifth-largest iron ore producer in the country and second-largest merchant/commercial iron ore miner after NMDC.

The major minerals mined by OMC are iron, chromite and bauxite ores, which cater to the requirements of mineral-based downstream industries such as steel, sponge iron, pig iron, ferro-chrome, and aluminium.

The company derives majority of its revenue from the iron ore mining businesses. In fiscal 2025, company produced 40.3 million tonnes of ore, with turnover of more than Rs. 23,630.00 Crores.

For fiscal 2026, the company reported iron ore production of 40.02 MT, showcasing a year-on-year growth of 11%.

EMIL

Incorporated in 1950, EMIL is part of the Aditya Birla Group. It is a leading natural resource company that deals in commercial coal mining, manufacturing (Iron ore beneficiation & pelletisation, and Noble ferro alloys), Mining services through a Mine Developer and Operator model, and Renewable energy.

EMIL, through its subsidiaries, operates five coal MDO projects. Key subsidiaries operating under this model include Bhubaneswari Coal Mining Ltd (BCML), Rajamahal Coal Mining Limited (RCML), Amelia Coal Mining Limited (ACML), Subadhra Coal Mining Limited (SCML) and EMIL Mines and Mineral Resources Limited (EMMRL). BCML has a capacity of 30 MTPA which operates the Bhubaneswari open-cast coal project of Mahanadi Coalfields Ltd (MCL), a CIL subsidiary in Angul, Odisha. BCML has a contract from MCL to mine 269.5 MT of coal over 15 years. Rajamahal Coal Mining Ltd (RCML) operates the 18.7MTPA Rajmahal open-cast coal project of Eastern Coalfields Ltd (ECL), a CIL subsidiary in Godda, Jharkhand. RCML has a contract with ECL to mine 199.8 MT of coal over 12.5 years. Amelia Coal Mining Limited has a capacity of 5.6 MTPA and SCML has a planned capacity of 25 MTPA.

The company's Iron Ore beneficiation & palletisation (IOBP) business is located in Keonjhar, Odisha with a capacity of 1 MTPA.

The company also operates in the ferro alloys and renewable power segments.

Adani Enterprises

Adani Enterprises is a leading MDO player in India with a heavy presence in the coal and iron ore sectors. The company currently have portfolio of 2 iron ore blocks at Kurmitar and Taldih in the state of Odisha of which Kurmitar mine is operational. The Kurmitar mine is owned by Odisha Mining Corporation Limited (OMC) and the Taldih mine is owned by Steel Authority of India (SAIL). The mine has a concession period of 25 years.

The reported iron ore dispatch from Kurmitar block has seen a year-on-year increase of 6% from 3.4 MT in the fiscal 2025 to 3.6 MT in fiscal 2026.

Table 6: Iron ore mines with Adani Enterprises as MDO

Type	Name	Capacity (MT)	Location	Status
Iron ore mining services	Kurmitar iron ore mine	6	Odisha	Operational
	Taldih mine	7	Odisha	Capacity expansion from 2 to 7 MTPA ongoing

Source: Company report, Crisil Intelligence

Mining – coal mining

Overview of the structure of the mining industry (Coal)

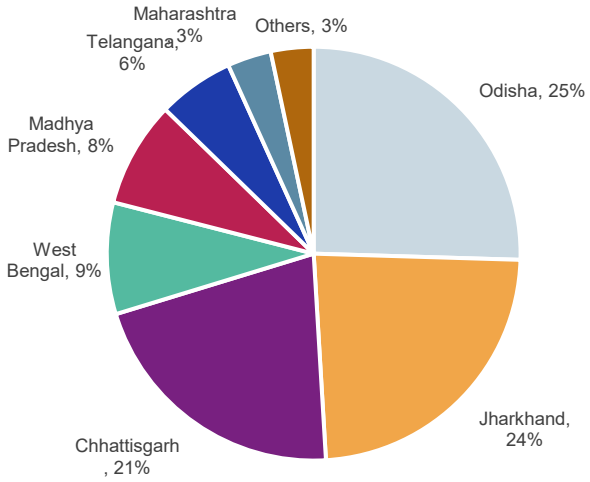
Coal is naturally occurring sedimentary rock found within the earth's crust and is one of the most abundant fuels on earth with proven reserves of ~1,285 billion tonnes in 2023. The world's proven reserve base can last more than 100 years at the current pace of production. Coal reserves are widely distributed across globe, making it one of the cheapest fuels for consumption in production of electricity. In 2024, coal accounted for ~34% in electricity generation across the globe and ~26% in overall primary energy consumption.

Coal is classified under two major categories: coking and non-coking coal. Coking coal is primarily used in production of steel whereas a large share of non-coking coal is used for electricity generation. In India, coking coal is categorised or graded on the basis of ash while non-coking coal is categorised as per gross calorific value of the coal.

Overview of India's coal sector

As of April 2025, India had coal reserves of ~401 BT. Coal deposits are mainly concentrated in the country's eastern and south-central regions. Jharkhand, Odisha, Chhattisgarh, West Bengal, Madhya Pradesh, Telangana, and Maharashtra account for ~98% of the country's total coal reserves.

Figure 23: Snapshot of coal resources in India as of April 2025



Source: Ministry of Coal, Crisil Intelligence

India is the world's second-largest coal producer. In fiscal 2026, India produced ~1,041 MT of coal, witnessing a 0.6% decline from ~1048 MT a year ago.

Coal production in India is dominated by public sector enterprises such as Coal India Limited (CIL) and Singareni Collieries Company Limited (SCCL). In fiscal 2025, CIL and SCCL accounted for 75% and 7%, respectively, of India's total coal production.

The remaining ~19% was produced by captive and commercial players, wherein both, the public and private sectors, have ownership of mines.

To attract more private investment in the coal mining sector, Government of India opened up the sector to private enterprise in fiscal 2018. Commercial mining allows the private sector to mine coal commercially without placing any end-use restrictions.

Despite abundant coal reserves, domestic coal production in India has consistently lagged due to delays in getting environment and forest approvals, hurdles in land acquisition, and construction delays, among other issues, and consequently, has led to increasing reliance on coal imports to meet domestic coal demand. However, post fiscal 2014, domestic coal production has improved consistently following the government's focus on reducing dependence on imported coal. As a result, India's domestic coal production logged a 5.6% CAGR between fiscal 2015-2025.

However, in CY 2022, a broad-based pick-up in the economic activity across major economies, coupled with energy shortage in the Europe, led to increase in non-coking coal prices accompanied with supply disruptions over the short term. Further, the tense geopolitical situation increased uncertainty, impacting coal demand. This resulted in Australian and Indonesian thermal coal prices at an average $344 per tonne and $86 per tonne respectively in CY 2022.

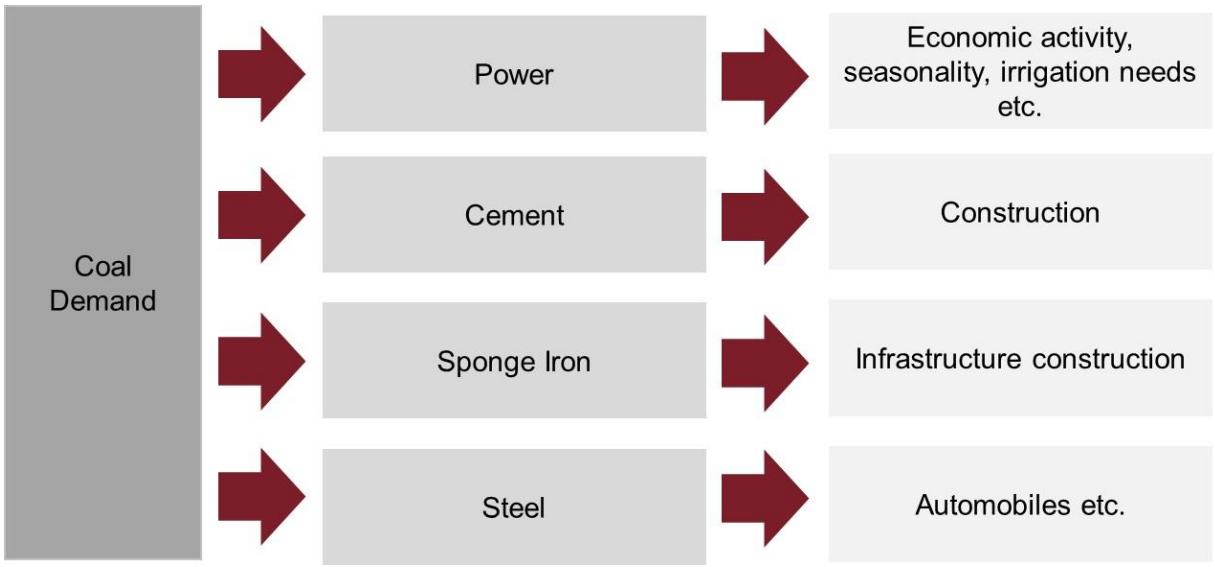
On the domestic front, supply chain issues coupled with a sharp uptick in power demand led to a coal shortage crisis at power plants in fiscal 2022 and 2023. Post this, in order to ensure India's energy security, the Ministry of Coal has ramped up coal production. Between fiscal 2021 and fiscal 2026, India's domestic coal production registered a CAGR of ~7.8%, with non-coking coal output growing at a comparable ~8% CAGR over the same period, thereby supporting adequate availability to meet domestic consumption requirements.

Key demand drivers for India's coal sector

Demand for non-coking coal is led by the power segment (Commercial and Captive), which is estimated to account for ~74% of non-coking coal demand as of fiscal 2026. The remaining stems from non-power sectors, such as sponge iron, cement, and aluminium. In some of these segments, coal is used as an input for production, for example, in sponge iron and cement, and may also be used to generate power from captive plants, for example in aluminium and cement. Demand for coking coal is led by steel production cycles as it is a key input in the production process.

Growth in coal demand from these segments depends on their respective growth aspects; for instance, improved economic activity would lead to higher electricity consumption, coupled with spending on infrastructure, which would spur power, steel, and cement demand, consequently leading to coal requirement.

Figure 24: End-user segments for coal



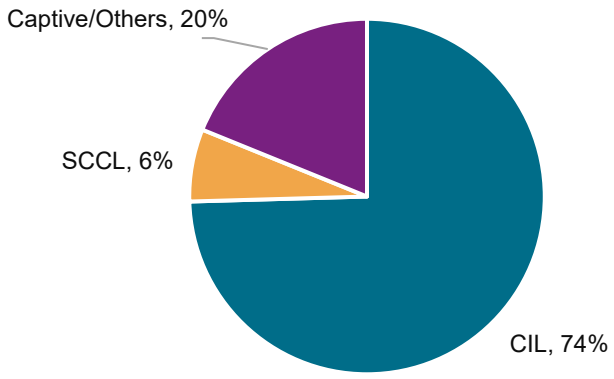
Source: Crisil Intelligence

The Indian government aims to increase EVs to 30% of total cars by 2030, promoting adoption through incentives and infrastructure development. Charging infrastructure will expand, with stations every 25 km on major highways. The government has allocated Rs 10 billion for nationwide EV charging infrastructure. This will boost power demand, with 425-445 BUs expected to be added in terms of power consumption between 2026 and 2030.

Overview of pricing regime of coal sector

In India, coal produced domestically by CIL and SCCL is sold via two mechanisms – long-term fuel supply agreements (FSA) and e-auctions (spot coal market). Both these supply streams have different pricing mechanisms. Captive coal mine producers are able to sell up to 50% of the coal produced in a financial year to other entities commercially.

Figure 25: Coal production by sources in fiscal 2026 (1,041 million tonnes)



Source: Ministry of Coal, Crisil Intelligence

Prices of coal via the FSA route are notified by CIL, which is primarily based on a cost-plus model. This is revised by CIL from time to time. FSAs account for 85-90% of the total sales volume of CIL and SCCL combined.

These FSAs were earlier allocated through the Standing Linkage Committee route under the Ministry of Coal. The Standing Linkage Committee under the Ministry of Coal decides long-term coal linkages as well as short-term coal linkages. The agreements were entered into based on recommendations by the ministries of steel, cement, power and various state governments. However, in February 2016, the Cabinet Committee on Economic Affairs (CCEA) modified the mechanism to promote transparency in the allocation of coal linkages. As per the new mechanism, the FSAs in non-regulated sectors (sponge iron, steel, cement and captive power plants) are signed/renewed on the basis of an auction. Also, for consumers in the power sector, the government launched a new scheme in May 2017 for linkage allocation -- Scheme for Harnessing and Allocating Koyala (Coal) Transparently in India (SHAKTI). Under SHAKTI, power plants that do not have an assured linkage of thermal coal can participate in auctions conducted by coal-producing companies and secure supply via competitive bidding.

Under e-auctions, which account for the remaining 10-15% of CIL and SCCL's sales volume, coal is typically sold at a premium to that sold under the FSA route. This is essentially the Indian spot market for coal, where bidders submit their pricing bid above the base pricing notified by the respective nodal entities (various subsidiaries of CIL, SCCL).

The Ministry of Coal, Government of India, has introduced the National Coal Index (NCI), a comprehensive price index that monitors coal price movements in the country. The NCI serves as a benchmark for coal pricing and royalty calculations, aggregating prices from various channels, including notified prices, auction prices, and import prices. In the case of coking coal, select Coal India Limited (CIL) subsidiaries are responsible for production and are authorized to set notified prices.

These regulated notified prices apply to both coking and non-coking coal, primarily for supply to power plants, steel industries, and other sectors. The prices vary depending on the coal grade, which is determined by ash content. BCCL raised notified coal prices by Rs 10/tonne in April 2025, with ST-I coal now at Rs 6,163/tonne and WIV coal at Rs 3,336/tonne.

Table 7: National coal index for coal grades

Channel	Mar-21	Mar-22	Mar-23	Mar-24	Mar-25	Mar-26*
Indian Coal	101.89	193.02	168.96	150.13	128.27	138.96
Non-coking	107.32	184.79	156.83	137.44	129.09	134.3
Coking	86.26	216.73	203.92	186.65	125.92	152.37
Non-coking, top grade (G1-G6 or imported)	107.61	223.28	163.48	141.67	131.62	147.13
Non- coking, middle grade (G7-G14 or imported)	107.36	171.9	154.8	136.07	128.23	130.25
Non-coking, bottom grade (G15-G17)	91.21	215.96	138.59	136.30	132.09	115.13
Coking, top grade (STI- STII or imported)	78.98	234.18	220.07	203.10	127.95	161.83
Coking, bottom grade (WI-WIV)	115.27	147.2	139.58	121.11	117.84	114.65

Source: Ministry of coal, Crisil Intelligence
Note: Coal Index values for Mar 2026 are provisional

Review and outlook of mining industry - Coal

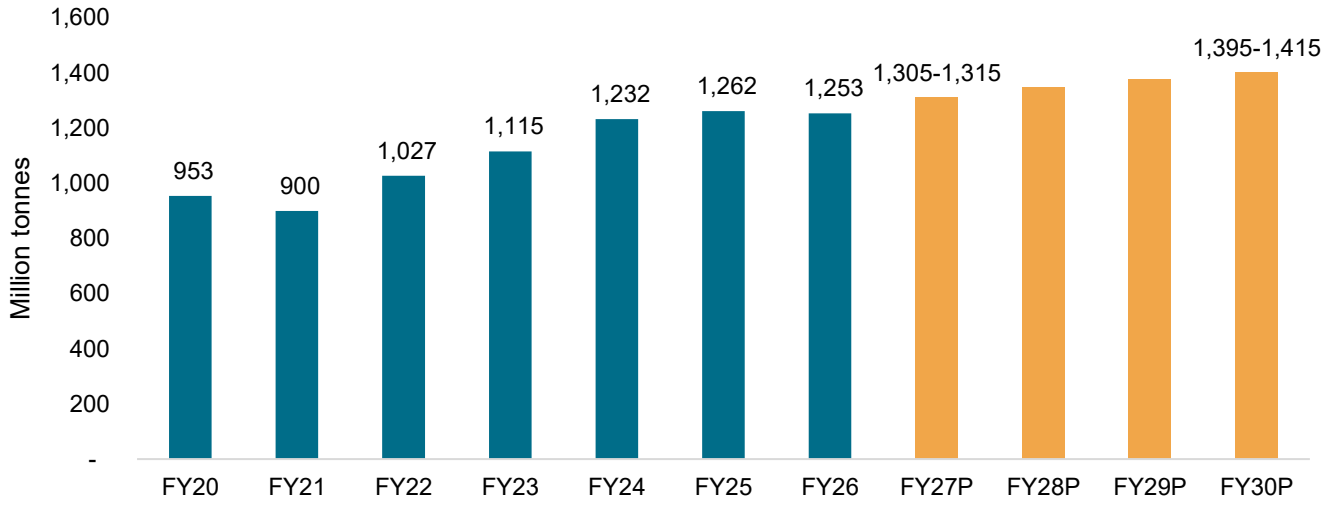
Review of coal demand in India

Domestic consumption of coal (both coking and non-coking coal combined) has seen healthy growth of ~7% for the period of 2021-2026 to reach ~1,253 MT. Of this, ~1,184 MT of non-coking coal was consumed in fiscal 2026.

Going forward, non-coking coal consumption is expected to grow at 2-3% CAGR between fiscal 2026-2030, driven by growth in power demand and key end-use industrial segments. India's base power demand grew at a 6% CAGR from fiscal 2021 to 2026 to reach ~1,709 billion units. Growth has been led by economic growth, improvement in T&D infrastructure coupled with extensive rural electrification under various schemes. Demand from the power and non-power sectors such as cement, sponge iron, aluminium and other industries has led to non-coking coal consumption increasing at a CAGR of ~7.5% for the period of 2021-2026.

Coking coal, which is mainly used by steel players for production of steel, saw consumption grow at a CAGR of ~2% over fiscal 2021-2026, alongside a stronger expansion in India's crude steel production which increased at a CAGR of 7% over the same period

Figure 26: Domestic coal consumption, FY20-30 (MT)

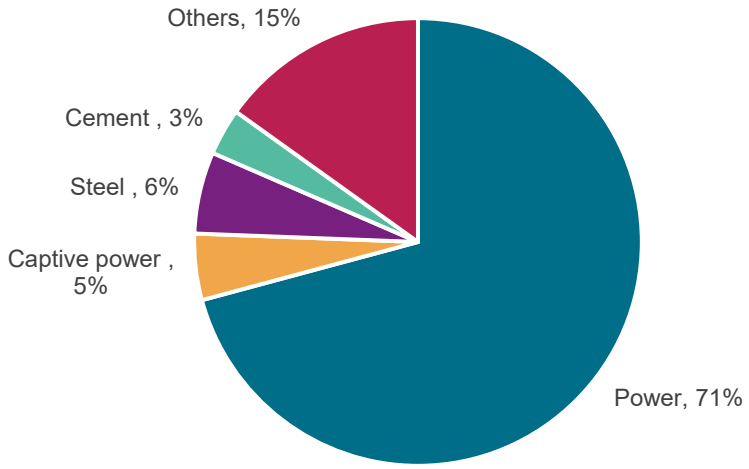


Source: Ministry of Coal, Crisil Intelligence

Break-up of coal demand into end-user segments

Coal demand is dominated by the power sector, which accounts for three quarters of overall domestic demand, followed by captive power generation across various industrial segments.

Figure 27: Sector-wise break-up of non-coking coal demand in fiscal 2026

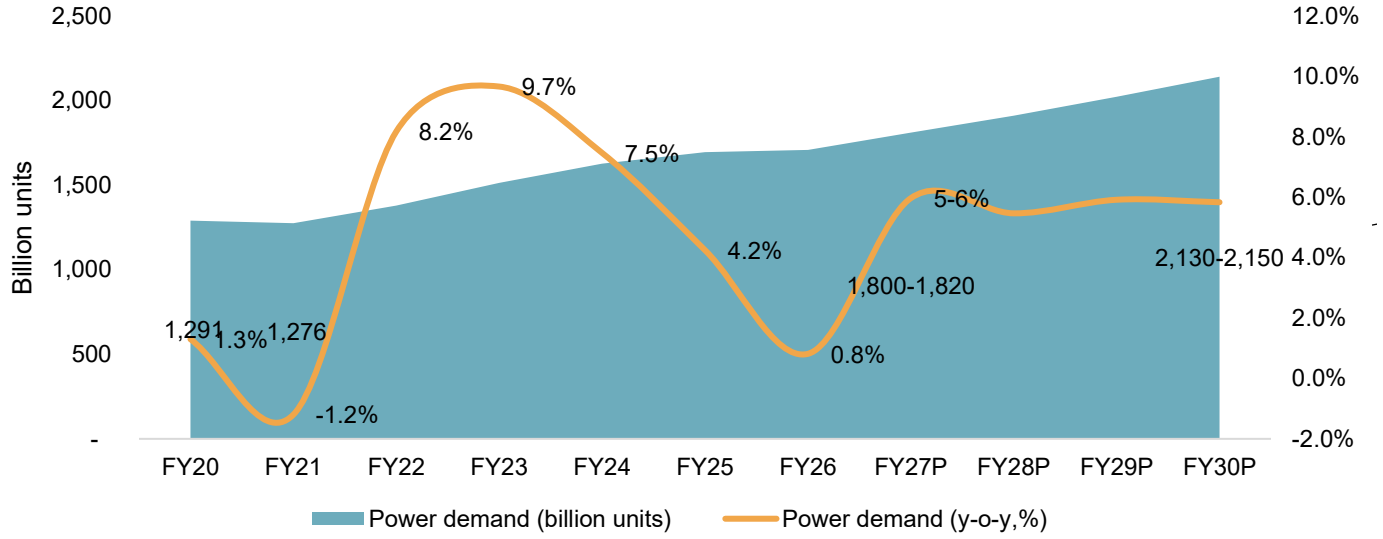


Source: Ministry of Coal, Crisil Intelligence

Power: Coal-based capacity accounted for 41.5%, or 222 GW, of the total installed base of ~533 GW at the end of fiscal 2026. India's total installed power capacity rose from ~475 GW in fiscal 2025, witnessing a 12% on year increase. The bulk increment capacity came from renewables (including large hydro), which expanded by ~55 GW to ~278 GW, raising their share of the total mix from 46% in fiscal 2025 to ~52% in fiscal 2026. Coal-based capacity registered a modest increase of ~7 GW (3% on year growth), though its share in the overall mix contracted from 45% to 42%. 33-38 GW coal-based capacity is expected to be added between fiscal 2026-2030.

Power demand is expected to register CAGR of 5-6% between fiscals 2026 and 2030, driven by a recovery in economic activity, intensive rural electrification, power transformation, urbanisation, and the government's focus on manufacturing and urban infrastructure. Capacity additions of coal-based power plants will also support the demand for coal. PLFs are expected to be at 60-65% by fiscal 2030 resulting in coal consumption from the power sector to register CAGR of 2.5-3.5% over fiscals 2026-2030.

Figure 28: Power demand to log 5.5-6.5% CAGR till fiscal 2030



P – projected

Source: Central Electricity Authority (CEA), Crisil Intelligence

Captive plant: Captive plants account for 5% of non-coking coal consumption. This segment is being led by aluminium sector. India's broader captive market is expected to increase by 1-2 % in fiscal 2027.

Cement: The production process of cement accounts for 4% of non-coking coal demand. The cement industry is anticipated to drive non-coking coal demand growth by 11-12% in fiscal 2027. Government push in key projects such as PM Gati Shakti, National Infrastructure Pipeline are expected to drive the demand for cement.

Sponge iron: The production process of sponge iron accounts for 6% of non-coking coal demand. Driven by infrastructure development and rising housing demand in rural and urban areas, the long steel sector is expected to experience significant growth, leading to an increase in sponge iron production. As a result, coal demand from the sector is anticipated to increase by 7-8% in fiscal 2027.

Other: Other sectors, such as paper, fertilisers, and brick kilns, are also key consumers of coal. These segments account for ~16% of non-coking coal consumption. Performance of the overall economy will drive demand from these industries at 1-2% in fiscal 2027.

Review of coal dispatch

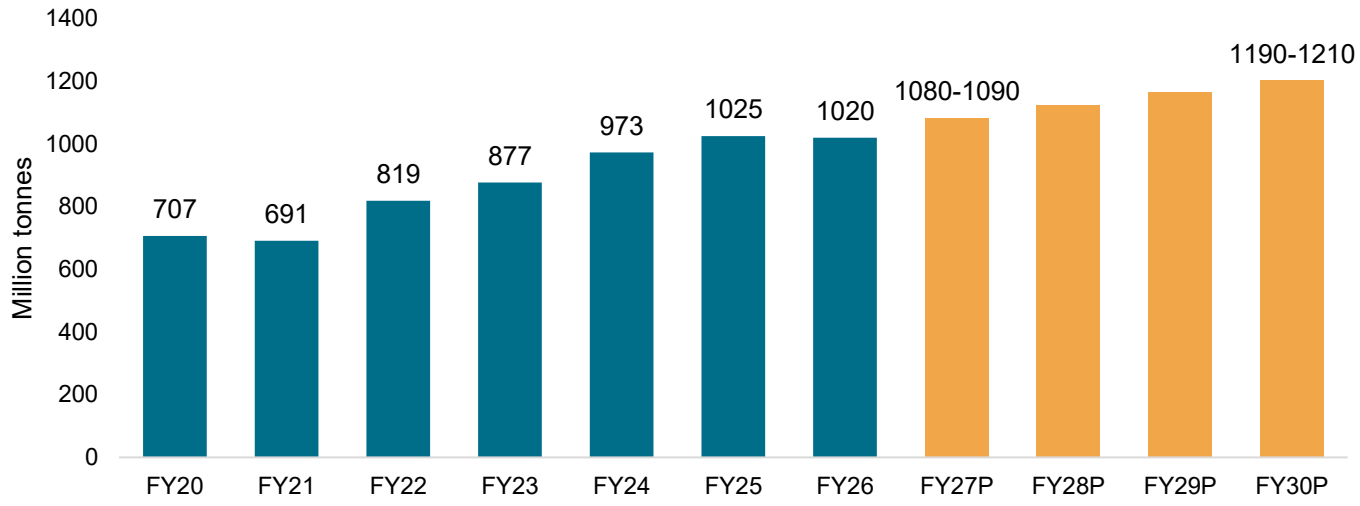
India's coal dispatch clocked a CAGR of ~8% over fiscals 2021-2026 to reach 1,020 MT. In fiscal 2026, CIL accounted for 73% of the total domestic coal dispatch. SCCL accounted for ~6%, with captive and commercial mines constituting 19% share.

Coal dispatch is led by CIL, which saw its dispatch increase by 171 MT over fiscals 2021-2026 at a CAGR of 5%. SCCL saw marginal growth at ~5% CAGR over the said period to reach dispatch of 64 MT in fiscal 2026. Dispatch from captive commercial and other sources has increased to ~213 MT in fiscal 2026 from a mere 69 MT is fiscal 2021 with allocation of new mines over the said period.

By opening up the sector to commercial mining for private players in February 2018, the government enabled participation from a wider set. On June 18, 2020, the government launched auctions for commercial mine blocks with no restrictions on end-use. This meant that the coal produced at such mines need not be used for captive consumption and can be sold to other entities, including end-users such as power and cement plants. This is expected to encourage

competition in the coal sector while boosting coal dispatch, thereby increasing domestic coal availability in the longer run.

Figure 29: Domestic coal dispatch, FY20-30 (MT)

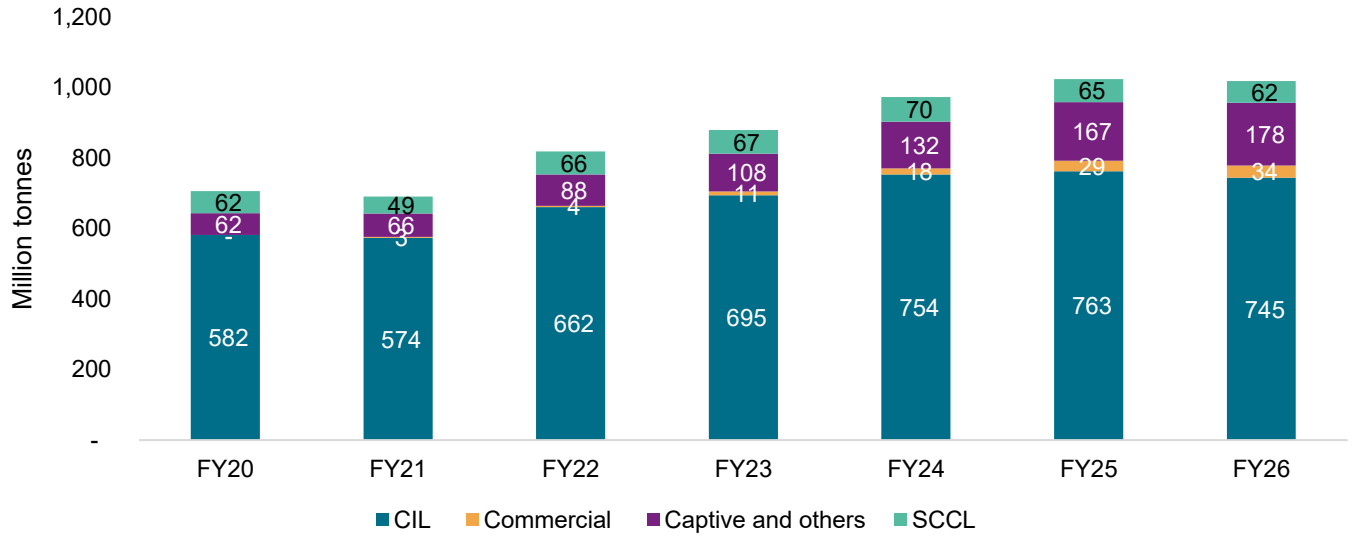


Note: P: Projected
Source: Ministry of Coal, Crisil Intelligence

Domestic dispatch is estimated to increase at a CAGR of 4.5-5.5% between fiscal 2026 and 2031 to 1,190-1,210 MT by fiscal 2030 from 1,020 MT in fiscal 2026.

The government has also opened the coal mining sector to commercial mining for private players in February 2018, enabling participation for a wider set of participants. Further on June 18, 2020, the government launched auctions for commercial mine blocks with no restrictions on end-use, thereby meaning that the coal produced at such mines need not be used for captive consumption and can be sold to other entities, including end-users such as power plants and cement plants. This is expected to encourage competition in the coal sector whilst boosting coal dispatch, thereby increasing domestic coal availability in the long run, post fiscal 2026, when we expect commissioning from these mines. Over the long term, addition of new mines along with improved technology is expected to increase production. Additionally, improvement in evacuation infrastructure in terms of commissioning of rail lines will aid in supply from the linked mine to the end user.

Figure 30: Company wise domestic coal dispatch between fiscal 2020-2026



Source: Ministry of Coal, Crisil Intelligence

Review of coal consumption and import

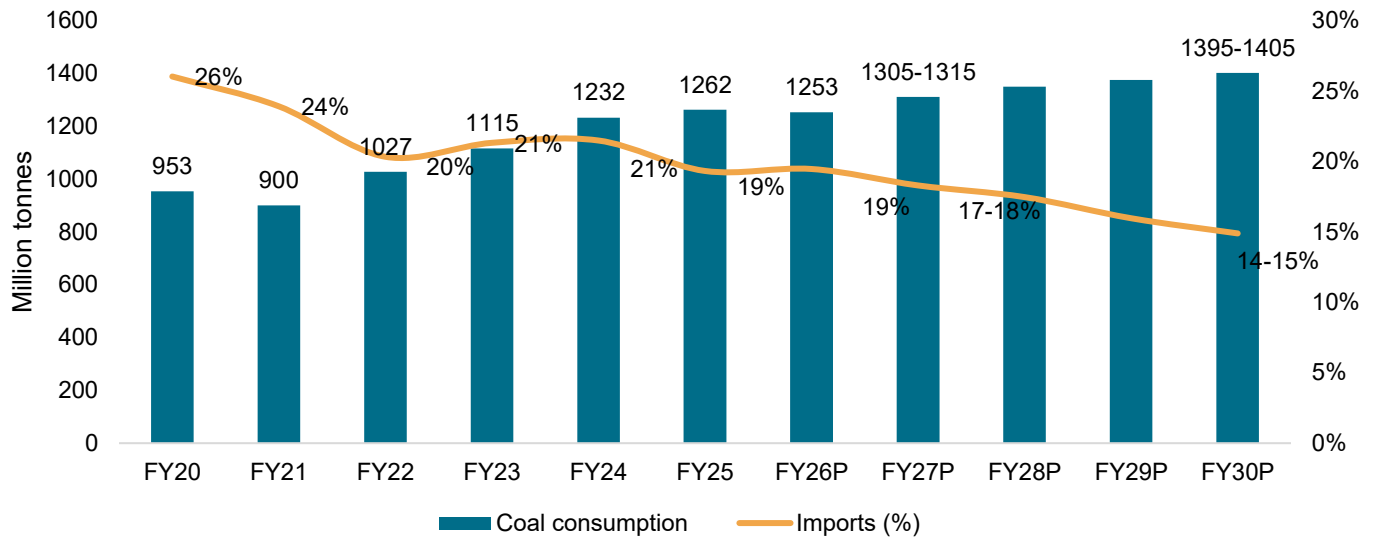
India's coal consumption is estimated to have clocked a CAGR of 7% over fiscals 2021-2026 to reach ~1,253 MT. Non-coking coal accounted for an average of 94% of total coal consumption while coking coal accounted for an average of 6% during the period.

Coal-based power generation sector is the largest user of non-coking coal, accounting for ~71% of the country's total non-coking coal consumption. The remaining 29% is primarily used by industries such as cement, sponge iron and other industries such as textiles.

The steel industry is the primary consumer of coking coal, using it to produce coke for steel manufacturing. However, domestic production has been hindered by subpar resource quality, inadequate washery capacity, and difficult mining conditions, resulting in a significant reliance on imports, which account for ~91-92% of total coking coal consumption.

Between fiscal 2021-2026, ~78% of India's coal consumption was met by domestic supply while ~19% was serviced by imports. Sufficient domestic coal supply is going to cap non-coking coal imports, limiting them mainly to need-based blending and supplying power plant that depend structurally on imported coal. The share of non-coking coal imports in total non-coking coal consumption is expected to decline to below 10% by fiscal 2030, from the current range of 15–16%. However, dependence on coking coal imports is likely to offset this reduction, keeping overall coal imports broadly stable at ~14-15% of total coal consumption.

Figure 31: Domestic coal consumption between fiscal 2020-2030



Source: Ministry of Coal, DGFT, Crisil Intelligence

Risk and challenges

Coal mining in India faces significant risks from natural perils to governmental policies to other risks:

Offtake risks: Coal is utilised in various industries, primarily as a source of fuel or as feedstock, in some cases. Offtake by coal-based power plants is a key to sustenance avenue of the coal sector as it accounts for ~70% of the overall coal consumption in India. Any fluctuation in coal-based power generation directly impacts demand for non-coking coal. The government's increased focus on renewables, especially solar, and slowdown in coal-based capacity additions is expected to pose significant risk to coal-based power generation.

In addition, offtake demand from other sectors such as steel and cement, is another key monitorable. The growth of competitive fuels, such as PCI injection in the steel sector and pet coke in the cement sector, can limit coal demand growth in the future.

Infrastructure risk: While domestic coal production has improved significantly over the last few years, the end-user industries still face some issues pertaining to coal supply, primarily owing to constraints in coal dispatch infrastructure. Reliance on rail infrastructure remains high as a large quantity of coal is transported via rail. Consequently, the lack of railway lines and coal rakes can impact growth of the coal sector, in spite of the timely development of coal mines.

Manpower risk: The coal mining sector in India is highly dependent on manual labour for carrying out production operations. The relatively low levels of automation as compared to international standards in the older mines requires higher dependence on manpower.

Natural perils: The coal mining sector faces a significant threat from natural perils owing to the nature of its primary operations. Over the past decades, there have been numerous instances of mine collapse, mine fires, gas leaks, etc., that have posed a serious threat to mining operations. Another peril is in the form of flooding, especially in the monsoons, that severely constrains coal production and dispatch during heavy rain.

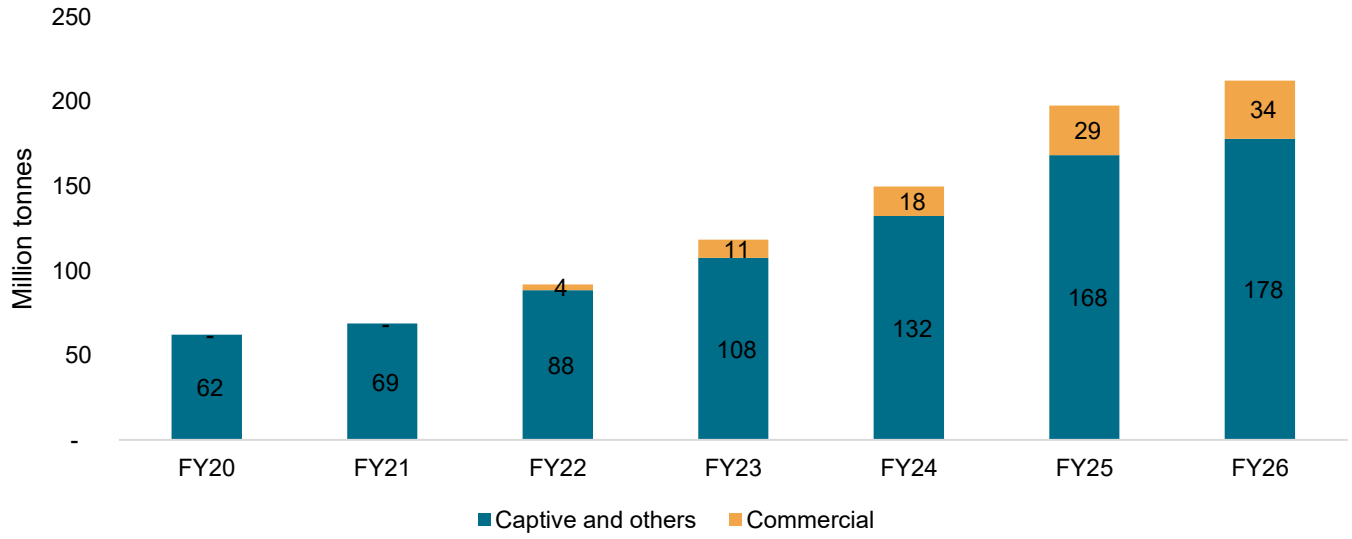
West Asia conflict : Indonesian thermal coal prices firmed modestly through February as policy-driven supply uncertainty (RKAB production quota resubmissions) and weather-related disruption reduced spot offer visibility, while demand remained cautious amid the Lunar New Year lull and generally comfortable coal-inventory levels in China and India. The prices have further increased in the month of march amid market volatility in freight rates on account of tighter supply and sporadic price volatility in the energy space due to uncertainties in the Middle East.

Overview of the captive coal mining and coal logistics segments

Captive coal mining and associated operations

Apart from dispatch of coal from CIL and SCCL, presently there are coal blocks also allocated to other stakeholders (state and private enterprises) to mine coal for consumption in their own operations. For instance, state power generation companies such as Rajasthan Rajya Vidyut Utpadan Nigam Ltd (RRVUNL), Telangana State Power Generation Corporation Ltd (TSPGCL) and the central power generator - National Thermal Power Corporation (NTPC) own mine blocks for production of coal to utilise for power generation operations. Other participants from industries such as aluminium and cement also own certain blocks to utilise such coal production for their manufacturing operations. During the period of April-December of fiscal year 2026, coal dispatch from Captive, commercial and other players stood at ~171.31 MT, registering a ~6% year-on-year increase from the same period in fiscal year 2025.

Figure 32: Dispatch from captive and commercial coal mining



Source: Ministry of Coal, Crisil Intelligence

In this segment, participants for whom this may not be a core business operation often contract third party mine developers and operators (MDO) who help in mining and production of coal from such blocks. The operator enters into arrangements with third parties who have been allocated coal blocks, where it is responsible for developing the mine, mining the coal, washing the coal, transporting and dispatching the washed coal to the required destination. The primary difference here is in terms of ownership, an MDO would be in most cases, a third-party contractor engaged to carry out mining and associated operations while the mine ownership would rest elsewhere. This is different from commercial or captive mining. Captive mining refers to mines owned and utilised by entities for captive coal production and consumption. Commercial mine allocations, which the government has introduced recently in the sector, is where mine ownership is being allocated to interested bidders (private and otherwise) for mining of coal for sale in the market at large. Both a captive and a commercial mine owner may then engage a third-party contractor, such as an MDO, to handle the operations as defined above.

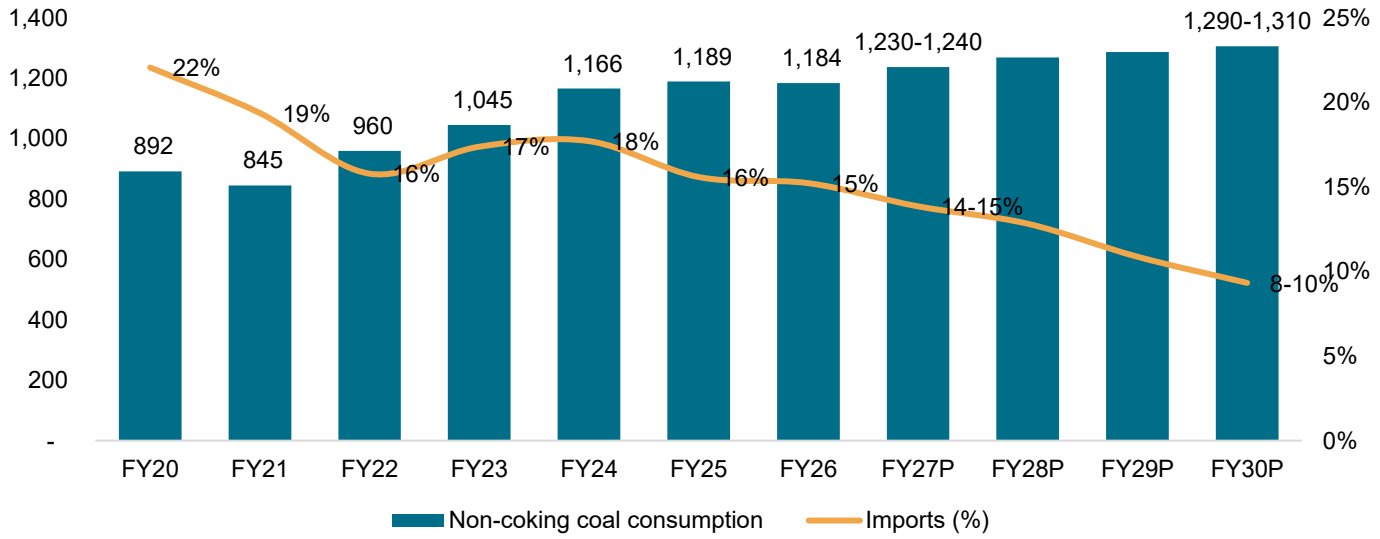
Adani Enterprises also has presence in the Indian MDO service sector, where it develops and operates coal mines. The company provides MDO services to five operational coal mines with eight under development coal mines as of H1 FY26. Dispatched coal quantity increased by 33% for the period of April-December in fiscal 2026 to 31 million tonnes.

Coal resource management

Coal supply requires the supply and logistics segment to appropriately manage sourcing. This involves sourcing resources (such as coal) from suppliers, managing sea-borne logistics, providing an intermediate holding facility at discharge ports, and delivering the resources to customers. Efficiency in such activities may result in cost and resource savings, especially in logistics, aiding sustainability of operations.

Historically, consumption of non-coking coal in India has been higher than the supply available from domestic resources, necessitating imports. Between fiscal 2021-2026, on average, 17% of the domestic non-coking coal requirement (the major coal variety used in India) has been imported.

Figure 33: Non-coking coal supply avenues



Source: Ministry of Coal, DGFT, Crisil Intelligence

Over the long term, between fiscal 2026-30, thermal coal consumption is expected to increase by 2-3% to 1,290-1,310 MT. This is expected on account of lower coal-based power generation as India braces to reach its Panch Amrit target of 50% non-fossil-based power generation by fiscal 2030. Consumption of thermal coal will be mainly driven by higher consumption of inputs for national infrastructure projects such as upcoming airports, metro and highways. However, since input sectors such cement, sponge iron etc. have a low share in overall non-coking coal consumption, overall trend is expected to only increase marginally.

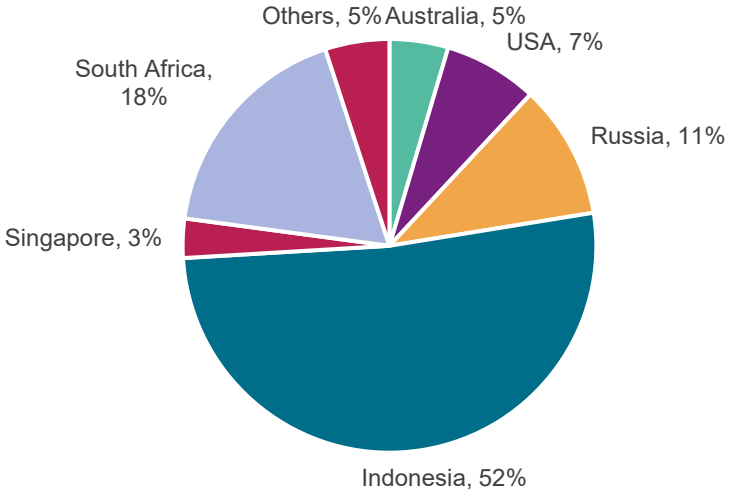
Domestic supply is expected to increase at a CAGR of 4.5-5.5% between fiscal 2026-30. Total non-coking coal imports are expected to decline at a CAGR of 9-10% during the same period.

The government has been pushing for substituting coal imports through domestic resources by investing in better infrastructure and mine expansions through CIL. It recently allowed commercial coal mining by allocating coal blocks to private enterprises and pushing for increased captive coal production in times of shortfall.

In fiscal 2026, non-coking coal accounted for ~73% of total imports, with the balance ~27% comprising other coal categories. The share of non-coking coal has moderated in recent periods and is expected to witness a further gradual decline through fiscal 2031.

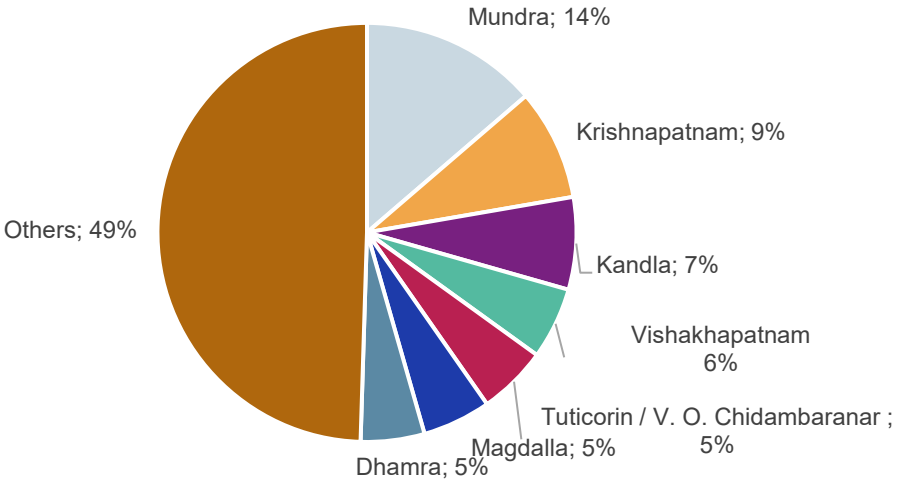
Imports are sourced from multiple coal-producing countries, with Indonesia accounting for a majority share. Certain industries have specific coal requirements (coal with a higher gross calorific value), which is generally produced in South Africa and Australia, resulting in high imports.

Figure 38: Country wise share of non-coking coal imports by India in fiscal 2026



Source: Ministry of Coal, Crisil Intelligence

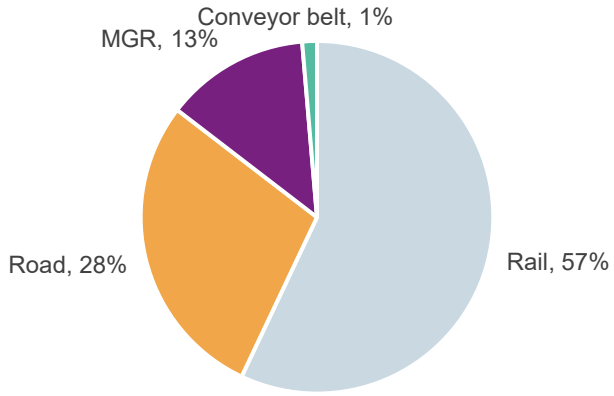
Figure39: Share of major ports as of fiscal 2025



Source: Ministry of coal, Crisil Intelligence

Most of the major domestic ports handle coal imports, with west and south India witnessing maximum traffic via the Mundra, Krishnapatnam, and Kandla ports in fiscal 2025. While shipping would be the primary transportation method for imported coal, inland transportation, too, takes place through various methods, especially rail.

Figure 40: Share of various methods of coal transportation



Note: Above data is as of fiscal 2025
MGR: Merry-Go-Round is a specific hopper wagon designed to carry large amounts of loose bulk commodities such as coal, aggregates and grain
Source: Ministry of Coal, Crisil Intelligence

Consequently, supply of coal requires stakeholders to manage operations, including sourcing and handling logistical operations. India imported ~246 million tonnes of non-coking in fiscal 2026.
Adani Enterprises handled volume of 44.6 million tonnes in fiscal 2026, under its Integrated Resource Management operations (a division dealing with resource management and logistics).

Assessment of regulatory framework in the coal industry

Coal is a highly regulated sector in India with various regulations impacting the industry.

Coal Mines (Nationalisation) Act, 1973

This Act was formulated after all private mines were nationalised and laid down the eligibility to mine coal in the country. This Act allowed mining by only the following entities:

The central government

A government company (including a state government company)

A corporation owned, managed and controlled by the central government

A person to whom a sub-lease has been granted by the central government

A company or corporation having a coal mining lease, subject to the condition that the coal reserves covered by the sub-lease are in isolated small pockets or are not sufficient for scientific and economic development in a coordinated manner and that the coal produced by the sub-lessee will not be required to be transported by rail.

This Act was further amended in 1976, 1993 and 1996, permitting coal mining for captive use by private companies engaged in power generation, coal washing and cement production.

Coal Mines (Special Provisions) Act, 2015

The Supreme Court passed a judgment in August 2014 cancelling the allocation of almost all the coal blocks allotted from 1993 to 2010, declaring the process to be illegal. Following this, the central government passed the Coal Mines (Special Provisions) Bill, 2015 to allot mines to players operating in eligible end-use sectors so as to ensure adequate availability of domestic coal and limit imports. The key features of this regulation are highlighted below:

Allows captive mining by private companies engaged in power generation (including for captive use), production of steel, cement and coal washing

Coal mines will directly be allotted to the public sector units (PSUs) whereas allotment to private players will be done through auctions

Private power producers will be awarded captive coal blocks through the reverse auction method whereas forward auction will be used for allocating mines to companies in the non-power sector

Captive coal blocks are classified into three schedules: Schedule I mines include all the 204 coal mines cancelled by the Supreme Court in August 2014. Schedule II includes 42 Schedule I mines that are currently under production or about to start production. Schedule III mines include the 32 Schedule I mines that have been earmarked for a specified end-use.

Mines and Minerals Development and Regulation Amendment Bill, 2015

The bill allows for the transfer of mining leases which have been granted through an auction process. The holder of these mining leases may transfer the lease to any eligible person, with the approval of the state government, and as specified by the central government.

The bill also allows for the transfer of mining leases which have been granted through procedures other than auction, and where the minerals are used for captive purpose. Captive purpose has been defined as the use of the entire quantity of mineral extracted in the lessees' own manufacturing unit. Such lease transfers will be subject to terms and conditions, and transfer charges as prescribed by the central government. Also, these transfers will be in addition to the existing transfers that are allowed.

Thus, this provision would allow for merger and acquisition of companies with captive mining leases.

The bill adds a definition of the leased area, as the area within which mining operations can be undertaken. This will also include the non-mineralised area required for the activities defined under mine in the Mines Act, 1952.

Mines and Minerals Development and Regulation Amendment Act, 2020

The Mineral Laws (Amendment) Act, 2020 was enacted to amend the Coal Mines (Special Provisions) Act, 2015 [CMSP Act] and the Mines and Minerals (Development and Regulation) Act, 1957 [MMDR Act]. The amendments in the Acts enabled following:

Allocation of coal blocks for composite prospecting license-cum-mining lease which will help in increasing of the inventory of coal, lignite blocks for allocation. Repetitive and redundant provision requiring previous approval of the central government in cases where the allocation or reservation of coal/lignite block has been made by the central government itself has been done away with.

Provided flexibility to the central government in deciding the end-use of Schedule II and III coal mines under the CMSP Act. Companies which do not possess any prior coal mining experience in India can now participate in auction of coal blocks.

The government abolished the restrictions related to the end-use of captive and non-captive leases.

Methodology for auction of coal and lignite mines/blocks for sale of coal/lignite on revenue-sharing basis under the CMSP Act and the MMDR Act was approved by the CCEA.

Commercial coal mining in India

To boost private participation in the sector, the government has been actively taking steps to open up the mining sector to private enterprises.

Under the same, the government had aimed to auction 500 mineral blocks by the end of 2024 as per a plan released by the Press Information Bureau in 2022. An assessment by the NITI Aayog in August 2021 indicated that a potential 160 projects under coal mining with an indicative worth of Rs 28.747 crore could be monetised over fiscals 2022 to 2025. On the ground, since the inception of commercial coal mining in 2020, the Ministry of Coal has successfully auctioned a total of 125 coal mines, with a combined production capacity of 273 million tonnes per annum (MTPA). Once operationalized, these mines will play a crucial role in enhancing domestic coal production and strengthening India's energy security. Collectively, these mines are expected to generate an annual revenue of Rs 38,767 crore, attract a capital investment of Rs 40,960 crore, and create employment opportunities for ~4,69,170 people as reported by the Ministry of Coal.

In November 2020, the Indian government conducted an auction under the first tranche of commercial mines. While 41 mines were initially included in the auction, the number was brought down to 38 after excluding three non-coking coal mines, owing to environmental issues, ultimately comprising 34 non-coking coal mines and four coking coal mines. The 38 mines had geological reserves of 14,983 million tonne, of which ~32% were proven reserves and had a peak rated capacity of 226.5 million tonne.

In the first round of bidding, a total of 73 bids were received for 19 coal blocks located in Chhattisgarh, Jharkhand, and Madhya Pradesh, and having a cumulative peak rated capacity of 51 MT and proven reserves of 3,067 MT. Of the 73 bids, 62 bids had been received for 16 non-coking coal blocks, whereas 11 bids had been received for 16 coking coal blocks. The highest bid received was for a 66.75% revenue share by a steel manufacturing company for the Gare-Palma IV/7 block. Companies that won bids in the 1st tranche were from diverse sector profiles of commodity trading, metal manufacturing, real estate, power generation and petroleum products.

In the second tranche of bidding held in August 2021, eight mines were auctioned, four of which were partially explored. The cumulative peak rated capacity of these eight mines was of 3 MT and proven reserves were of 849 MT. Seven mines were of non-coking coal, whereas one mine was of coking coal. The highest bid received was of a 75.5% revenue share, with the average premium for all mines at 30%.

In the third tranche of bidding, nine mines were auctioned, eight of which were fully explored with cumulative peak rated capacity of 22 million tonne per annum and proven reserves of 1,692 million tonne. The highest bid received was for 345% of revenue share with weighted average premium of 20%.

In the fourth tranche of bidding, four mines were auctioned. All mines were non-coking coal with cumulative peak capacity of ~15 MT. The highest bid received was for 85% of revenue share with weighted average premium of 35%. The 5th/6th round of bidding during February 2023, twenty-nine mines were auctioned, seven of which were partially explored. The cumulative peak rated capacity of the fully explored mines was 74.96 MTPA. The highest bid for revenue sharing was bid at 79.25% by Ultratech Cement, while the average premium for all the mines was 22.12%. In the 7th round of bidding held in August 2023, 6 mines with a cumulative peak rated capacity of 7 MTPA were sold. The highest bid received was for 43.75% revenue share by Shri Bajrang Power and Ispat Limited. Auction under the 8th and 9th round was held in November and December 2023 with a combined peak rated capacity of 4.2 MTPA.

As of December 2025, the government has concluded the 13th round of bidding. The latest allocated mines are expected to be commissioned by fiscal 2030 while the mines prior to this round are expected to be operationalized by fiscal 2028. The actual schedule is likely to depend on the winning bidder's profile and capabilities. Though implementation is key, private participation through commercial mine auctions is expected to increase efficiency and domestic production, thereby improving coal availability, particularly to non-power sectors, over the longer run. Utilization of mines will depend on the peak rated capacity of the mine, miner's capabilities and on ground restrictions. On average, the mines are expected to have an average utilization rate of 50-75% in the first year of commencement.

Table 8: Profile of commercial coal mine auction winners

Sr.No.	Name of Coal Mine	Successful Bidder / Allottee
1	Gare Palma IV/7	Sarda Energy and Minerals Limited
2	Gare Palma IV/1	Jindal Power Limited
3	Rajhara North (Central & Eastern)	Fairmine Carbons Private Limited
4	Gondulpara	Adani Enterprises Limited
5	Urma Paharitola	Aurobindo Reality and Infrastructure Private Limited
6	Brahmdiha	APMDCL
7	Chakla	Hindalco Industries Ltd
8	Urtan North	JMS Mining Private Limited
9	Sahapur West	Sarda Energy and Minerals Limited
10	Urtan	JMS Mining Private Limited
11	Dhirauli	Stratatech Mineral Resources Private Limited
12	Bandha	EMIL Mines and Mineral Resources Limited
13	Marki Mangli- II	Yazdani International Private Limited
14	Takli-Jena-Bellora (North) &Takli-Jena-Bellora (South)	Aurobindo Reality and Infrastructure Private Limited
15	Radhikapur West	Vedanta Ltd
16	Kuraloi (A) North	Vedanta Ltd
17	Gotitoria (East) & (West)	Boulder Stone Mart Pvt Ltd
18	Bhaskarpara	Prakash Industries Limited
19	Jhigador	CG Natural Resources Private Ltd
20	Khargaon	CG Natural Resources Private Ltd
21	Jogeshwar & Khas Jogeswar	Southwest Pinnacle Exploration Limited
22	Rauta Closed	Shreesatya Mine Private Limited
23	Gondkhari	Adani Power Maharashtra Ltd
24	Bhivkund	Sunflag Iron and Steel Company Limited
25	Gonbahera Ujheni East	MP Natural Resources Private Limited
26	Beheraband North Ext.	Auro Coal Private Limited
27	Tokisud Block -II	Twenty First Century Mining Private Limited
28	Barra	Bharat Aluminium Company Ltd
29	Brinda & Sasai	Dalmia Cement (Bharat) Limited
30	Maiki North	Maiki South Mining Pvt. Ltd.
31	Marki Barka	Birla Corp. Ltd
32	Utkal-C	Jindal Steel and Power Limited
33	Bijahan	Mahanadi Mines & Minerals Pvt. Ltd.
34	Bankhui	Yazdani Steel and Power Limited
35	Kasta East	Jitusol developers Pvt Ltd
36	Koilajan	Assam Mineral Development Corporation Limited
37	Garampani	Assam Mineral Development Corporation Limited
38	Meenakshi	Hindalco Industries Limited
39	Gare Palma IV/6	Jindal Steel and Power Limited
40	Utkal B1 & B2	Jindal Steel and Power Limited
41	Alaknanda	Rungta Sons Pvt Ltd.
42	Rabodih OCP	Twenty First Century Mining Private Limited
43	Rampia & Dip Side of Rampia	Jhar Mineral Resources Private Limited
44	Basantpur	Gangaramcha k Mining Pvt Ltd

45	Jitpur	Terra Mining Private Ltd
46	Bandha North	Jaiprakash Power Ventures Limited
47	Marki Mangli- IV	Sobhagya Mercantile Limited
48	Sitanala	JSW Steel Limited
49	Choritand Tiliaya	Rungta Metals Private Limited
50	Datima	Shree Cement Limited
51	Ghogharpalli & Its Dip Extension	Vedanta Ltd
52	Arjuni East	Ultratech Cement Limited
53	Arjuni West	Ganga Khanij Private Limited
54	Baitarni West	Gujarat Mineral Development Corporation Ltd
55	Binja	Assam Mineral Development Corporation Limited
56	Burakhap Small Patch	Shreesatya Mines Private Limited
57	Burapahar	Gujarat Mineral Development Corporation Ltd
58	Chendipada (Revised)	Rungta Sons Private Limited
59	Dahegaon-Gowari	Ambuja Cements Limited
60	Gare Palma Sector - I	Jindal Power Limited
61	Gare Palma IV/2 and Gare Palma IV/3	Jindal Power Limited
62	Gondbahera Ujheni	MP Natural Resources Private Limited
63	Kagra Joydev	Orissa Metallurgical Industry Private Limited
64	Mandla North	Dalmia Cement (Bharat) Limited
65	Marwatola – VI	JSW Cement Limited
66	Marwatola – VII	Rama Cement Industries Private Limited
67	Northwest of Madheri	MH Natural Resources Private Limited
68	Parbatpur Central	JSW Steel Limited
69	Patal East (Eastern Part)	RCR Steel Works Private Limited
70	Purunga	CG Natural Resources Private Limited
71	Sakhigopal – B Kankili	Rungta Sons Private Limited
72	Kalambi Kalmeshwar (Western Part)	Samlok Industries Pvt. Ltd.
73	Namchik Nampuk	Coal Pulz Private Ltd
74	North Dhadu (Eastern Part)	NTPC Miniing Ltd
75	North Dhadu (Western Part)	NLCIL
76	Pathora East	Shree Bajrang Power & Ispat Ltd
77	Pathora West	Shree Bajrang Power & Ispat Ltd
78	Meenakshi West	Hindalco Industries Ltd
79	Sherband	Neelkanth Coal Mining Pvt Ltd
80	Mara II Mahan	Mahan Energen Ltd
81	Kudanali Lubri	Gujarat Mineral Development Corporation Ltd
82	Machhakata (Revised)	NLC India Limited
83	Sakhigopal-B Kakurhi	TANGEDCO
84	Mahan	JK Cement Ltd.
85	Binodpur Bhabhaniganj	JMS Mining Private Limited
86	Marki-Zari-Jamani-Adkoli	Nilkanth Infra Mining Limited
87	Babupara East	Rungta Sons Private Limited
88	Baisi	Indermani Mineral India Pvt Ltd

89	Dumri	S M Steels and Powver Limited
90	Duni Central	Bull Mining Private Limited
91	Lalgarh South	Rungta Sons Private Limited
92	Lamatola	ACC Limited
93	South of Damuda	Rungta Sons Private Limited
94	West of Shahdol (South)	JK Cement Ltd.
95	Bundu	S M Steels and Power Limited
96	Gare Palma IV/5	Sarda Energy and Minerals Limited
97	Kerendari-BC North	Orissa Alloy Steel Private Limited
98	Marwatola South	Mineware Advisors Private Limited
99	New Patrapara South	NLC India Limited
100	Sarai East (South)	ACC Limited
101	Ulia Gamhardih	S M Steels and Power Limited
102	Gawa (East)	Shreeji Nuravi Coal Mining and Trading Private Limited
103	Bartap (Revised)	JSW Energy Utkal Limited
104	Jawardaha North	Jharkhand Exploration and Mining Corporation Limited
105	Dahegaon/Makardhokra-IV	Western Coalfields Limited
106	Saradhapur Jalatap East	Jindal Steel and Power Limited
107	Marwatola-II	Singhal Business Private Limited
108	Namchik West	Pra Nuravi Coal Mining Private Limited
109	Banai & Bhalumunda	Jindal Power Limited
110	Sahapur East	Mineware Advisors Private Limited
111	Seregarha	Rungta Sons Private Limited
112	Vijay Central	Rungta Sons Private Limited
113	Bhandak West	New Era Cleantech Solution Private Limited
114	Tandsi III & Tandsi III Ext	Lloyds Metals and Energy Limited
115	Senduri	Sarda Energy and Minerals Limited
116	West of Baisi (Revised)	Ind Synergy Limited
117	Cholapathar	Shaktibhumi Mining Private Limited
118	West of Tubed	Oriental Quarries and Mines Private Limited
119	Chitarpur (Revised)	Orissa Alloy Steel Private Limited
120	Phutamura	Alom Solar Private Limited
121	Tangardihi North	Odisha Coal & Power Ltd. (OCPL)
122	Mahuagarhi	Damodar Valley Corporation (DVC)
123	Rajgamar Dipside (Devnara)	TMC Mineral Resources Private Limited
124	Rajgamar Dipside (South of Phulakdih Nala)	Mivaan Steels Limited
125	Pakri Barwadih	NTPC Mining Limited
126	Tasra	SAIL
127	Moher & Moher Amloghri	Sasan Power Limited

Note: Data is for commercial mine auction tranches (1st-13th)

Source: Ministry of Coal, Crisil Intelligence

Presence of Adani Enterprises in commercial coal mining

Under the commercial coal mine allocations, Adani Enterprises has also won commercial coal mines through the competitive bidding process conducted by the Government of India. As of fiscal 2026, the company has a total portfolio of 15 coal mines under coal mine service and 6 mines under domestic commercial mining contracts.

Further, Adani Enterprises also has the Carmichael mine and rail project which is located near the Queensland coast in Australia. The Carmichael project is a thermal coal mine and rail project, which transports coal from the Galilee Basin to countries in Asia, including India. The Carmichael mine has a peak capacity of 15 million tonnes per annum (MTPA) which became operational in the fourth quarter of fiscal 2022. The mine has witnessed a decline in production of 11% on year in fiscal 2026 to ~11.4 million tonnes.

Purchases of stock-in-trade declined by 8.84% to Rs 39,814.18 crore in fiscal 2025 from Rs 43,676.49 crore in fiscal 2024, largely attributable to lower volumes and prices of commodities traded in the Integrated Resources Management segment, as well as subdued order volumes during the year.

Further, Revenue from the Commercial Mining segment declined by 19.75% to Rs 5,642.30 crore in fiscal 2026, from Rs 7,031.00 crore in fiscal 2025, primarily driven by an 8.22% decline in volumes, along with moderation in price realisations in line with the softening of global coal prices during the year.

Coal imports continue to influence production costs and expose the sector to volatility in global markets. Any adverse movement in demand for imported coal could, in turn, impact the Company's operational performance and financial position.

Table 10: Mining services and commercial mining under Adani Enterprises

Mine Name of Mine & States	Peak Capacity	SPV Name
Gondulpura, Jharkhand	4.0 MMT	Adani Enterprises Ltd
Bijahan, Odisha	5.3 MMT	Mahanadi Mines and Minerals Pvt Ltd
Gondbahera Ujheni, Madhya Pradesh	4.1 MMT	MP Natural Resources Pvt Ltd
Jhigador, Chhattisgarh	TBD	CG Natural Resources Pvt Ltd
Khargaon, Chhattisgarh	TBD	CG Natural Resources Pvt Ltd
Rampia 8, Dip side of Rampia, Odisha	15.0 MMT	Jhar Mineral Resources Pvt Ltd
Parsa East and Kanta Basan Coal Block	18	Parsa Kente Collieries Ltd
Talabira II & III Coal Block	23	Talabira (Odisha) Mining Pvt Ltd
Gare Palma-III Coal Block	5	Gare Pelma III Collieries Pvt. Ltd
Suliyari Coal Block	6	Adani Enterprises Ltd
Parsa Coal Block	5	Rajasthan Collieries Ltd
Kente Extension Coal Block	9	Rajasthan Collieries Ltd
Gare Palm-II Coal Block	23.6	Gare Pelma II Collieries Pvt. Ltd
Pelma Coal Block	15	Pelma Collieries Ltd
Dahegaon Coal Block	1	Adani Mining Ltd
Dhirauli Coal Block	6.5	Adani Mining Ltd
Gondkhari Coal Block	2	Adani Mining Ltd
Mara II Mahan Coal Block	TBD*	Adani Mining Ltd
GBU East Coal Block	3.0	Adani Mining Ltd
Jitpur	2.5	Adani Mining Ltd
Purunga	2.25	Adani Mining Ltd

Module 3: PVC Industry

Industry developments and outlook

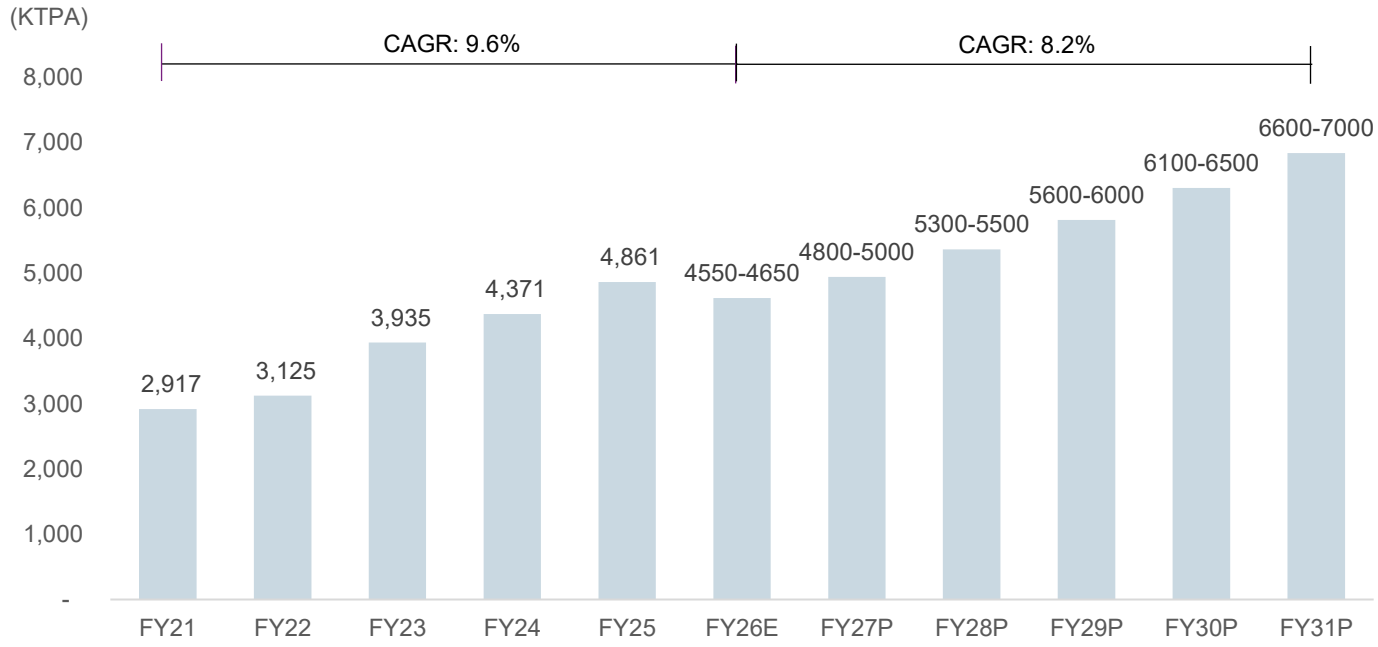
Demand review

The polyvinyl chloride (PVC) market demand in India stood at 2,917 kilo tonne per annum (ktpa) at the end of fiscal 2021. Continued demand from construction and infrastructure segments is expected to clock a growth of ~10% CAGR between fiscal 2021 and fiscal 2026 with growth slowed down by demand de-growth in fiscal 2026. Prolonged monsoon season in fiscal 2026 impacted the demand from plastic piping especially in the agricultural and infrastructure applications. As a result, demand for PVC from pipes & fittings segment is estimated to decline by 8-10% in fiscal 2026.

According to Crisil Intelligence the demand grew by approximately 11% in fiscal 2025. The rise in consumption was underpinned by continued structural momentum in end-use construction and agriculture sectors. Strong construction sector demand growth was seen on account of urbanization, expansion of housing, strong pipeline activity (water, gas and sewage) and support from government programs, while demand from agriculture sector came from applications like irrigation supported by government initiatives like Pradhan Mantri Krishi Sinchayee Yojana (PMKSY). Non-traditional applications such as pharmaceutical-grade PVC, profiles, and OPVC pipes are also projected to contribute an increasing share to overall demand.

Imports continued to be critical in supply accounting for approximately 70% of share, growing by 13% year on year.

Figure 34: Domestic PVC demand in India (FY21-31P)



E: Estimated, P: Projected

Source: Industry, Crisil Intelligence

Demand outlook

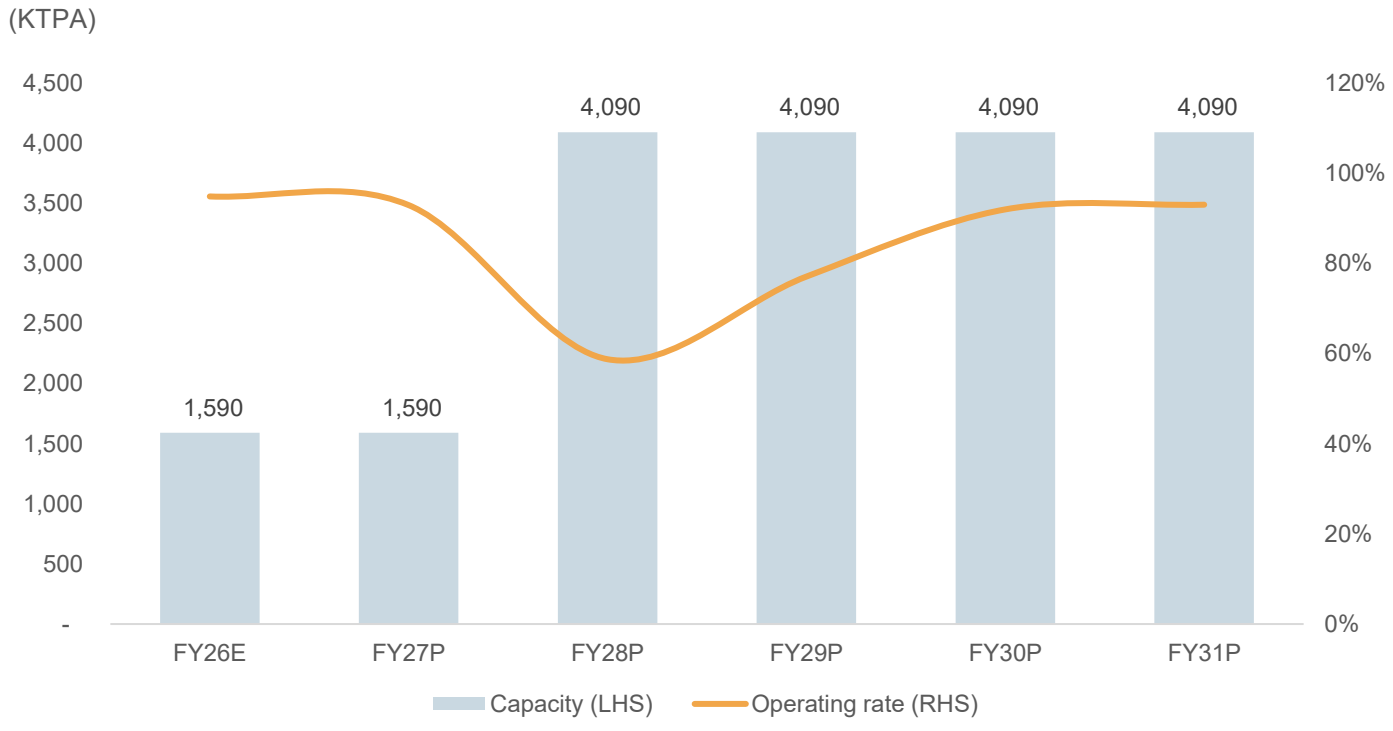
PVC demand is set to increase 6-8% on-year in fiscal 2027 to 4,800-5,000 ktpa. The pipes and fittings segment, which accounts for approximately 75% of PVC offtake, will be the primary driver of demand growth. With government schemes such as Jal Jeevan Mission and Pradhan Mantri Awas Yojna, which focus on the water supply, sanitation and housing segments having doubled their budgetary allocation this fiscal, on-year, will drive up the requirement of PVC pipes and fittings even more.

Over the medium term, from fiscals 2026 to 2031, rising infrastructure projects and increasing consumption across multiple sectors like packaging will fuel growth. The government's push for ISI-marked pipes, which reduces filler usage and boosts PVC consumption, is a key factor for PVC growth. The extension of the Jal Jeevan Mission until 2028 is expected to provide additional momentum by supporting nationwide water supply initiatives.

Capacity and production outlook

Production of PVC started in India in 1961. Since then, production capacity has increased multi-fold, with a large-scale plant commissioned by Reliance Industries in 1990-91, the largest player. The total production capacity in India is 1,590 ktpa as of fiscal 2026.

Figure 35: Domestic PVC capacity and plant operating rates (FY26-31P)



E: Estimated, P: Projected

Note: Capacity addition assumed for Adani Mundra is 1 MTPA

Source: Industry, Crisil Intelligence

Domestic utilisation rate of the PVC manufacturing industry rose to 96% in fiscal 2025 owing to better production driven by stronger end-use demand in the later part of the year. Crisil Intelligence expects domestic utilisation to marginally

decline in fiscal 2026 due to lack of any capacity addition and relatively slower demand growth from pipes segment with prolonged monsoon.

Going forward, over the next five years, Crisil Intelligence expects the overall operating rates will dip post fiscal 2027, as new capacities from Adani group and Reliance Industries start to come online.

Outlook on PVC demand by key application

PVC products are widely used in various industries due to its superior strength, non-flammability and ease of processing and moulding. Various government initiatives are also likely to aid the demand growth under each segment. The growth of PVC has historically been driven by the agriculture and infrastructure segments, which is evidenced by the significant contribution of the pipe and fittings segment in the overall demand mix for PVC.

Pipe and fittings segment is the largest consumer of the PVC, about three-fourths of the overall Indian demand in fiscal 2025. The major application under this segment is the manufacturing of PVC pipes, which have a long product life, are cost-effective, and are easy to handle. With increased spending on infrastructure and usage of PVC for irrigation, water supply, sewerage and plumbing, the contribution of this segment is expected to grow even further by fiscal 2031.

Other key applications include calendars and film sheets, contributing to approximately 15% of the overall demand. It is used for stationary products applications, electrical insulation tapes, tablet and capsule manufacturing, and packaging for industrial and consumer goods.

PVC is also used in wires and cables segment for insulation and sheathing purpose. Insulated wires are used for residential, industrial, and commercial purposes as it is flame retardant, easy to install and are tough. It is also used in high temperature environment for kitchen appliances.

Figure 37: Segment-wise demand of PVC (FY26E)

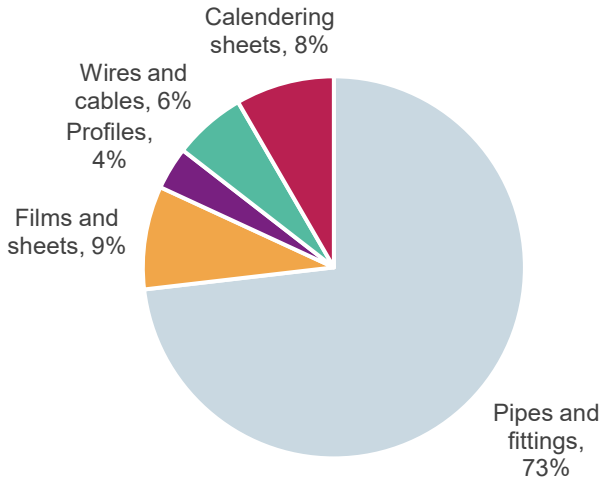
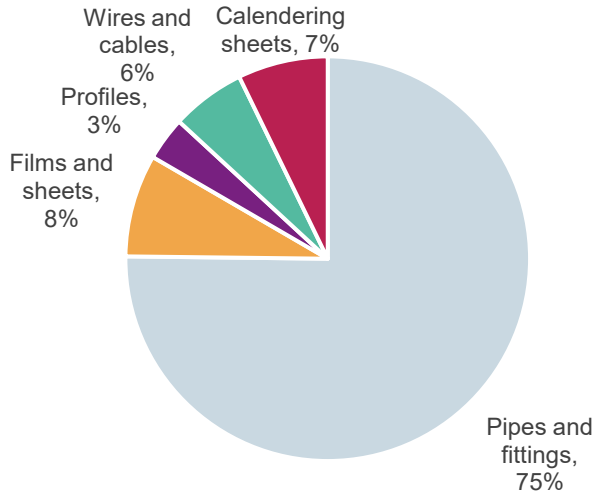


Figure 36: Segment-wise demand of PVC (FY31P)



E: Estimated, P: Projected

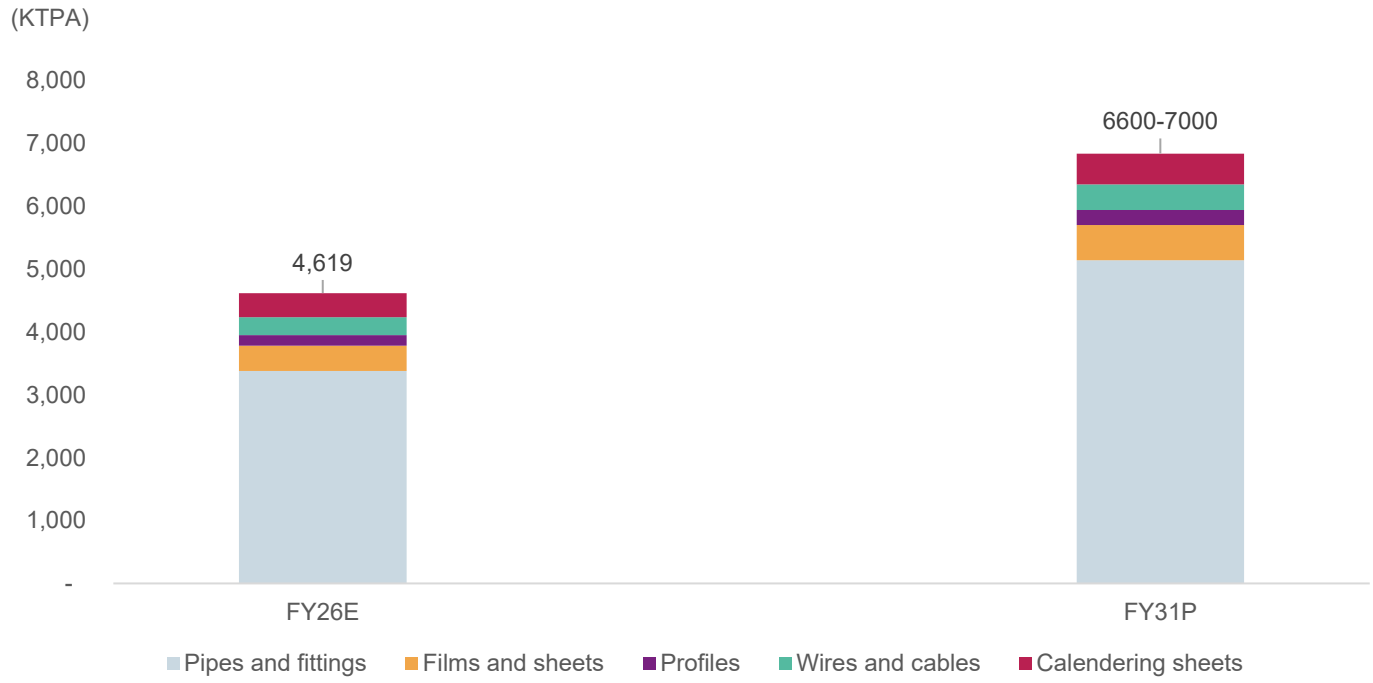
Source: Industry, Crisil Intelligence

Growth Drivers

Application growth outlook

Segment-wise consumption projections are as follows:

Figure 38: Application growth (FY26-31P)



E: Estimated, P: Projected

Source: Industry, Crisil Intelligence

- The pipes and fittings segment is anticipated to experience a CAGR of 8-10% over the forecast period. This growth is expected to be driven by investments in irrigation, water supply, and sanitation projects, as well as the ongoing trend of replacing metal pipes with PVC. The government's initiative to increase irrigation in non-rainfed areas through the Prime Minister Krishi Sinchayee Yojana is also expected to boost demand for PVC pipes.
- Films and sheets segment is projected to clock 6-8% CAGR, led by demand from consumer-driven sector such as packaging
- Calendaring segment is projected to log 4-6% CAGR, owing to demand from pharmaceuticals segment
- Profiles, wires and cables segment is expected to rise at 6-8% CAGR

Government Initiatives

Government measures which would aid the growth of PVC are as follows:

- **Jal Jeevan Mission**: This Mission is being implemented in partnership with States to make provision of tap water supply to every rural household and public institutions in villages such as schools, anganwadi centers, ashramshalas (tribal residential schools), health centres, and gram panchayat buildings. Demand for distribution pipes for water

supply could aid growth of the PVC industry. Extended to 2028 with a budget of INR 67,300 crore for fiscal 2027, it focuses on connecting the remaining ~16 crore households.

- **Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)**: PMKSY promotes efficient irrigation to enhance agricultural productivity through schemes like “Per Drop More Crop” (micro-irrigation) and watershed development. It supports drip and sprinkler irrigation systems.
- **Smart Cities Mission**: This initiative aims to develop 100 smart cities with modern infrastructure, including water supply, sanitation, and urban mobility. The initiative will support demand for PVC pipes, fittings, and profiles in urban water supply, drainage, and sewage systems. PVC’s corrosion resistance and ease of installation make it ideal for smart city infrastructure. As of May 2025, a total of 7,555 projects 94% of the total 8,067 projects have been completed. With the mission in its last leg of completion, limited PVC offtake is expected from the initiative now.
- **Atal Mission for Rejuvenation and Urban Transformation (AMRUT)**: The government launched AMRUT to provide basic services to households and build amenities in urban areas. The initiative will enhance demand for PVC pipes and fittings in urban water management systems due to their durability and cost-effectiveness.

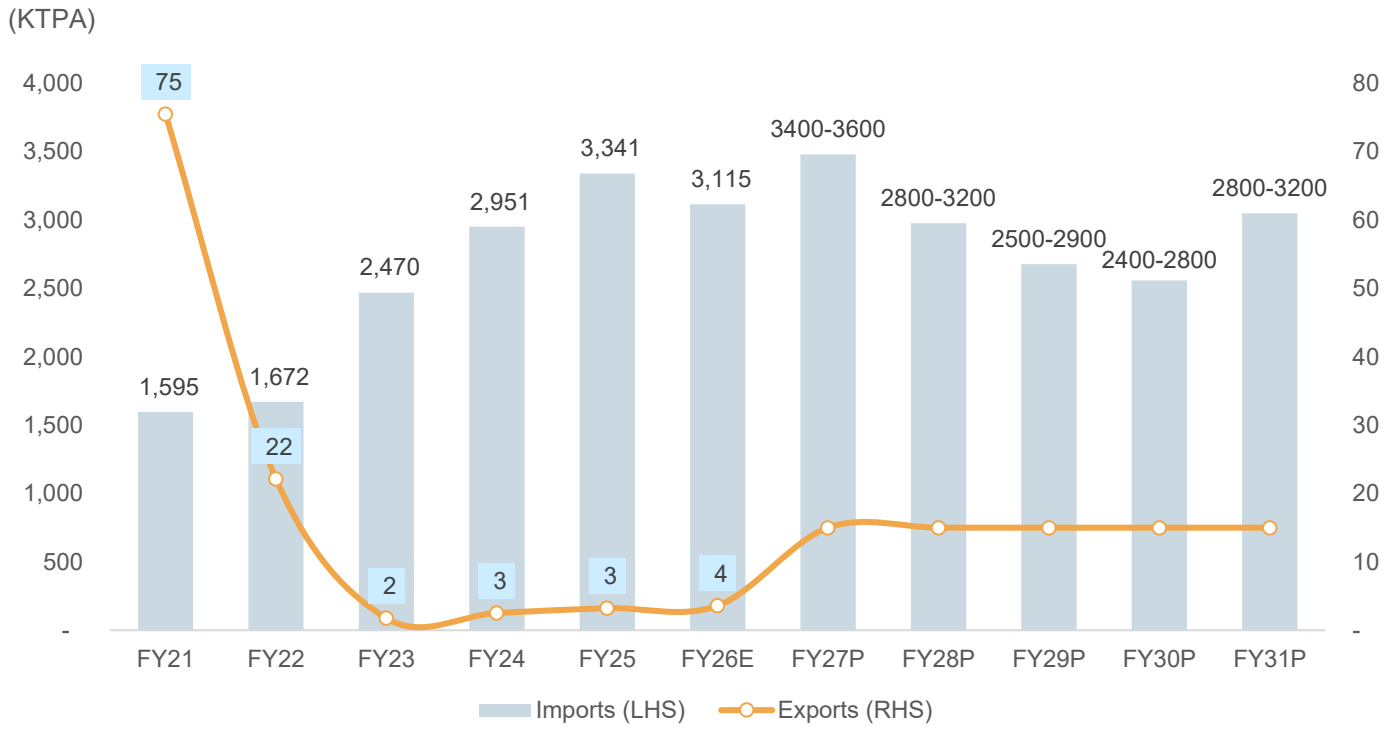
Trade Outlook

PVC imports and exports

India continues to be one of the largest demand centres for PVC globally. Limited growth in capacity in recent years had led to an increasing reliance on imports which currently account for two-thirds of the supply. While imports have risen sharply between fiscals 2021 and 2026, they are set to decline marginally by ~0.5% CAGR over the next five years on account of domestic capacity increase.

India is not an exporter of PVC and hence no major exports are noticed, except in fiscal 2021, owing to reduced domestic demand due to Covid-related restrictions.

Figure 39: PVC imports and exports (FY21-31P)



E: Estimated, P: Projected

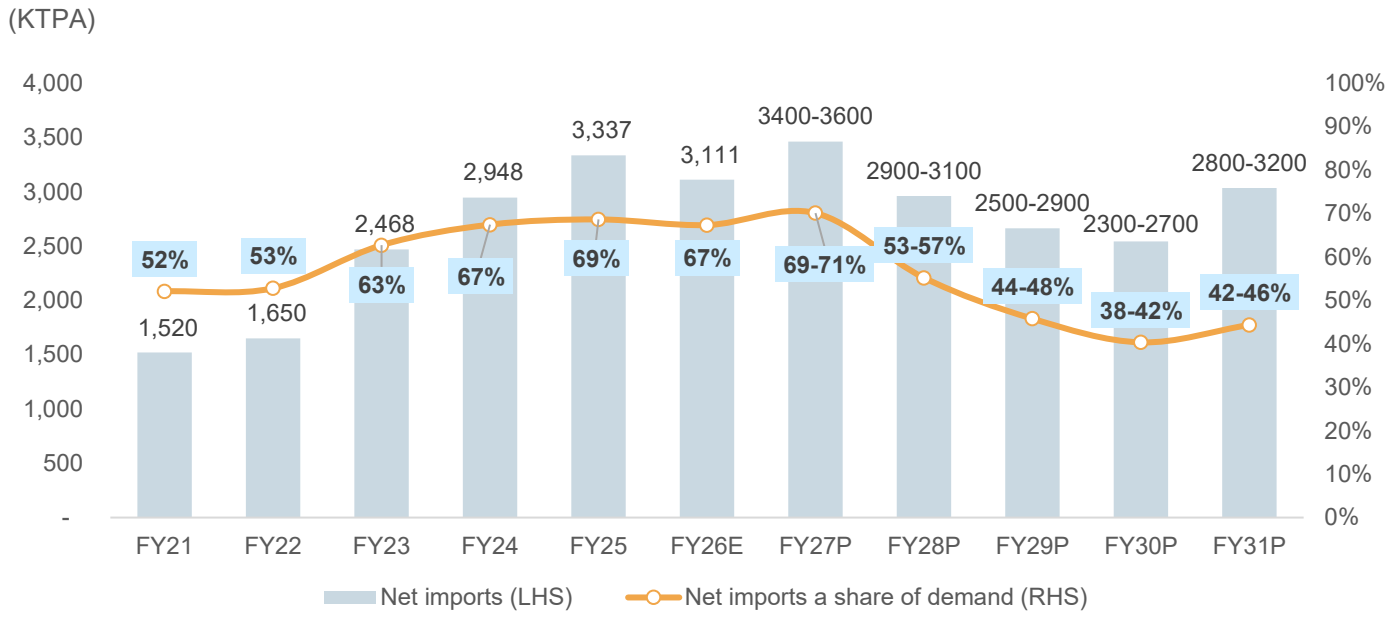
Note: Capacity addition assumed for Adani Mundra is 1 MTPA

Source: Industry, Crisil Intelligence, DGFT

Imports as a percentage of overall demand

The reliance on imports will continue to increase till fiscal 2027, post which a decline in the share is expected, however despite capacity additions the share of net imports in demand will remain significant at 42-46% by fiscal 2031.

Figure 40: PVC net imports, % of demand (FY21-31P)



E: Estimated, P: Projected

Note: Capacity addition assumed for Adani Mundra is 1 MTPA

Source: Industry, Crisil Intelligence, DGFT

The demand for PVC is expected to register a CAGR of ~10% between fiscals 2021 and 2026 while production barely grew at ~2% during the same period no major capacity additions. As a result, imports took over the incremental demand with their share growing from ~52% in fiscal 2021 to ~67% in fiscal 2026.

Over the next few years, operating rates of existing plants are expected to remain high while addition of new capacities of 1.5 MTPA from Reliance Industries and 1 MTPA from Adani group will curb imports to an extent.

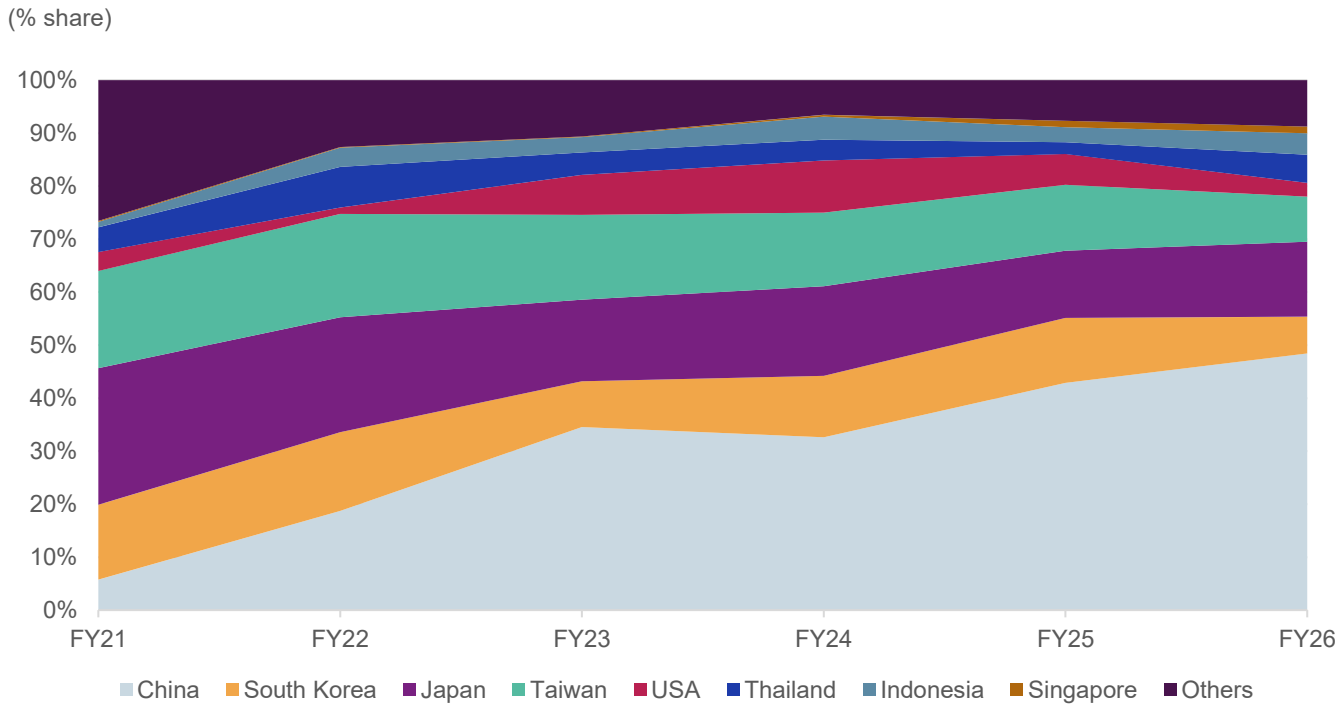
Key trade partners for India

India is the world's largest importer of PVC. India's total PVC imports stood at ~1600 kta as of fiscal 2021 and grew at a CAGR of ~14% till fiscal 2026 to reach ~3,100 kta.

China is the largest exporter to India with current share of ~48% as of fiscal 2026. China's share in imports has jumped from 6% in fiscal 2021 increasing nearly 7 times. This rise was largely driven by competitive pricing and surplus capacity coupled with weakness in domestic downstream real estate sector. In the last 3 years, the United States has accounted for 6% of the supply, making it a significant supplier outside of Asia, although its market share has been subject to fluctuations due to changes in trade regulations and freight rates.

Asia has been the dominant region over the past four fiscals with share in supply rising from approximately 70-75% in fiscal 2021 to 87-92% as of fiscal 2026. Going forward, surplus capacity and geographical proximity is expected to keep Asia as the leading supplier to India.

Figure 41: Key trade partners (FY21-26)



E: Estimated, P: Projected

Source: Industry, Crisil Intelligence

Anti-dumping duty development

- **Background:** The government had imposed anti-dumping duty on PVC imports in 2008 to aid domestic growth of domestic producers. However, the duty was not extended on its lapse in February 2022 after various extensions during the last decade. But, with increased inflationary pressure, the government in May 2022 decided to reduce the customs duty on PVC from 10% to 7.5%. However, this resulted in increase in imports from China in fiscal 2022 and fiscal 2023. This coupled with fall in international PVC prices led significant erosion of margins for domestic PVC players.
- **Current Scenario:** Consequently, the three of the domestic players accounting for ~35% of the capacity initiated an anti-dumping duty (ADD) investigation on suspension-grade PVC (s-PVC) imports in March 2024, to address alleged dumping from seven countries: China, Indonesia, Japan, South Korea, Taiwan, Thailand, and the United States**.** In October 2024 DGTR imposed provisional duties. In August 2025, India finalized the anti-dumping duty (ADD), ranging from USD 22-284 per tonne aiming to curb cheap imports and encourage domestic producers to operate more freely.
- However, the Ministry of Finance opted against the safeguard measures in November 2025, considering guidance from Niti Aayog and the High-Level Committee on Non-Financial Regulatory Reforms. Officials cited the need to avoid unnecessary intervention for widely traded raw material intermediates that pose no health, safety, or environmental risks. The Ministry also highlighted the potential for higher input costs to disrupt supply chains and reduce competitiveness, particularly for MSMEs who are reliant on imported raw materials.
- Further, Ministry of Chemicals and Fertilizers has revoked the Bureau of Indian Standards (BIS) Quality Control Orders (QCOs) for various petrochemicals including PVC in November 2025. Under the QCO framework,

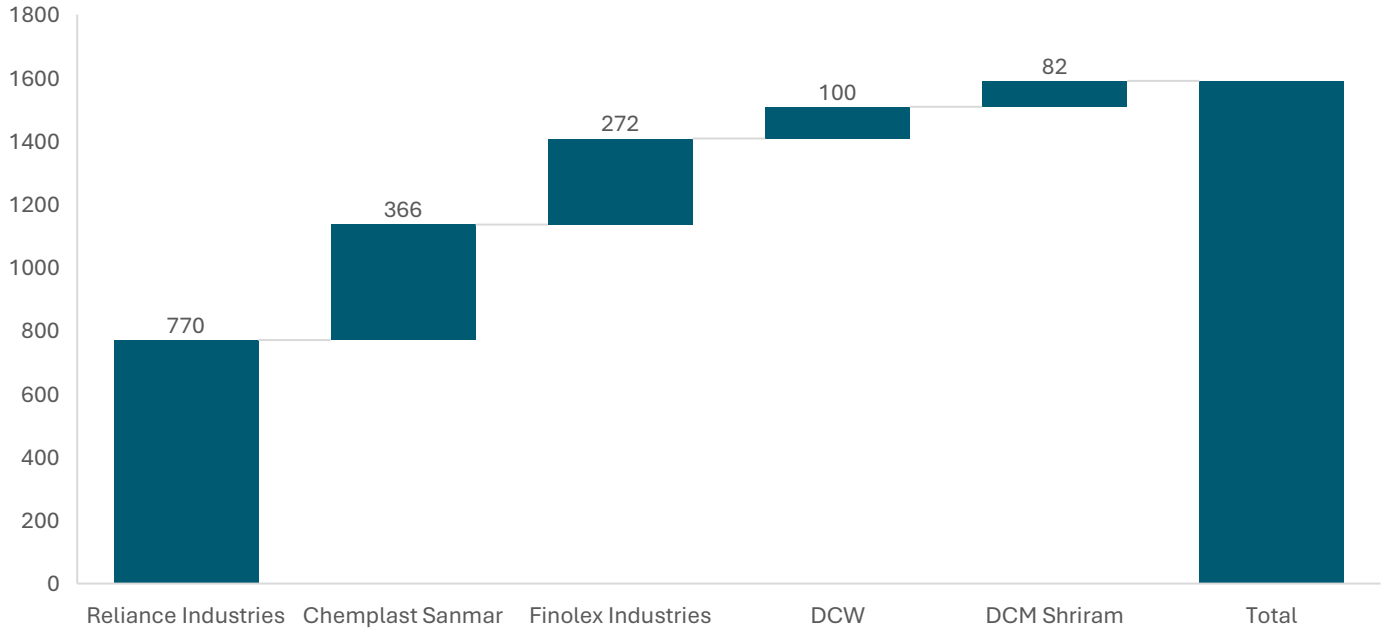
manufacturers were required to obtain BIS certification through a process involving in-person audits and approval of production facilities. Only certified suppliers could label their packaging with the BIS standard for shipments bound for India. The revocation is expected to ease import restrictions and improve raw material availability for domestic converters in the short term.

Competition Landscape

Capacity of Leading Players

The domestic capacity of PVC in India was 1,590 ktpa at the end of fiscal 2026, with Reliance Industries contributing ~48% to the total capacity. Other key players are Chemplast Sanmar (23%), Finolex Industries (17%), DCW (6%), and DCM Shriram (5%).

Figure 42: PVC manufacturers in India (FY26), capacity in KTPA



There have been fewer capacity additions in India owing to uncertainty around import duty fluctuations. The details of demand and capacity shares of leading manufactures in India are given below:

- Reliance Industries, with its three plants at Dahej, Hazira and Jamnagar, and a combined production capacity of ~770 ktpa, is the leading producer of PVC in India
- Chemplast Sanmar has two manufacturing facilities for PVC resin in Mettur in Tamil Nadu and Karaikal in the Union Territory of Puducherry. With a total capacity of 366 ktpa, the company is the second largest manufacturer in the country

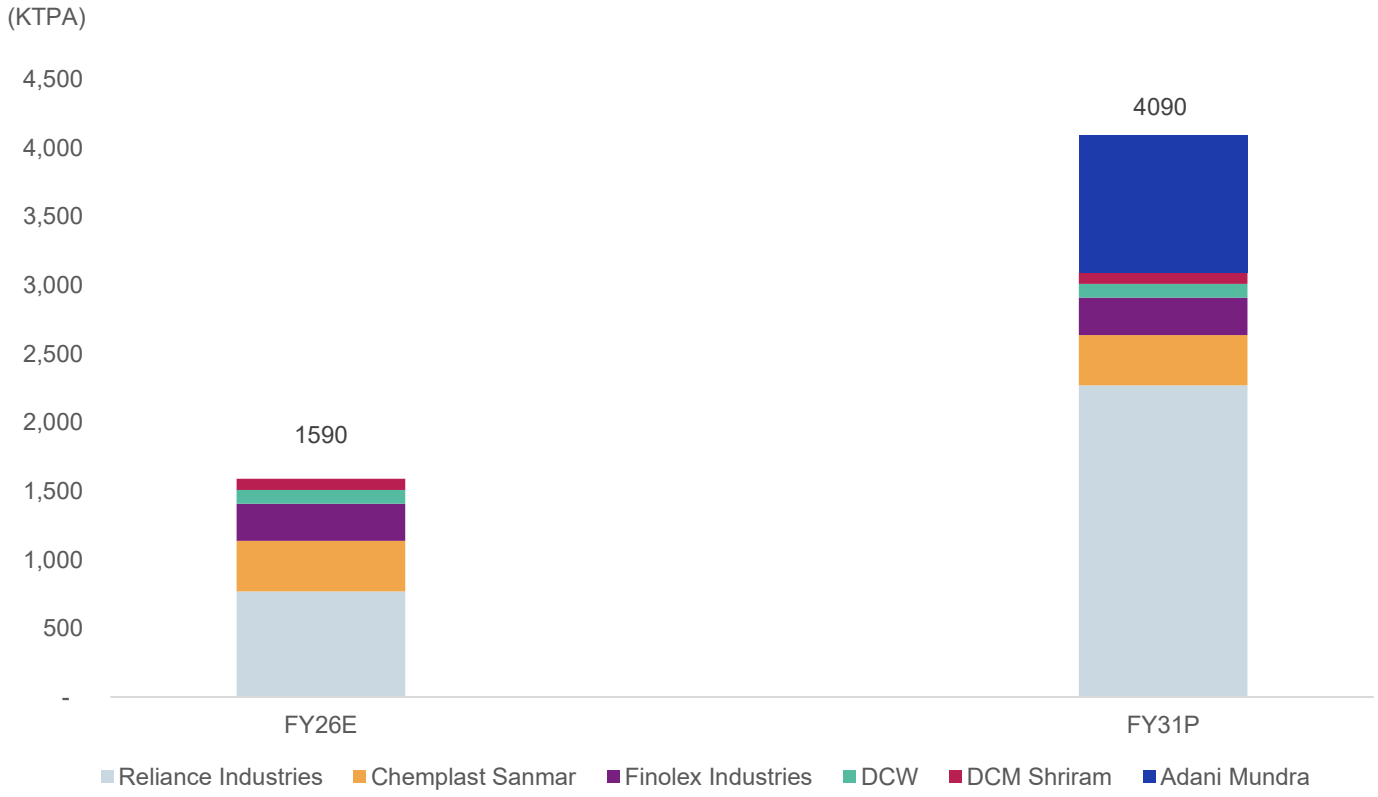
- DCW's plant is situation at Sahupuram in Tamil Nadu with a production capacity of ~100 ktpa
- DCM Shriram's sole plant with capacity of ~80 ktpa is based at Kota in Rajasthan

Owing to fewer domestic players in the market, there is limited competition within the industry. However, high imports and absence of duty protection for the manufacturers in India had led to increased linkage with international market movements.

Planned expansions in short to mid-term

PVC capacity in India had remained rather stable between fiscals 2021 and 2026 due to high entry barriers and uncertain duty applicability on imports.

Figure 50: PVC capacity additions (Current vs projected)



E: Estimated, P: Projected

Note: Capacity addition assumed for Adani Mundra is 1 MTPA

Source: Industry, Crisil Intelligence

We expect current capacity to rise from ~1,590 ktpa currently to reach ~4,090 ktpa as per announced expansions. No major capacity additions are expected other than Reliance Industries' ~1,500 ktpa plant and Adani Group's ~1,000 ktpa plants. The 1,500 ktpa capacity addition by Reliance Industries would strengthen its position as the leading PVC manufacturer with ~56% share. Further, Crisil Intelligence believes that owing to high cost of infrastructure and increased cost of capital, aided by knowledge intensive nature of the industry, extensive capacity additions are not envisaged in this sector.

The current production capacity in India at 1,590 ktpa represents only about a third of the domestic demand. Even with 2,500 ktpa capacity is expected to come onstream, demand is expected to reach 6,600-7,000 ktpa by end fiscal 2031 leading overall imports to stay close to ~45%. With growing demand, imports are expected to play an important role in supply-mix. Japan, China, Taiwan, and Korea are the major suppliers to India for PVC, and overall imports are expected to be above 3 million tonnes per annum in fiscal 2031. Such high level of imports coupled with international demand-supply dynamics always pose the risk of dumping from other countries.

Positioning of Adani Enterprises in the PVC segment

Seeing the opportunity in import substitution, the company ventured into the petrochemicals business in 2021 with an intention to develop a petrochemical cluster at Mundra. The proposed project of 1 MTPA green PVC capacity is expected to be commissioned by fiscal 2028. The company plans to use carbide-based production process rather than conventional oil-based route. With growing opportunity in green fuels to move towards Net Zero as a country, Adani Enterprises intends to build and operationalize the project, leveraging group resources and the Mundra locational advantage.

Environmental clearance and consent to establish the project has been obtained and construction has been resumed after a pause in early 2023.

Risks and challenges

One of the major factors impeding the development of the PVC industry is the lack of a consistent policy surrounding anti-dumping duty. The setting-up of a PVC plant entails significant capex, and the government decisions regarding anti-dumping duties might turn out to be a significant factor. The dependence on import for raw materials is another major factor preventing capacity expansion.

Crisil Intelligence believes there is massive scope for adding to the domestic PVC capacity due to the increased demand supply imbalance. However, uncertainty of protection from dumping, volatile raw material prices, and higher exposure to forex rates and overcapacity in the global market is expected to weigh on any extensive capacity additions and have a deleterious effect on domestic consumption.

Module 4: Copper

Overview

According to estimates in fiscal year 2026, the domestic refined copper production was valued at approximately Rs. 70,000 crores. Copper consumption has been on the rise as the material plays a key role as a raw material for major sectors – such as power, capital goods, consumer durables, construction, infrastructure, and automotive. For India's sustained economic growth, uninterrupted power access is a key contributor, and with copper playing an integral role in the electrification process, it becomes an invaluable commodity for meeting the broader economic goals.

In recent times, copper finds itself in even greater demand as the push for green transition gathers momentum. Copper is also a key material in green energy production and energy storage. The new age EVs also have a higher intensity of copper compared to traditional automobiles.

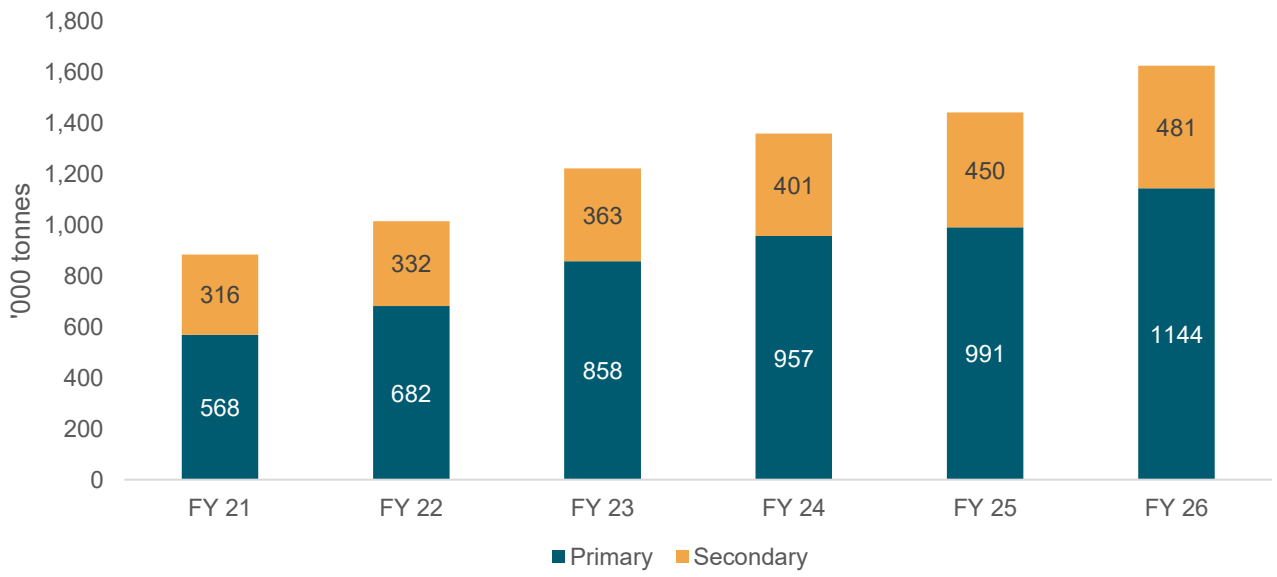
Domestic production of refined copper has continued to grow at a healthy rate, despite facing challenges which have held back the growth. This has resulted in India's import dependence to continue for meeting its domestic needs. While newer projects will add to the domestic supply and reduce the dependence, the demand growth is only going to go up. Additionally, India's per capita consumption of copper, which is estimated at approximately 0.9 Kg, stands significantly below the Chinese average of ~10.9 Kg and below the global average of ~3.3 Kg. As India looks to bridge the gap with its peers on the economic front, both domestic supply and demand of copper are expected to increase at robust rates.

Review of domestic consumption

Domestic copper consumption is met through primary and secondary copper. Primary copper is produced through refining and smelting processes to convert copper concentrate to copper, whereas secondary copper is produced through copper scrap.

Demand segregation by primary and secondary copper

Figure 43: Overall domestic copper consumption



Source: Industry, Crisil Intelligence

Domestic copper demand logged a 12.9% compound annual growth rate (CAGR) between fiscal years 2021 and 2026. The share of secondary copper has been rising gradually since fiscal year 2021, owing to better scrap availability and fluctuating primary copper prices.

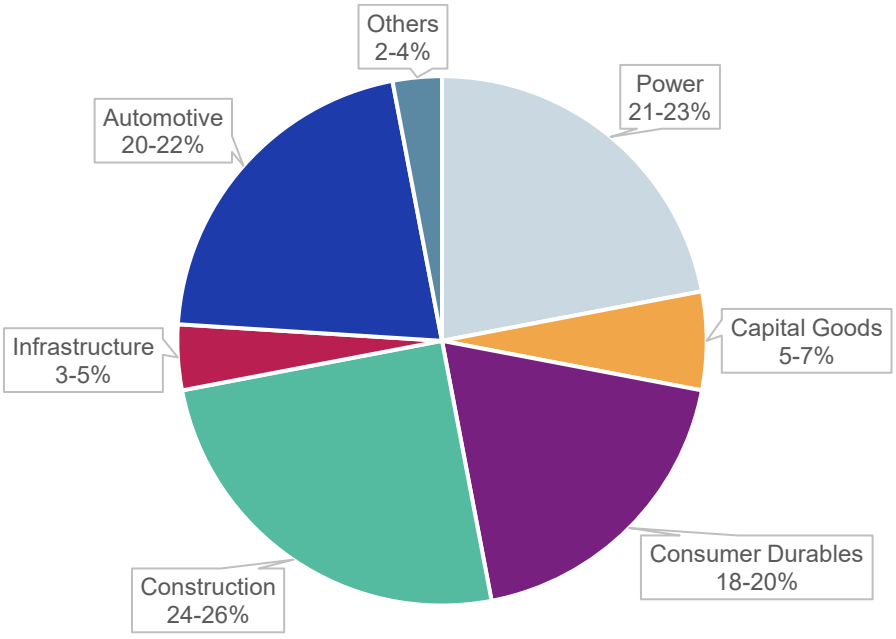
After a sharp fall of ~21% between fiscal 2020 and 2021 due to the pandemic-induced lockdowns, domestic copper consumption has been consistently growing. Between fiscal 2021 and 2023, demand showed strong recovery with a CAGR of ~17.5%. The growth continued in the next fiscal years as well, with demand exceeding pre-pandemic levels, and the CAGR between fiscal 2024 and 2026 reaching ~9.4%.

In fiscal 2025, as major geographies around the world displayed partial economic recovery, global trade improved. This impacted domestic consumption positively, with demand increasing by an estimated 6.2%, as the demand from the power and consumer durables sector remained robust. The auto sector, however, showed signs of weakness towards the second half of the fiscal year.

In fiscal 2026, domestic consumption continued its growth momentum with an increase of 12.7% during the fiscal year. Downstream products witnessed an increase during the year, which kept the demand growth high on a strong base. However, high prices combined with global demand push created an increase in copper exports.

Key end-use industries

Figure 44: Shares of key end-use industries (FY26)



Source: Industry, Crisil Intelligence

Power: The power segment accounts for 21–23% of overall copper demand. Copper is used as an alloy with aluminium in power distribution lines. During fiscals 2021–2026, demand from the power sector witnessed a healthy increase in demand, with an increase in capital expenditure (capex) by Power Grid Corporation of India Limited (PGCIL). The addition of transmission lines increased by a 5% compound annual growth rate (CAGR) during the period, with higher orders from PGCIL and state electricity boards. There was a sharp improvement in transmission line additions in fiscal 2026. The production of power transformers and distribution transformers increased by a CAGR of 12.3% and 13.7%, respectively, during fiscals 2021–2026. On the other hand, the production of power cables logged a 13.6% CAGR during fiscals 2021–2026, driven by higher domestic demand and export orders.
Transport: The transport segment is one of the major demand drivers for the domestic copper industry. Copper is used for wiring, connectors, batteries, radiators, and bearings. This segment is a major growth driver of secondary copper. The production of cars and utility vehicles improved robustly by 12.6% CAGR between fiscals 2021 and

2026, due to a revival of demand post-pandemic since fiscal 2022. The production of two-wheelers also improved, albeit at a slower rate than PVs, by 7.8% during the same period. However, copper intensity increased marginally, which boosted the overall copper demand. Copper is also used heavily in railway electrification.

Building & construction: Copper is used to make industrial roofing, heating systems, expansion joints, and wall cladding in the building and construction sector. Although copper is costlier than other alternatives, it is used only in premium urban construction projects. Copper is also used in various industrial projects. During fiscals 2021–2026, various government schemes focused on housing, such as the Pradhan Mantri Awaas Yojana-Urban (PMAY-Urban), witnessed significant growth. The scheme, along with industrial developments, spearheaded overall copper demand from the construction segment.

Infrastructure: Copper is used for broadband cables, telecom cables, and the electrification of various infrastructure projects, such as roads, airports, and ports. During fiscals 2021–2026, copper demand from this segment improved by a 12.3% CAGR, due to increasing investments in roads, airports, and ports.

Capital goods: Copper is used to make bearings, gears, hydraulic tubing, and fasteners in the capital goods sector. During the period under review, demand from capital goods improved by a healthy 12.2% CAGR, owing to higher production of motors and agricultural equipment.

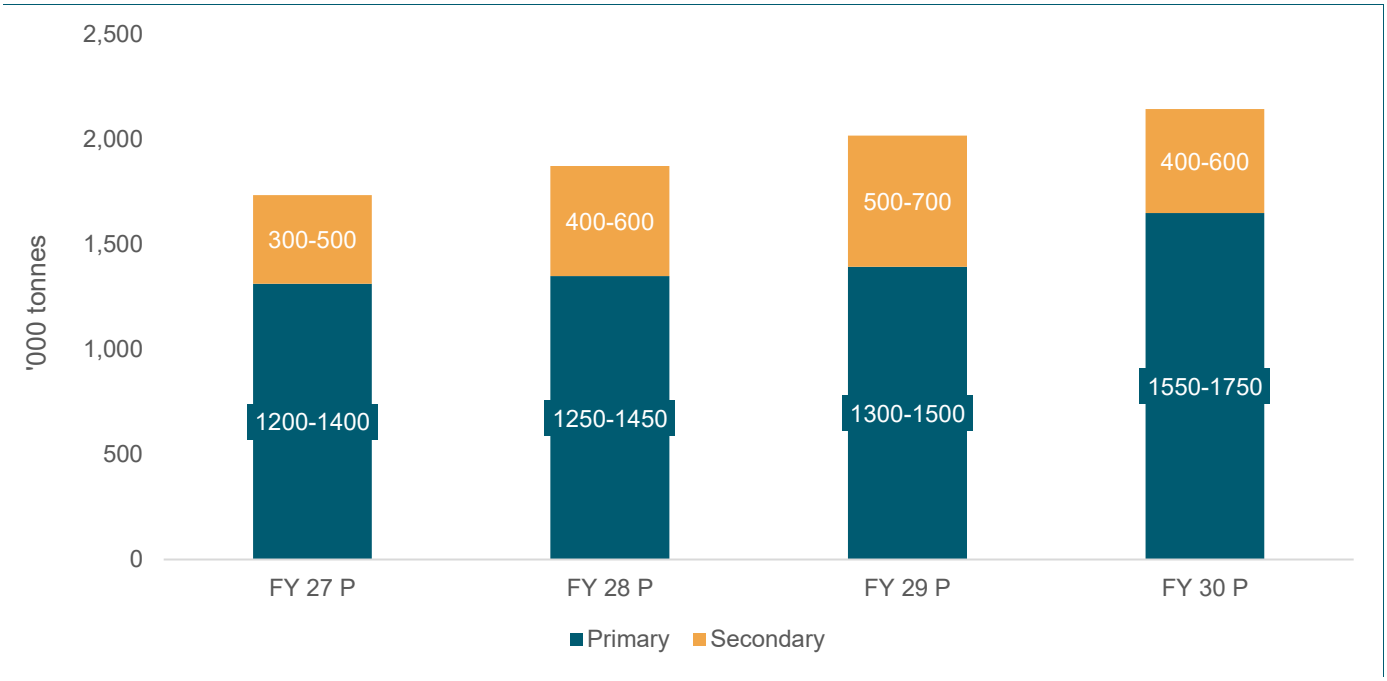
Consumer durables: Copper is used to make tubes for heat exchange systems in refrigerators and air conditioners, and in electric motors in washing machines, in the consumer durables sector. During the period, the production of refrigerators increased by 7.2%, air conditioners by 6.9%, and washing machines by 16%, owing to higher demand from rural areas. To support consumer durable production in India, the Production Linked Incentive Scheme for White Goods (PLIWG) provided a financial incentive to boost domestic manufacturing and attract large investments in the white goods manufacturing value chain.

Under the PLI Scheme for White Goods (Air Conditioners and LED Lights), the Ministry of Commerce and Industry provided incentives to boost the production of copper tubes (plain and/or grooved) in the country. In fiscal 2026, India imported ~95 kilotons (kT) of copper tubes, up from ~54 kT in fiscal 2021. As production from domestic units picks up pace in subsequent years, the same demand is expected to be met through domestic production.

Outlook for domestic copper consumption

Demand segregation by primary and secondary copper

Figure 45: Domestic copper consumption outlook



Source: Industry, Crisil Intelligence

The intensity of copper usage per billion US dollars of GDP in India in 2023 was 163 metric tons (T), compared with Japan's 194 T, Mexico's 224 T, Belgium's 405 T, Turkey's 474 T, and China's 875 T, and the global average of ~401 T. The average per capita consumption of developed economies is ~10 kilograms (kg), compared to ~0.9 kg for India. Thus, going forward, the country is expected to witness healthy domestic consumption. Overall, copper demand is expected to log a 7–8% compound annual growth rate (CAGR) between fiscals 2023 and 2028, reaching 1,700–1,750 kilotons (KT), driven by strong demand from the consumer durables, automobile, and construction segments. The demand may see a significant upside, depending on renewable energy investments and electric vehicle (EV) penetration.

Key end-use industries

Power: It is estimated power demand to grow at a stable CAGR of 11-13% between fiscals 2027 to 2030 with the growth trajectory sustaining above long-term historical growth rate of 5% over the next five years. Infrastructure linked capex, strong economic fundamentals along with expansion of the power footprint via strengthening of transmission and distribution (T&D) infrastructure are expected to improve the quality of power supply, thereby spurting power demand in the long run. This is going to be further helped by major reforms initiated by the central government for improving the overall health of the power sector, particularly that of state distribution utilities.

Transport: The demand from transport segment is expected to grow at 9-11% CAGR between fiscals 2027 and 2030. Production of cars and utility vehicles is expected to clock a 5-7% CAGR during this period. Copper intensity is also expected to increase in various components to improve fuel efficiency. Production of two-wheelers is expected to register a 9–11% CAGR owing to better domestic demand, especially from rural areas, and healthy export orders. Production of tractors is expected to remain robust, with a 4-6% CAGR in export orders and a 5-7% CAGR in domestic demand owing to better rural income. During the period, increasing railway electrification and the adoption of electric vehicles are expected to drive growth in this segment.

Building and construction: Overall demand from building and construction segments is estimated to grow at pace of 4-6% CAGR over fiscal 2027-2030. PMAY-U 2.0 launched with mission of "Housing for all" with effect from Sep 2024 with proposals for construction of 3.52 lakhs approved under PMAY-U 2.0 in March 2025. Government Assistance of ₹2.30 lakh crore will be provided under the Scheme with an investment of ₹10 lakh crore

Capital goods: Increasing demand for new plants and machinery due to growing industrialization will help the demand from the sector to grow at a CAGR of ~6-8% between 2027-2030. As the government focuses on self-reliance and onshoring of manufacturing capabilities, heavy and industrial machinery has become a key area of focus, thus driving demand.

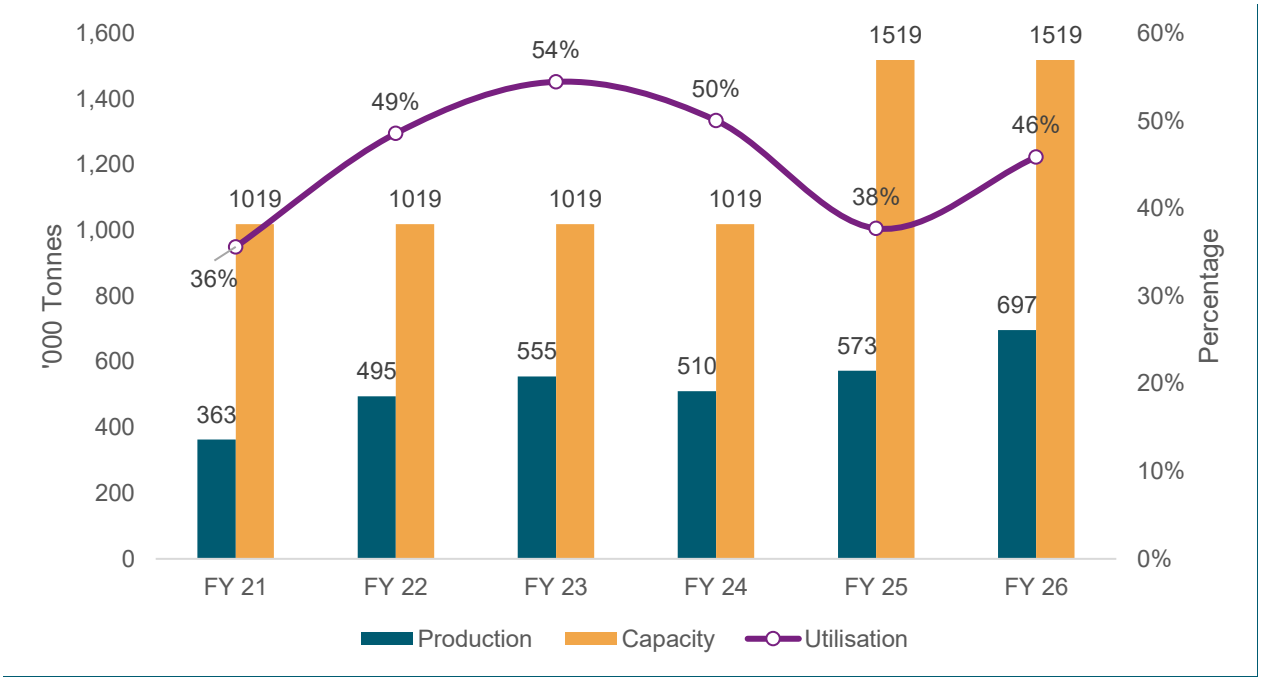
Consumer durables: Over fiscals 2027-2030, the demand from consumer durables segment is expected to clock a 5-7% CAGR with robust production amid improving income and affordability, especially from rural areas. Copper usage in the segment is expected to be driven by higher copper intensity in various consumer durables, such as ACs, refrigerators, and washing machines.

New-age industries

- **Renewable energy**: This sub-segment in the overall power segment will be a major factor in determining copper demand over the medium term. Copper is used to make solar modules and electric motors for wind and hydropower generation. Currently, India is importing solar modules to meet most of its requirements. China accounts for more than 85% of the imports. However, The Approved List of Models and Manufacturers (ALMM) requirement had been reimposed in fiscal 2025, with relief only being provided on case-to-case basis. A temporary abeyance was granted for projects commissioned before 31st March 2024 has lapsed. This will boost overall copper demand from the power segment. We estimate a surge in solar power capacity additions, reaching 210-250 GW from fiscal years 2027 to 2031, significantly surpassing the 99 GW added between fiscal years 2021 and 2026. This growth is primarily spurred by robust government backing, demonstrated through an aggressive tendering strategy. Key catalysts include technological advancements (e.g., floating solar and module efficiency), affordable financing, and supportive policies. However, infrastructural challenges such as land and connectivity availability are impacting project momentum as on date. Similarly, we estimate competitively-bid capacity additions of 21-22 GW over fiscals 2026-2030. We expect additions of 6-6.5 GW from competitively bid standalone wind and 15-15.5 GW from competitively bid mixed resources wind component to be commissioned by fiscal 2030, factoring in delays due to evacuation infrastructure, etc.
- Electric vehicles: This sub-segment in the transport segment will play a major role in boosting aluminium demand over the medium term. Aluminium usage in EVs is significantly higher than in conventional vehicles, as the metal is lighter but as strong as steel. So, using aluminium will be a crucial factor that improves the overall driving range of EVs. As of fiscal 2026, EV penetration stood at 4-4.5% in fiscal 2026.

Review of domestic copper supply

Figure 46: Domestic primary copper supply trend



Source: Industry, CRISIL Intelligence

Domestic copper capacity logged 8.3% CAGR over fiscals 2021-2026 from 1,019 KT to 1,519 KT mainly due to the new capacity of Kutch Copper. During the period, other players remained stagnant in terms of new capacity additions. Kutch Copper has planned to add 1 MT capacity with operationalisation of this capacity planned in two phases of 500 KT each.

Domestic copper production improved by ~13.9% CAGR between fiscals 2021 and 2026, from 363 KT to 697 KT in fiscal 2026. During the period, Vedanta's copper production is estimated to witness a sharp 10.9% CAGR increase due to the lower base of production set in fiscal 2021 during the lockdown phase. HCL's copper production continues to be nil in fiscal 2026 as profitability issues in cathode manufacturing led the company to focus on the copper concentrate segment. In fiscal 2026, the production reached 697 KT increasing by ~21.6% compared to last fiscal.

The utilisation rate of the industry fell sharply in 2018 with the closure of operations in Sterlite copper smelter in Tuticorin. The utilisation rate in the domestic copper segment remained at 40% in fiscal 2020, as the closure of operations at HCL smelters had an adverse impact on the utilisation. However, the utilisation rate improved sharply to above 50% in fiscal 2024 due to higher efficiency at Hindalco's smelters while Vedanta also ramped up production. The utilisation rates in fiscal 2025 fell due to the addition of Kutch Copper facilities but production during the period remained negligible. In FY 2026, the domestic refined copper production was estimated to be ~697 KT, compared to 573 KT for the last fiscal year. The utilisation rates, however, remain to be affected by ore and concentrate availability along with environmental issues.

Scrap copper

Globally, the proportion of secondary copper in refined copper production (refining secondary) is anticipated to experience a notable rise from ~17% in 2022 to around 22% by the year 2035. India utilizes scrap to meet a large portion of its domestic metal consumption. In fact, globally, India is one of the largest importers of copper scrap. While the imports have supported the demand requirements for now, the global scrap market is likely to face a supply-side tightness. Major economies around the world are seriously contemplating an export ban on copper scrap while easing their import policies for scrap. For example, China imposes no import duty on copper scrap; however, it levies a 4% tax on imports of copper rod. Similarly, for most EU countries, the import duty on copper scrap stands at 0%. Even India, in the Union Budget for

2021–2022, reduced the import duty on copper scrap from 5% to 2.5%. Aside from constituting a major portion of global consumption, scrap is also poised to play a big role in the production of low-emission metal. As a result, the demand for scrap is only going to pick up.

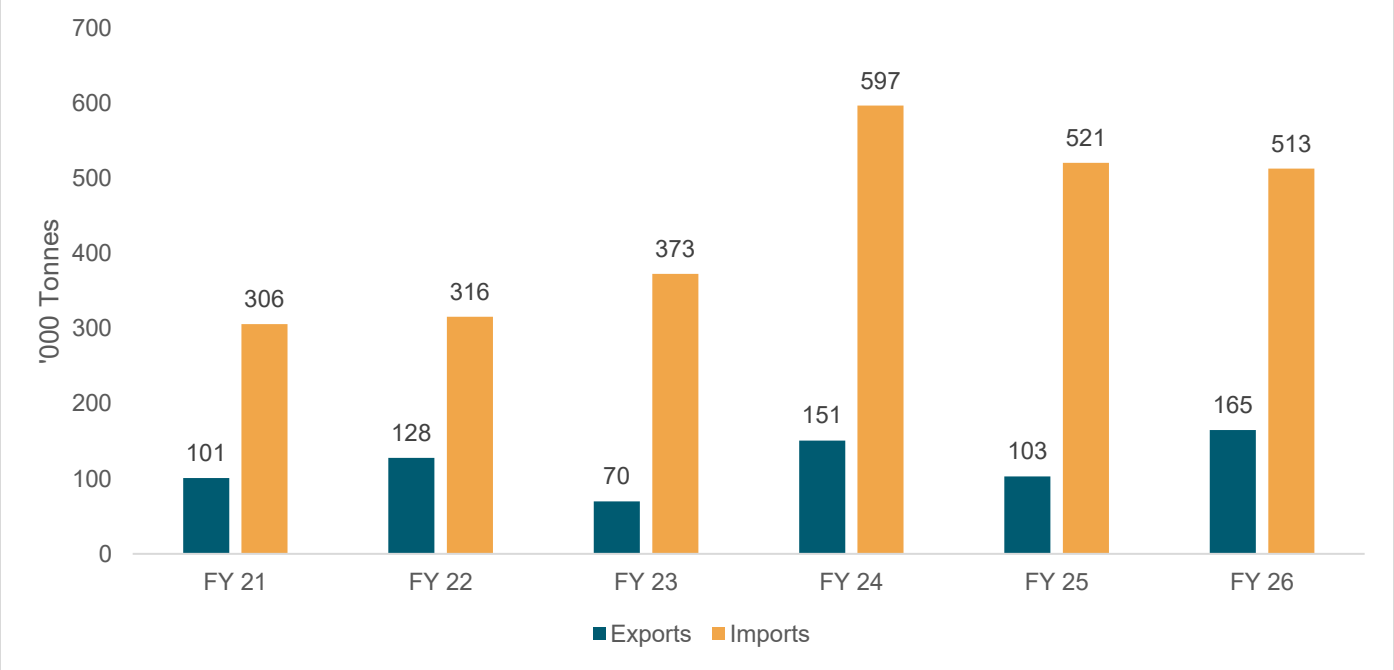
The copper currently being used in India can be classified into two categories from a recycling perspective. Copper used in buildings and infrastructure can be recycled after a period of 30 to 50 years, while consumer products and vehicles yield scrap within 15 to 20 years. At present, China utilizes roughly 116.1 million tonnes of copper, which can be recycled over a period of ~20 years to mitigate the risk of supply interruptions. In comparison, India possesses 15.2 million tonnes, resulting in a possible relative scarcity of scrap copper. Therefore, developing a more efficient domestic scrap market has the potential to foster recycling, thereby ensuring a steady supply of secondary copper and advancing a circular economy in industry. There are some initiatives that have been introduced in the same direction:

- Reverse Charge Mechanism (RCM): In October 2024, the Indian government implemented a Reverse Charge Mechanism (RCM) for transactions involving metal scrap under the Goods and Services Tax (GST). This initiative is designed to enhance tax compliance within the informal metal scrap sector, formalize the industry, and mitigate tax evasion.
- Removal of Basic Customs Duty (BCD): In the 2025 Union Budget, the Indian government declared the elimination of BCD on waste and scrap from twelve essential minerals, including copper. This measure aims to bolster domestic manufacturing by guaranteeing a consistent and cost-effective supply of materials such as copper, cobalt, lithium-ion battery waste, lead, and zinc.
- Extended Producer Responsibility (EPR): It is a strategic policy that imposes charges on producers, importers, and brand owners for managing post-consumer waste. This policy recognizes that manufacturers bear responsibility for the waste generated throughout a product's lifecycle, as they significantly influence the design, packaging, and material choices of their products.
- Vehicle Scrapping Policy: The policy aims to eliminate unfit and polluting vehicles strictly according to their fitness levels while also reintroducing the scrapped parts and materials back into circulation. This policy envisions the establishment of a network of Registered Vehicle Scrapping Facilities (RVSFs) throughout the country. As of January 2025, there are 84 operational RVSFs in the nation.

Copper trade assessment

Review of primary copper trade

Figure 47: Primary copper trade review

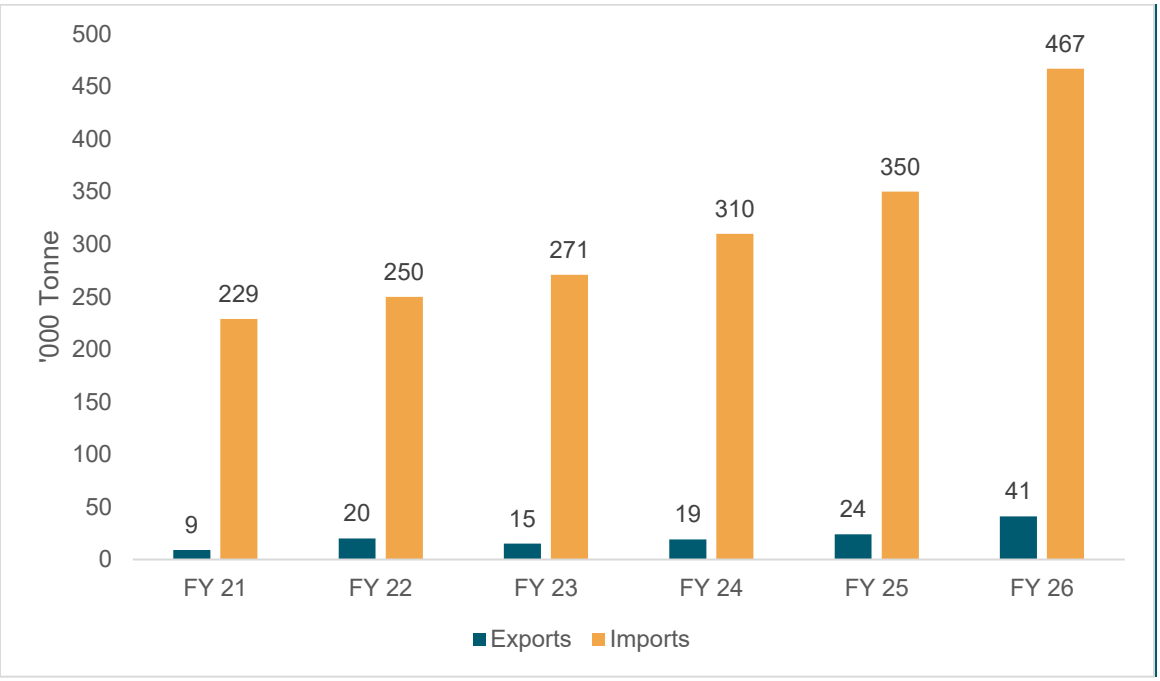


Source: DGFT, Crisil Intelligence

Primary copper exports improved by 10.3% CAGR between fiscal years 2021 and 2026, from 101 KT to 165 KT, due to the improved production from Vedanta and Hindalco during this period. On the other hand, imports logged a 10.9% CAGR from 306 KT to 513 KT. During fiscal years 2021 and 2022, imports fell sharply due to the end user demand drying up amid the pandemic induced lockdowns. Vedanta was driving the overall primary copper exports. India continues to be a net importer of refined copper.

Review of copper scrap trade

Figure 48: Domestic copper scrap review



Source: DGFT, Crisil Intelligence

India's copper scrap exports are negligible as scrap collection is at a nascent stage domestically. In fact, copper scrap is essential for producing secondary copper. Thus, India imports copper scrap heavily. During fiscals 2021-2026, copper scrap imports clocked a 15.3% CAGR from 229 KT to 467 KT due to higher secondary copper production and volatility in refined copper prices.

Supply side challenges coupled with growing global demand is likely to push the global market balance into a surplus in 2026. Therefore, the demand for scrap is going to elevate sharply. Additionally, with players managing better margins compared to refined copper smelting, the desirability of scrap is further enhanced. While the domestic demand for scrap is currently being met through imports, scrap collection needs to be focused on as countries around the world push for aggressive procurement scrap.

Competitor's profile

Vedanta Ltd

Sterlite (India) Industries Ltd, an associate company of Vedanta Resources Plc, is one of the largest copper manufacturers in India. It is a leading producer of copper cathode and copper rods. It is the largest mining and non-ferrous metals company in India and has mining operations in Australia and Zambia and oil and gas operations in three countries. Its main products are zinc, lead, silver, oil and gas, iron ore, steel, aluminium and power. Vedanta is the second-largest copper producer in India with a capacity of 460 kilo (smelting, refining, and VAP) tonne per annum (KTPA) and holds a ~17% market share in terms of capacity. After protests by the local populace alleging environmental violations at Sterlite's copper plant in Tamil Nadu's Thoothukudi, the Tamil Nadu Pollution Control Board (TNPCB) ordered the company to shut down the plant in May 2018. The company, however, continues to operate its refinery in

Silvassa, Dadra and Nagar Haveli. Vedanta produces limited primary copper using copper anodes at its Silvassa facility and converts the majority of primary copper into value-added products (VAP), such as copper rods.

Product description	Facility and location	Capacity
Copper Cathodes **(Copper concentrate to cathodes)**	Tuticorin, Tamil Nadu	0.400 MTPA (Production Suspended)
Refinery (Anode to cathode) and Value-added products	Silvassa, Dadra and Nagar Haveli	0.216 MTPA

Hindalco Industries Ltd

Hindalco Industries Ltd was established in 1958 as Hindustan Aluminium Corporation Ltd. The company, a subsidiary of the Aditya Birla Group, commenced operations in 1962 with a plant at Renukoot, Uttar Pradesh. It was renamed Hindalco Industries Ltd in 1989. Subsequent acquisitions and mergers with Indal and Birla Copper strengthened the company's production of primary aluminium, value-added aluminium and copper products. The company has one of the largest integrated copper smelters with port facilities at Dahej. Hindalco produces primary copper as copper cathode and converts cathode into various products such as rods, wires etc.

Product description	Facility and location	Capacity
Copper Cathodes and CC rods	Dahej, Gujarat	0.50 MTPA
Copper rods and ABC wire	Asoj, Gujarat	0.225 MTPA

Hindustan Copper Ltd (HCL)

Public sector Hindustan Copper Ltd (HCL) was incorporated in 1967 to take over copper operations from National Mineral Development Ltd (NMDC). The company become the only fully integrated copper company of India in 1975 by establishing 31 KT refinery at Khetri. It established downstream facility with 60 KT capacity at Taloja, Maharashtra, in 1989. The company also established 50 KT secondary copper refinery in Gujarat in 2015. HCL is the only fully integrated copper manufacturer in India. However, the company stopped producing copper cathode due to profitability issues. Thus, the company started selling metal in concentrate (MIC) to other local manufacturers.

Product description	Facility and location	Capacity
Mine and Beneficiation	Malanjkhand Copper Project, MP Khetri & Kolihan Mine, RJ Surda Mine, JH Ghatshila mining project, JH	3.9 MTPA ROM Ore

Copper Cathodes	Khetri mining complex	0.0685 MTPA (Production suspended)
Wire rods and CC rods	Indian Copper Complex, Ghatsila, Jharkhand Khetri Copper Complex, Khetri, Rajasthan	0.06 MTPA (Production suspended)

Kutch Copper Limited (Adani Enterprises)

Adani Enterprises has set up a plant with 1 million tonnes per annum copper cathode production capacity and 0.5 MTPA continuous cast copper wire rod capacity in Mundra, Gujarat, in phased manner. The company has built a 0.5 MTPA copper cathode production in phase 1. Production from the first phase has started since the start of fiscal 2025 with output ramping up in the last couple of months. The company has already obtained BIS certification for their continuous cast rods, and the production for the same has also started.

Product description	Facility and location	Capacity
Refined copper	Mundra, Kachchh, Gujarat	0.5 MTPA
Copper rods	Mundra, Kachchh, Gujarat	0.25 MTPA
Inner Grooved Tubes & Plain Tubes	Mundra, Kachchh, Gujarat	0.03 MTPA

Risk and challenges for domestic copper industry

- **Raw material sourcing:** Securing copper concentrate is one of the major challenges for the copper industry in India, as more than ~40% of the mined copper globally is produced in Latin America, and India imports from Latin America and Indonesia. Some players also import copper anode to produce copper cathode, making importing copper anode a key challenge.
- **Margins:** Treatment and refining charges (TC/RC) margins will be the biggest factor for profitability, as India's copper cathode producers act as copper concentrate converters. In the last few quarters, these margins have fallen dramatically, with spot margins in certain cases falling sharply to negative levels, meaning the smelters have had to pay the miners for beneficiating the concentrates just to gain access.
- **Coal sourcing:** Copper manufacturing is a power-intensive process, and thus, coal security also poses a challenge. To address this, players are entering into coal linkages and actively participating in coal mine auctions.
- **Foreign exchange rates:** The Indian copper industry heavily relies on imports, so fluctuations in foreign exchange rates pose a risk for the industry.
- **Trade-related uncertainty:** The recent imposition of 50% import tariffs by the US has created challenges for global players. While accessibility to the US market is a risk, concerns about oversupply globally could impact refined metal prices and eventually affect the margins for Indian players.
- Global mining related issues: Concentrate markets have been tight for the last few years because of dwindling mine supplies and ore quality. With Sulphur availability becoming an additional pain point as the GCC region

contributes a significant share of global supply, Sulphuric Acid, a key input material in the leeching process of copper ore, has also become scarcely available. Thus, as the mining costs increase, concentrate prices follow the cue. To add to this situation, South American countries are expected to experience heavy rainfall this year, further impacting the mining exercises and pressurizing global supplies.

Module 5: Aluminium

Overview

In the financial year 2026, Indian primary aluminium production is estimated to be valued at Rs 1.16 lakh crores. Beyond the sheer size of the segment, the importance of aluminium lies in the role it plays in the overall growth of major domestic sectors, where aluminium serves as a key raw material – including power and electricity, automotive, building and construction, packaging, and consumer durables. Therefore, the availability of aluminium becomes a major requirement for these industries, which, in turn, provide utility to large sections of the domestic population, making aluminium indispensable for the average citizen.

Additionally, aluminium is a key material in the production of energy-efficient products – such as solar panels, wind turbines, and energy-efficient buildings – and is a strategic metal with applications in defence, aerospace, and other critical sectors, making it essential for India's national security and defence preparedness.

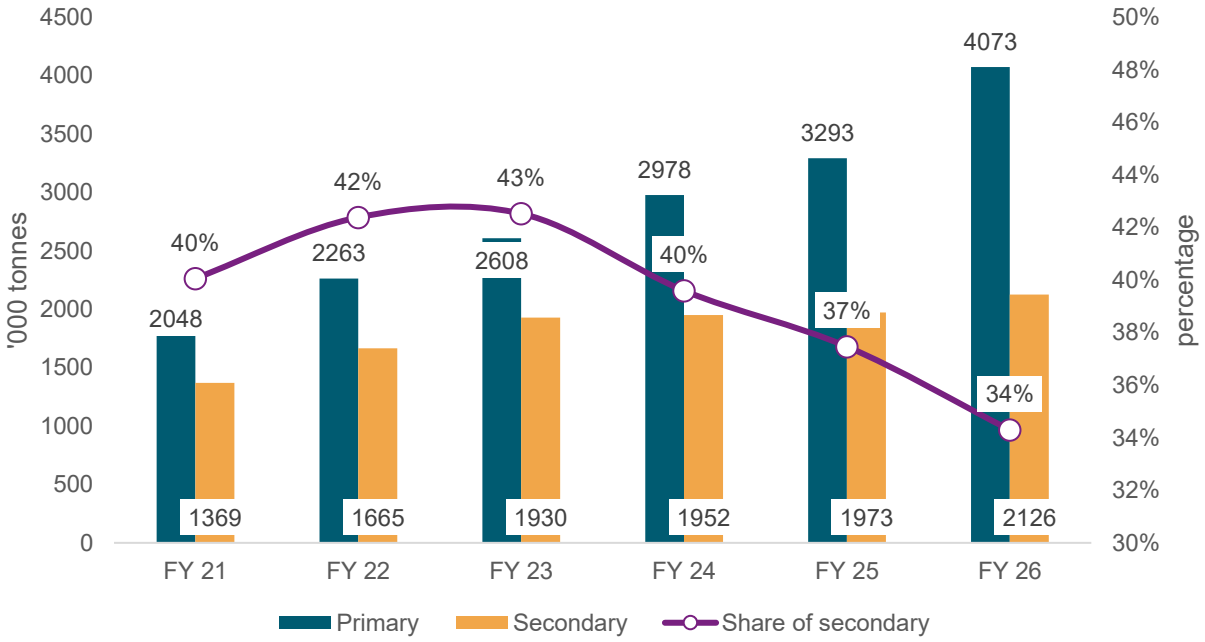
Domestic aluminium production has continued to display strong growth over the years, with primary producers continuing to operate at high utilization rates while expanding capacities to meet the growing demand. Even as domestic consumption of aluminium has been registering strong growth in the post-pandemic recovery, per capita consumption lags significantly behind global and peer averages. In the calendar year 2024, domestic per capita consumption of primary aluminium stood at approximately 2.5 kg, compared to a global average of approximately 8.9 kg, while China stood at approximately 29.2 kg. Covering this gap in aluminium consumption will have a positive bearing on India’s economic growth.

Review of domestic aluminium consumption

Domestic aluminium demand is met through primary aluminium and secondary aluminium. Primary aluminium is produced through the refining and smelting process to convert alumina to aluminium. Secondary aluminium is produced from aluminium scrap.

Demand segregation by primary and secondary aluminium

Figure 49: Overall domestic primary aluminium consumption



Source: Industry, Crisil Intelligence

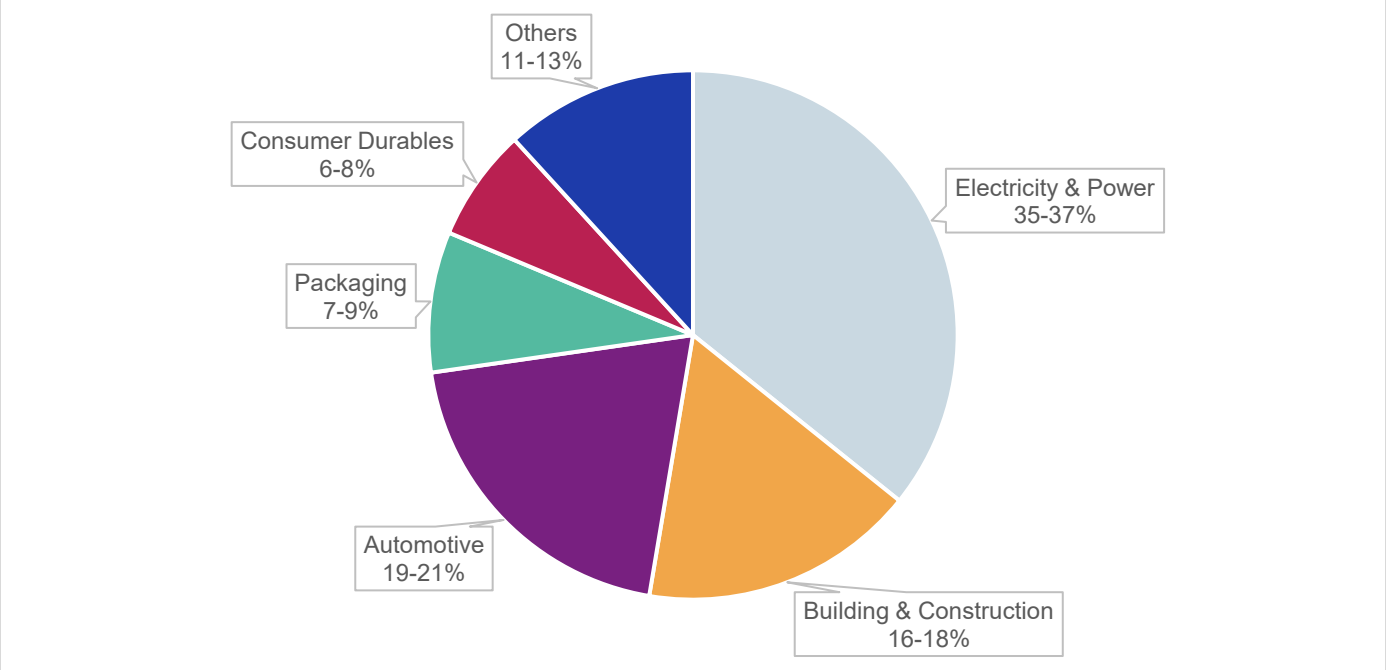
Domestic aluminium demand logged an 14.7% compound annual growth rate (CAGR) between fiscal years 2021 and 2026, reaching 6.2 million metric tonnes. The share of secondary aluminium, however, decreased from 40% in fiscal 2021 to 34% in fiscal 2026, even as the absolute volume of secondary metal being consumed increased at a CAGR 9.2% for the same period. The share of secondary aluminium peaked in fiscal 2023, reaching 43%. Domestic aluminium demand logged a healthy 15.2% CAGR between fiscal years 2021 and 2023, with end-user consumption increasing sharply by 15.5% year-over-year in fiscal 2023 as recovery from the preceding pandemic induced lockdown period began.

In fiscal 2025, demand improved by 14.7% year-over-year, as domestic infrastructure projects kept end-user demand healthy. Additionally, sectors such as automobile and renewable energy also drove demand growth, even as prices remained suppressed due to muted global demand.

In fiscal 2026, demand continued to ascend with a growth of 9.6%, as the power sector pushed demand upwards through installations of transformers and transmission lines. Demand from sunrise sectors continued; however, demand momentum from the auto sector cooled off during the second half of the fiscal year.

Key end-use industries

Figure 50: Share of key end-use industries (FY26)



Source: Industry, Crisil Intelligence

Power transmission and distribution: The power segment is a major driver of domestic aluminium demand. Aluminium is used in production of transmission lines, transformers, and cables. Over fiscals 2021-2026, demand from the sector increased at CAGR of 15.6% with increased capex from PGCIL. After falling sharply in fiscal 2020, the transmission lines installation has seen an upward trend on that low base moving towards the pre-pandemic levels. The production of power transformers and distribution transformers increased by 12.3% and 13.7% CAGR, respectively, during fiscal 2021-26. On the other hand, the production of power cables logged a 13.6% CAGR during fiscal 2021–26 with higher domestic demand and export orders. The segment is likely to witness a robust growth in fiscal 2027 as well, with provisional forecast numbers suggesting 8–10% year-on-year growth in fiscal 2027.

Transport: The transport segment is the second-largest demand driver for domestic aluminium. Aluminium is used in multiple spare parts of vehicles. Production of passenger vehicles improved by 12.6% CAGR between fiscal years 2021 and 2026. A semiconductor chip shortage was experienced during fiscal years 2021–22 before resuming in fiscal 2023. Production of two-wheelers remained flat during the period, whereas production of tractors increased marginally by 1.3%. The use of aluminium in commercial vehicles is high as it is lighter than steel and is as strong, improving fuel efficiency. Production of commercial vehicles increased by 7.8% CAGR during the period. However, aluminium intensity increased marginally, which boosted overall aluminium demand from the transport segment.

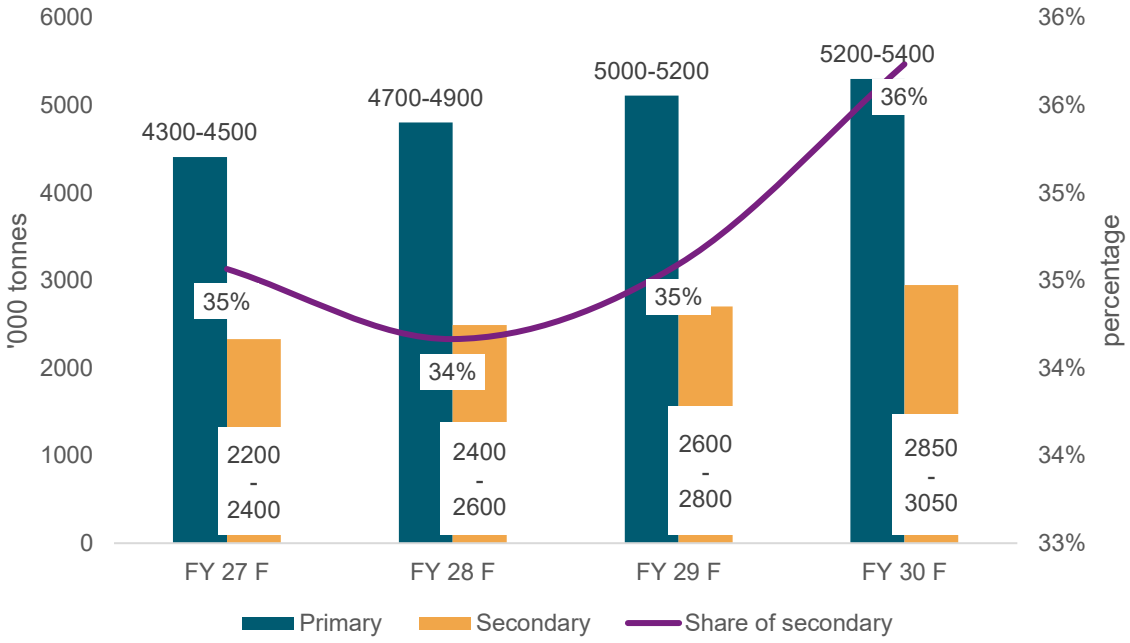
Construction: Aluminium is used to make window frames, doors, false ceilings, and industrial roofing. It is costlier than other alternatives, because of which its usage is restricted to premium urban construction projects. Aluminium is also used in various infrastructure projects. During fiscals 2021-2026, various government schemes focused on housing, such as PMAY-Urban, witnessed significant growth. The scheme spearheaded overall aluminium demand from the construction segment.

Packaging: Aluminium is used to make foils, beverage cans, and industrial metal-coated tapes. The segment mostly uses secondary aluminium. During fiscal years 2021–2026, metal packaging demand grew by over 16.4% CAGR with robust demand from end-use industries such as alcoholic beverages, food products, and pharmaceuticals.

Outlook for domestic aluminium consumption

Demand segregation by primary and secondary aluminium

Figure 51: Domestic aluminium consumption outlook



Source: Industry, Crisil Intelligence

Overall aluminium demand is expected to log 6-8% CAGR between fiscals 2027 and 2030 to 8.1-8.3 MT, driven by healthy growth in the power, construction and automobile segments. Renewable energy investments and deepening EV penetration may also boost the demand significantly.

Key end-use industries

Power transmission and distribution: Over fiscal years 2027-2030, the demand from the power sector is likely to clock a CAGR of 6.5-8.5%, mainly driven by renewable energy grid projects undertaken by PGCIL and supported by state transmission projects. While financial stress on discoms is likely to be a deterrent for demand in the short term, the Rs 3.03 trillion discom reform scheme launched in June 2021 is supporting demand growth over the long term as 25–30% of the scheme is expected to be used for cables and conductors.

Transport: The transport segment is expected to clock healthy growth during the period. Production of passenger vehicles may log 5-7%. Aluminium intensity in various components is also expected to increase as vehicle makers and consumers seek better fuel efficiency. Production of two-wheelers is expected to log a 7-9% CAGR owing to better domestic demand, especially from rural areas, and healthy export orders. Production of tractors is expected to remain robust, registering a 4-6% CAGR in export orders and a 5-7% CAGR in domestic demand owing to better rural income.

Construction: Over fiscal years 2027–2030, aluminium demand from the construction sector is expected to see a 4–6% CAGR, primarily driven by the increased intensity of the metal's usage within the sector. The usage pattern, earlier restricted to premium projects, is likely to change with increasing adoption of the metal in other real estate projects as

aluminium extrusion is witnessing rising acceptance in tier 2 and 3 cities. However, demand for primary aluminium may be limited as usage of secondary aluminium gains currency.

Packaging: Over fiscal years 2027–2030, the demand from packaging segment is expected to record a 6-8% CAGR with healthy demand from the beverages, consumer foods, and pharmaceuticals segments. The ban on single-use plastic products and increasing awareness about the hazards of plastic are expected to boost aluminium usage over the long term.

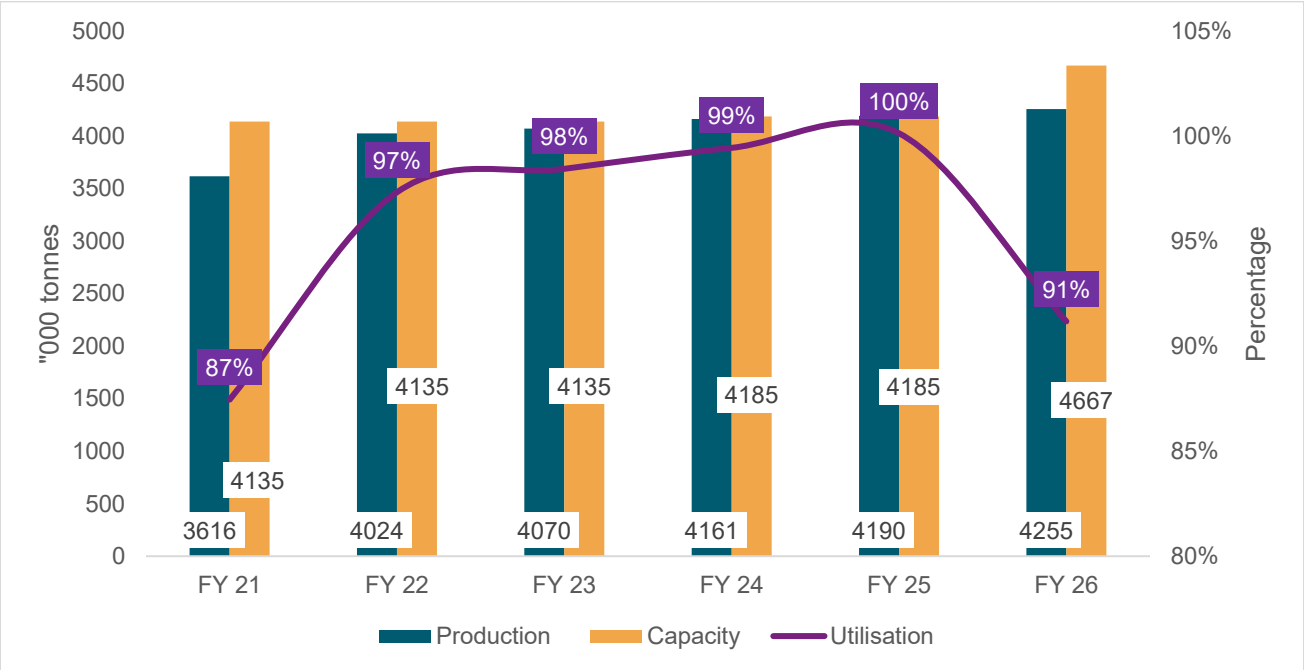
New-age industries

Renewable energy: This sub-segment in the power segment will be a major factor in aluminium demand growth over the medium term. The metal is used to make solar panels and wind turbines. As of now, India imports most of its solar module requirements. Over fiscal years 2026–2030, the country is expected to add 45-46 GW of wind energy capacity with investments of Rs. 3.5-4 trillion. The government also aspires to reach 134 GW of wind capacity by fiscal 2032 under its National Electricity Plan (NEP), which will also be a significant factor in boosting aluminium demand. Additionally, the growth in the solar industry will also generate additional; demand for aluminium.

Electric vehicles: This sub-segment in the transport segment will play a major role in boosting aluminium demand over the medium term. Aluminium usage in EVs is significantly higher than in conventional vehicles, as the metal is lighter but as strong as steel. So, using aluminium will be a crucial factor that improves the overall driving range of EVs.

Review of domestic aluminium supply

Figure 52: Domestic primary aluminium supply trend



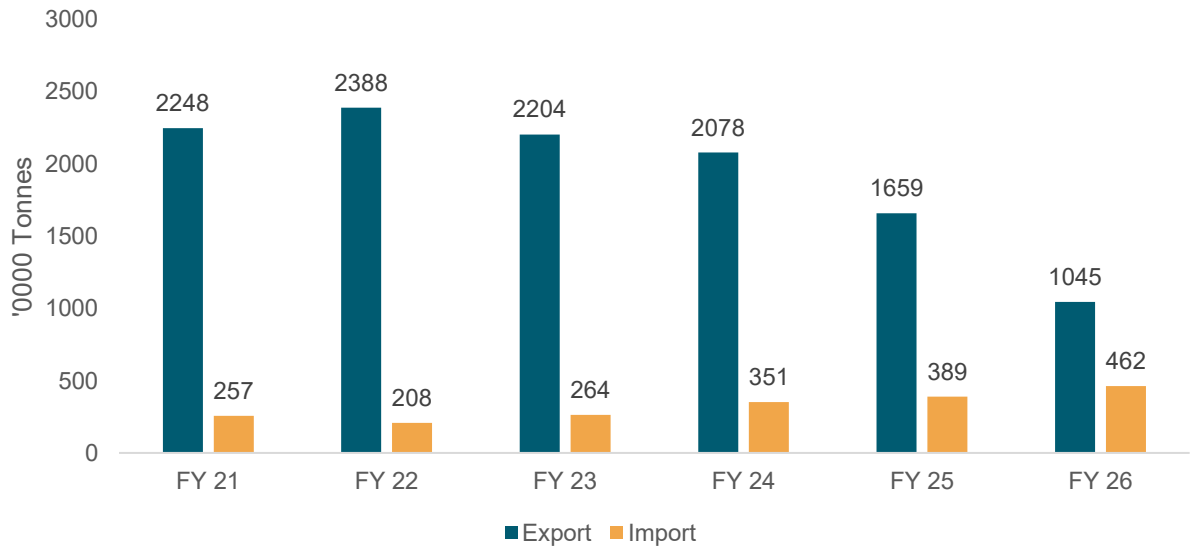
Source: Industry, Crisil Intelligence

Domestic aluminium capacity increased by .3% between fiscal 2021 and 2026 to reach at ~4.7 MT. During the period, Vedanta added 50 KT through debottlenecking to reach a capacity of 1.85 MT. Major capacity addition came from BALCO which increased its capacity by 430 KT with additional capacity coming online in fiscal 2026.

Domestic aluminium production registered a 3.3% CAGR between fiscal years 2021 and 2026, from 3.62 MT to 4.26 MT. During the period, Vedanta's aluminium production witnessed 4.6% CAGR from 2 MT to 2.5 MT with rapid capacity ramp-up at Jharsugudha.

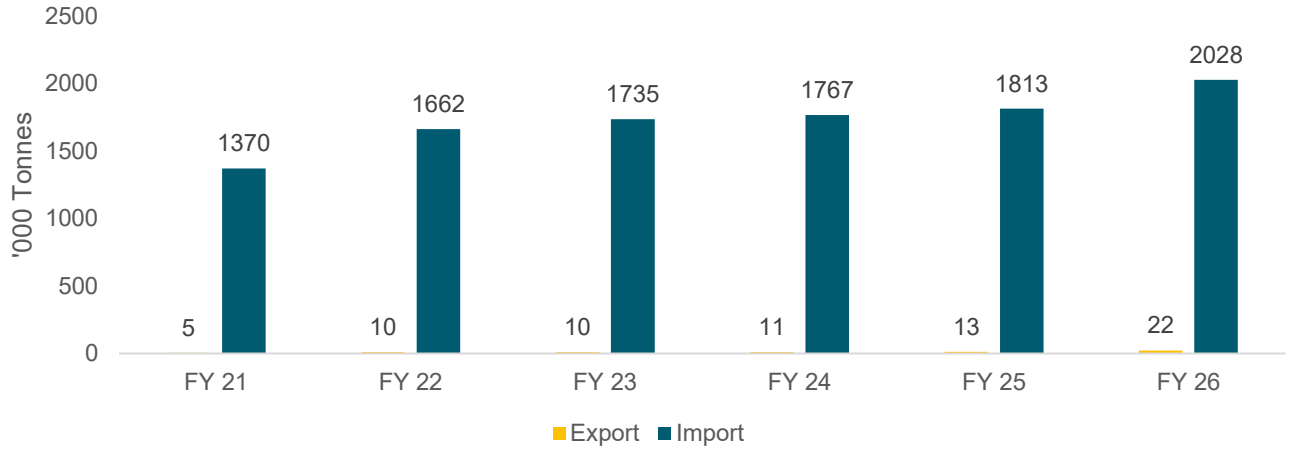
The domestic utilisation rate has seen a sharp improvement since fiscal 2021 owing to the speedy ramp-up of Vedanta's Jharsuguda smelter. Vedanta has quickly ramped up its output, backed by long-term coal and bauxite sourcing arrangements as well as a rally in global aluminium prices. Likewise, other players also improved their output amidst elevated metal prices. During fiscal 2026, the domestic primary aluminium output was ~4,255 KT compared to 4,190 KT last year.

Figure 53: Domestic primary aluminium trade movement



Scrap aluminium

Figure 54: Domestic aluminium scrap trade movement



In 2024, over 12 million tonnes of aluminium scrap were traded globally. India and China emerged as the top two importers of aluminium scrap in 2023, with imports of ~1.74 million tonnes and 1.78 million tonnes, respectively. India's significant aluminium scrap imports can be linked to the limited availability of domestic scrap, whereas China's substantial imports are primarily driven by the country's high metal consumption. India currently meets a large share of its domestic demand through secondary metal; however, it relies mostly on imports and imports indifferent-quality scrap from wherever available. In India, the import of aluminium scrap adheres to the specifications set forth by the International Scrap Recycling Institute (ISRI). To guarantee that the imported scrap is free from hazardous materials, Customs conducts inspections based on ISRI specifications, as well as checks for radioactive substances and explosives. The processing of scrap aluminium for reintroduction into the market involves several stages: pre-processing, melting, alloying, refining, and casting.

India imposes an import duty of only 2.5% on aluminium scrap, which is considerably less than the 7.5% charged on primary aluminium. This difference in tariffs leads to substantial price undercutting in the production of recycled aluminium, serving as a key motivator for the increase in scrap imports. Establishing the recycling industry by incorporating scrap collectors, aggregators, and rag pickers into the formal framework is crucial. A strong scrap metal recycling sector will greatly assist in fostering a circular economy within the aluminium industry, creating significant job opportunities and helping to address climate change by complying with COP21 commitments and fulfilling sustainable development goals (SDGs).

The energy required for producing aluminium from scrap is merely 5% of that needed to produce primary aluminium. There is a significant demand for scrap aluminium in the production of automotive components, construction materials, packaging (including cans and foil), and various consumer products. Enhancing the collection and sorting systems for aluminium waste, along with raising public awareness regarding the advantages of recycled aluminium, can lead to improved collection of scrap aluminium.

Competitor’s profile

Vedanta Ltd

Vedanta Aluminium, an associate company of Vedanta Resources Plc, was incorporated in 2001. It is a leading producer of metallurgical grade alumina and other aluminium products. It is the largest mining and non-ferrous metals company in India and has mining operations in Australia and Zambia and oil and gas operations in three countries. Its main

products are zinc, lead, silver, oil & gas, iron ore, steel, aluminium and power. Vedanta is the largest aluminium producer in India with a capacity of ~2.4 million tonnes per annum (MTPA) and holds a 57% market share in terms of capacity. Vedanta Aluminium has an installed capacity of 1.8 MTPA, backed by two smelters — 0.55 MTPA and 1.25 MTPA (SEZ) and two power plants with a combined capacity of 3615MW. BALCO operates through its plant at Korba in Chhattisgarh with a smelter capacity of 0.57 MTPA and power generation capacity of 2010 MW. The alumina refinery at Lanjigarh feeds the aluminium smelters at Jharsuguda and BALCO and forms a crucial link in the value chain. It is one of the world's largest, single-site integrated alumina refining complexes with a capacity of 2 MTPA that can be ramped up to 6 MTPA. Vedanta produces primary aluminium as ingots and converts the majority of primary aluminium into VAPs, such as flat-rolled products, billets, slabs and rods at their Jharsuguda facility.

Product description	Facility and location	Capacity
Alumina	Lanjigarh refinery, Lanjigarh, Odisha	3.5 MTPA
Primary aluminium	Jharsuguda smelter, Jharsuguda, Odisha	1.8 MTPA
	BALCO, Korba, Chhattisgarh	0.58 MTPA

Hindalco Industries Ltd

Hindalco Industries Ltd was established in 1958 as Hindustan Aluminium Corporation Ltd. The company, which is a subsidiary of Aditya Birla Group, commenced operations in 1962 with a plant at Renukoot, Uttar Pradesh. It was renamed Hindalco Industries in 1989. Subsequent acquisitions and mergers with Indal and Birla Copper strengthened the company's position in the production of primary aluminium, value-added aluminium and copper products. In May 2007, the company acquired Canadian company Novelis for about $6 billion. Following the acquisition, Hindalco figured among the top five global aluminium producers. It is also the largest rolling company in the world. The company is an integrated producer, with alumina and aluminium facilities in India and rolling capacities across the globe. Hindalco produces primary aluminium as ingots and converts ingots into various products such as extrusions, foils and beverage cans.

Product description	Facility and location	Capacity
Alumina	Muri refinery, Ranchi, Jharkhand	0.45 MTPA
	Belagavi refinery, Karnataka	0.34 MTPA
Primary aluminium	Hirakud smelter, Sonbhadra, UP	0.216 MTPA
	Mahan smelter, Singrauli, MP	0.371 MTPA
	Aditya smelter, Sambalpur, Odisha	0.38 MTPA
	Renukoot, UP	0.356 MTPA
Extrusions and alloys	Alupuram, Ernakulam, Kerala	0.012 MTPA
Flat rolled products	Belur, West Bengal	0.045 MTPA
Flat rolled products	Hirakud FRP, Sambalpur, Odisha	0.135 MTPA
Extrusions and profiles	Kuppam, Andhra Pradesh	0.015 MTPA

Downstream products	Renukoot and Renusagar plant, UP	0.054 MTPA
Extrusions	Silvassa, Dadra and Nagar Haveli	0.034 MTPA
Flat rolled products	Taloja, Raigad, Maharashtra	0.060 MTPA
Foil production capacity	Mouda, Nagpur, Maharashtra	0.017 MTPA

NALCO

National Aluminium Co Ltd (Nalco) was incorporated by the central government in 1981 to exploit the large bauxite deposits in Odisha. The company has one of Asia's largest integrated alumina complexes, encompassing bauxite mining, aluminium refining, aluminium smelting and casting, power generation, and rail and port operations. It has one of the largest integrated bauxite-alumina-aluminium-power complexes in the country. The company has a 68.25 lakh TPA bauxite mine and 21.00 lakh TPA (normative capacity) alumina refinery located at Damanjodi in the Koraput district of Odisha. It also has a 4.60 lakh TPA aluminium smelter and 1,200 MW captive power plant in Angul, Odisha. Nalco has bulk shipment facilities at Vizag port for export of alumina/aluminium and import of caustic soda and also utilizes the facilities at Kolkata and Paradip ports. The company has registered sales offices in Delhi, Kolkata, Mumbai, Chennai and Bangalore and nine operating stockyards at various locations in the country to facilitate domestic marketing. Nalco is a fully integrated aluminium manufacturer. It produces ingots which are also converted into VAPs such as billets and rolled products.

Product description	**Facility and location**	**Capacity**
Alumina	Damanjodi refinery, Damanjodi, Odisha	2.1 MTPA
Primary aluminium	NALCO smelter, Angul, Odisha	0.46 MTPA
Rolled Products	RP Unit, Angul, Odisha	0.05 MTPA

Adani Enterprises

The company has received approval to build a 2-4 MTPA greenfield alumina refinery from the Odisha High-Level Clearance Authority (HLCA). They have also secured two bauxite blocks in Odisha – Ballada and Kutrumali, through their aluminium special purpose vehicle Kalinga Alumina Limited. They also have plans to further build an aluminium smelter in Odisha to add to the domestic aluminium production. Land acquisition for the refinery project is in progress and they have received in-principle approval for their integrated aluminium projects from the Industrial Promotion and Investment Corporation of Odisha Limited (IPICOL).

Risk and challenges

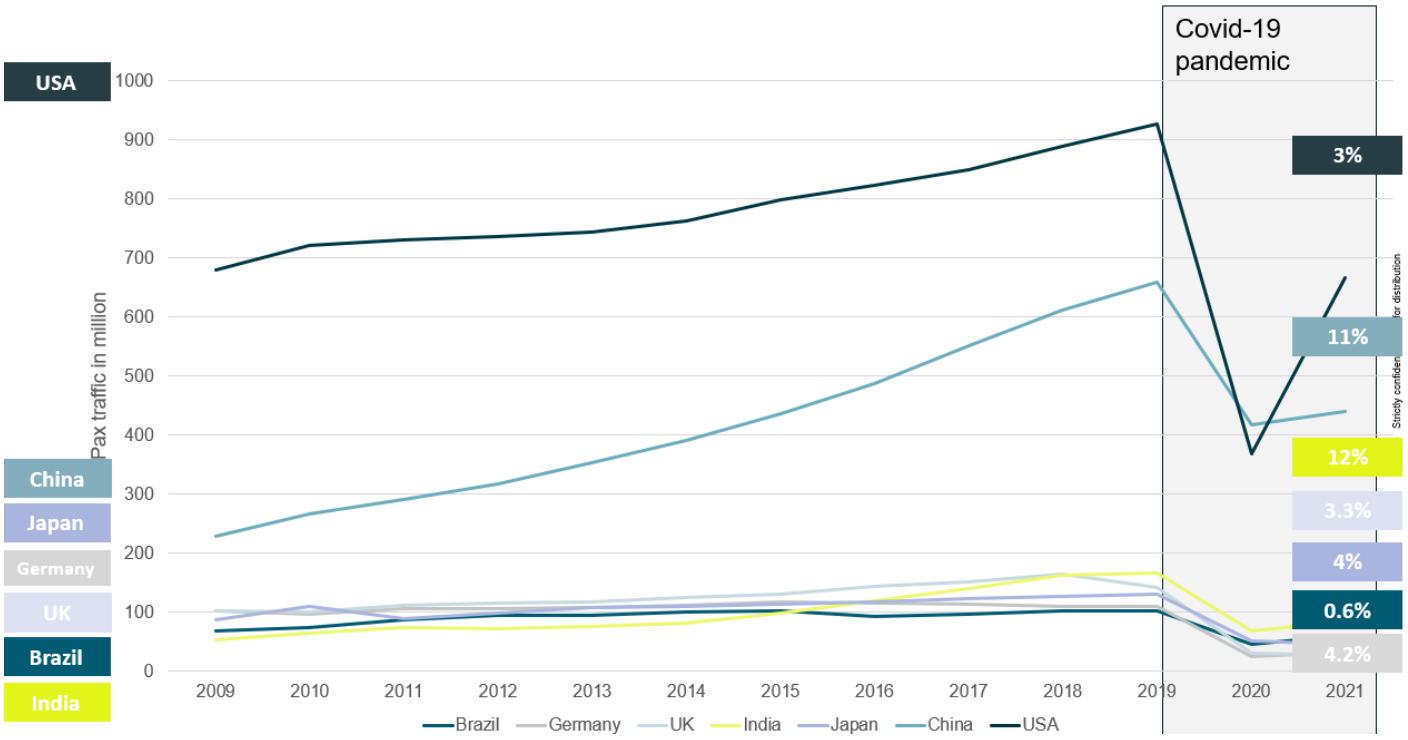
- **Raw material sourcing:** Securing raw materials, such as alumina, bauxite and coal, is a major challenge for the industry. All established players are taking part in bauxite and coal mine auctions. Most of their alumina requirements are met domestically and the balance is met through imports.
- **Carbon emissions:** Aluminium manufacturing process is power-intensive. Most of the power is produced through thermal coal. With the increased focus on climate risk mitigation, governments are formulating various regulations to reduce the usage of fossil fuels. As regions like EU implement CBAM, Indian exports might find it difficult to compete with its global competitors who produce aluminium at a lower carbon intensity.
- **Export competition:** A large portion of the aluminium produced in the country is exported. India is among top low-cost aluminium producers. However, it faces intense competition from the Middle East countries. With Indonesia and Guinea also looking to integrate their respective value chains and producing more ingots and downstream products, the export market will get crowded further.
- **Challenges related to scrap availability:** While India is self-sufficient for its primary metal needs, it still is import reliant for scrap sourcing with the US being a major source traditionally. As the US implements additional import tariffs on aluminium. It is likely to turn to its scrap metal to meet its domestic needs amid falling imports in the long run for the country. This will not only render one of India's largest scrap sources unviable but is also likely to create a squeeze on the supply side for scrap. In conjecture with the growing need to reduce carbon intensity, this problem gets compounded further as producing aluminium articles using scrap metal is the most efficient way of reducing carbon intensity.
- **West Asia conflict**: Globally, the GCC region has contributed 8% to 9% of global output in the last five years. Major players in the region have emerged from the UAE, Bahrain, Qatar, and Saudi Arabia. With the escalation of the conflict, this supply faces significant risks. Aluminum Bahrain has started to shut down approximately 19% of its existing capacity after declaring a force majeure. Other players, such as Qatalum, are trying to maintain a utilization level at approximately 60% of their 650 thousand metric tons of capacity. However, beyond operational concerns, the obvious concern for these players has been the disruption of shipping routes and logistics. While certain players have started using the land route to redirect their output, earmarked for export, to the Jeddah port in Saudi Arabia, other players are facing challenges in meeting their export commitments. Another hurdle for the smelters in the region has been the supply of alumina, an intermediary in the aluminum smelting process. Given that a major share of alumina demand is met through imports from countries such as Australia, players must rely either on their existing stockpiles, which are sufficient for only approximately one month of requirements, or source limited quantities from smaller regional refineries with limited capacity. Either way, the continuity of operations at these major smelters remains at risk. While there has been some consideration regarding the use of the Red Sea route, this would significantly add to the logistics cost.

  Another aspect of the closure of the shipping routes has been the supply shock regarding natural gas. Certain smelters, outside the GCC region, depend on natural gas-based energy to run their smelters. These players, however, have been hard-pressed to source economically feasible alternatives to the natural gas supplies coming from the Gulf, thereby increasing their production costs.
- All these direct and indirect supply woes pushed aluminum prices above $3,500 per metric ton on the LME in mid-March. It is also worth mentioning that because of the supply uncertainty, LME inventory levels have come down by approximately 40 thousand to 45 thousand metric tons since the conflict began in late February.

Module 6: Airports

India has been the fastest growing aviation market during 2009 to 2019 and has become the third largest by domestic air passenger traffic since 2018, behind only the USA and China. Between 2020 and 2023, the pandemic led to crimping of passenger traffic across the world. However, air travel has recovered swiftly post the pandemic with only China recording a higher domestic RPK (Revenue Passenger Kilometre – an indicator for number of passengers and average distance travelled) growth than India at 20.7% vs 11.7% for India, higher than the world average of 9.7% in 2024 compared with 2019.

Figure 55: India was the fastest growing aviation market pre-Covid

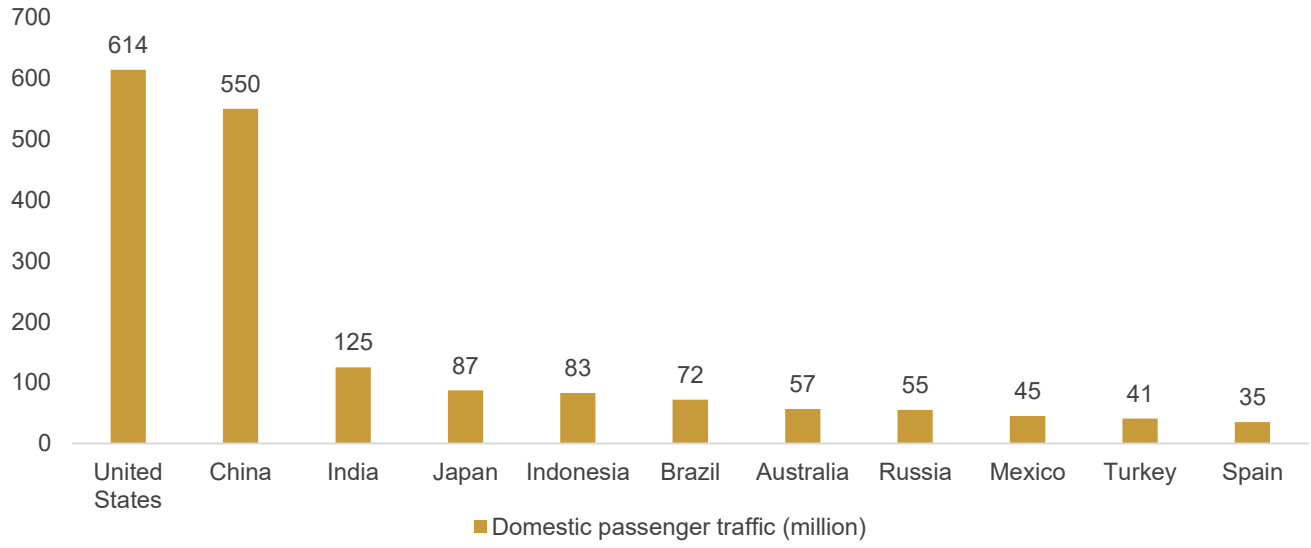


There are several macro tailwinds for the sector, including a large domestic population, a rising middle class aided by improving incomes, an evolving aviation ecosystem with a growing number of MRO facilities, local aircraft leasing companies, and pilot training schools. Air travel penetration in India remains relatively low compared to global benchmarks, providing significant headroom for growth. In 2019, India became the third-largest domestic civil aviation market in the world based on passengers flown, and it has immense potential to grow further. This growth is being supported by Government initiatives such as the National Civil Aviation Policy (NCAP) 2016 and regional connectivity through the Ude Desh Ka Aam Nagrik (UDAN) scheme. Additionally, an improving policy environment, a renewed focus on air cargo, rising e-commerce penetration, and growth in India's manufacturing sector are supporting freight traffic. India's strategic geographical location between the western and eastern hemispheres also provides a strong opportunity to develop transit traffic flows between the two regions.

As the Indian aviation sector continues to grow, the focus is shifting towards developing and modernizing airport infrastructure to cater to the increasing demand. Indian airports are undergoing significant transformations, with many undergoing expansions, renovations, and modernization. The Airports Authority of India (AAI) has plans to develop and modernize over 100 airports across the country, with a focus on creating world-class facilities and enhancing passenger experience. Private players such as GMR, Adani, Fairfax group and Zurich airports are also investing heavily in airport development, with a focus on creating modern and efficient airports that can handle increasing passenger traffic. The development of new airports, such as the Navi Mumbai International Airport, Jewar Airport, Bogapuram airport to name a few are also underway, which will further enhance India's airport infrastructure.

The development of Indian airports is critical to the growth of the aviation sector, as it will enable the country to handle increasing passenger traffic and cargo volumes. Indian airports are also focusing on adopting sustainable and environmentally friendly practices, such as the use of renewable energy and green buildings. With the growth of the aviation sector and the development of airport infrastructure, India is poised to become a major player in the global aviation industry, with its airports serving as gateways to the country's growing economy and tourism industry. The focus on developing world-class airports will not only enhance passenger experience but also contribute to the country's economic growth and development.

Figure 56: India became the third-largest domestic civil aviation market in CY19



Note: Data as of CY19
Source: IATA, Crisil Intelligence

Passenger traffic

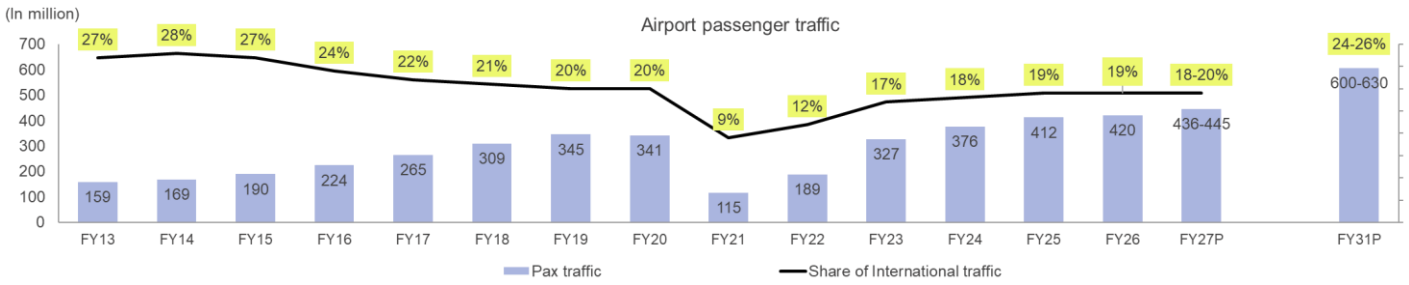
India’s airport passenger traffic logged a 4.7% CAGR between FY17 and FY26, despite the crippling impact of the Covid-19 pandemic on air travel between FY21 and FY23. Passenger traffic was 23% above pre-Covid levels at the end of FY26. Passenger traffic in FY26 stood at 420 million, recording a moderate 1.9% year-on-year increase. The relatively slower growth during the fiscal was attributable to a combination of supply-side and demand-side headwinds. Domestic passenger traffic growth remained subdued during FY26, impacted by capacity constraints arising from fleet groundings and operational disruptions. Demand was further affected by temporary travel hesitancy following the Air India aircraft crash and geopolitical developments, including the Pahalgam attack and Operation Sindoor, particularly during the first quarter. On the international front, traffic growth was moderated by disruptions arising from the West Asia conflict,

including airspace restrictions, flight rerouting, schedule adjustments, and higher operating costs, which affected connectivity on key international corridors and weighed on passenger demand during the last quarter.

For fiscal 2027, passenger traffic is projected to grow by 4-6% on year with estimated passenger numbers reaching 436-445 million. This will be strongly impacted by the ongoing middle east crisis along with the sharp rise in fares on account of the ATF prices brought about by the ME crisis. The Middle East accounts for nearly 50-55% of international passenger traffic, driven by a mix of business travel, leisure demand, VFR (visiting friends and relatives), labour movement, and strong transit flows via major hub airports. A sustained increase in fuel prices has led to an increase in air fares, particularly on long-haul and high-frequency Middle East routes, which could dampen discretionary travel demand. In the first half of April, escalating tensions in the Middle East led to widespread flight suspensions and airspace restrictions, disrupting key corridors linking India with the Gulf and beyond. Airlines were forced to cancel or reroute services due to safety concerns and operational uncertainty. Flight schedules had returned to normalcy post the ceasefire on 16th April, 2026 onwards. However, Given the region's continued volatility, there remains a material risk of renewed disruptions, with flights liable to be suspended again if the crisis intensifies.

Passenger traffic is expected to reach 600-630 Mn by fiscal 2031 as Indian aviation gets back to pre-pandemic double-digit growth rates, led by low travel density per capita, shift from rail to air travel, better air connectivity aided by rise in number of airports, expansion of capacity at current airports, rising fleet of Indian carriers, improving incomes and favourable demographic dividend. This growth will be driven by strong demand across leisure travel, visiting friends and relatives (VFR), corporate travel, meetings, incentives, conferences, and exhibitions (MICE), along with airlines expanding capacity through new aircraft deliveries.

Figure 57: Pax traffic seen recording a 4-6% rise in fiscal 2027 on account of middle east crisis leading to rise in fares



Note: Data for FY22 includes unscheduled international passenger traffic through Vande Bharat Mission and air transport bubbles
E: Expected; P: Projected
Source: AAI, Crisil Intelligence

International passenger traffic in India continued to witness steady growth in FY26, with its share reaching around 19% of overall passenger traffic, moving closer to historical averages. Growth was supported by strong outbound travel demand, increased international capacity deployment by Indian carriers, induction of new aircraft, expansion of services by newer airlines, and a continued focus on short-haul destinations in South-East Asia and the Middle East. However, growth during the year was moderated by operational disruptions, aircraft availability constraints, supply-chain related maintenance challenges, and the impact of aviation safety incidents and accidents across the industry, which led to capacity adjustments and affected passenger sentiment during certain periods. As a result, international traffic growth remained healthy but below its full potential.

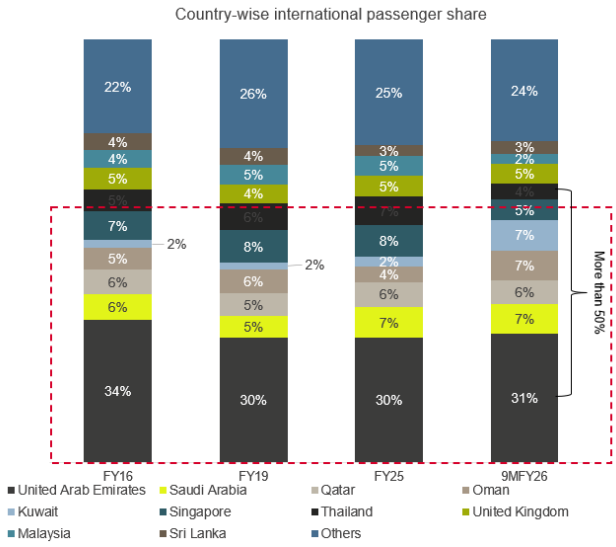
The Middle East accounts for nearly 50-55% of international passenger traffic, driven by a mix of business travel, leisure demand, VFR (visiting friends and relatives), labour movement, and strong transit flows via major hub airports. A

sustained increase in fuel prices has led to an increase in air fares, particularly on long-haul and high-frequency Middle East routes, which could dampen discretionary travel demand. In the first half of April, escalating tensions in the Middle East led to widespread flight suspensions and airspace restrictions, disrupting key corridors linking India with the Gulf and beyond. Airlines were forced to cancel or reroute services due to safety concerns and operational uncertainty. Flight schedules had returned to normalcy post the ceasefire on 16th April 2026 onwards. Given the region's continued volatility, there remains a material risk of renewed disruptions, with flights liable to be suspended again if the crisis intensifies. International traffic growth in FY27 is likely to face additional headwinds. Geopolitical tensions across key international corridors, elevated crude oil prices, and airline capacity rationalisation measures aimed at protecting profitability are expected to temper traffic growth. While international traffic share is projected to increase further, the pace of expansion may be slower than earlier expectations.

Despite these near-term challenges, the long-term outlook for international aviation remains favourable. Continued expansion of bilateral air service agreements, growing outbound tourism, rising disposable incomes, and significant investments in airport infrastructure are expected to support sustained growth. In addition, large widebody aircraft orders by leading Indian carriers will strengthen long-haul connectivity and expand India's international aviation footprint. Supported by these structural drivers and a conducive regulatory environment, international passenger traffic is projected to grow at a CAGR of approximately 6-7% between fiscals 2026 and 2031.

Changing trends in international passenger traffic

Figure 58: UAE is the largest market for Indian international passenger traffic



Source: DGCA, Crisil Intelligence

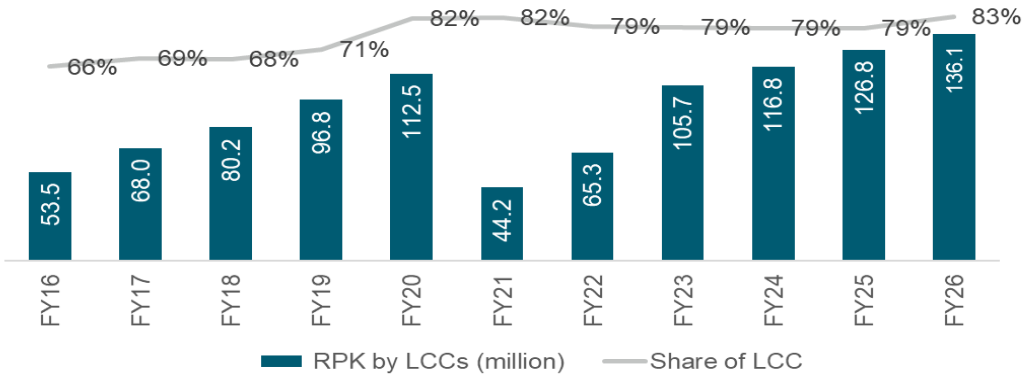
Indian aviation sector

Factors driving air passenger growth in India:

1. **LCCs boost affordability**

Low-Cost Carriers (LCCs) have been instrumental in democratizing air travel. LCCs now account for more than 80% of total RPK. They have aggressively expanded their fleet and network to dominate both the metro and regional markets with a no-frills, cost-effective model. By offering affordable, no-frills flights, LCCs are democratizing air travel, making it accessible to a broader segment of the population. This increased accessibility not only boosts passenger volumes but also stimulates economic activity by enabling more frequent travel for both business and leisure purposes.

Figure 59: Domestic aviation market dominated by LCCs

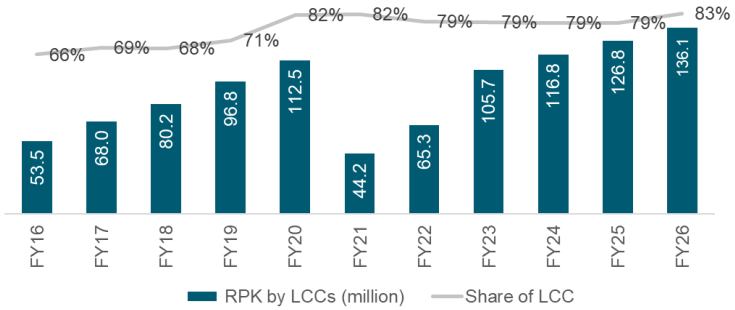


Note: Based on RPK
Source: DGCA, Crisil Intelligence

In international operations, particularly in dominating short-haul destinations with narrowbody aircraft, the rising market share LCCs is a key growth driver. LCCs' share has increased from 20% in fiscal 2016 to 48% in FY25 and further inched up towards 56% in FY26, making air travel more affordable and accessible. This expansion allows more passengers to travel internationally at lower costs, significantly boosting international passenger volumes and stimulating growth in the aviation sector.

LCC’s started gaining share in international operations fiscal 2015 onwards as they started exploring higher yielding international markets. The demise of Jet Airways and an ailing Air India under the erstwhile government control led to further expansion of share of LCC’s which operated and concentrated on short to medium haul destinations. The share of LCC’s rose to 48% in fiscal 2021 attributable to the pandemic but the continued expansion of TATA group led Air India post-merger with Vistara on the International market has led to FSC

Figure 60: LCCs gaining share in international operations, Dominating short-haul destinations with narrowbody aircraft



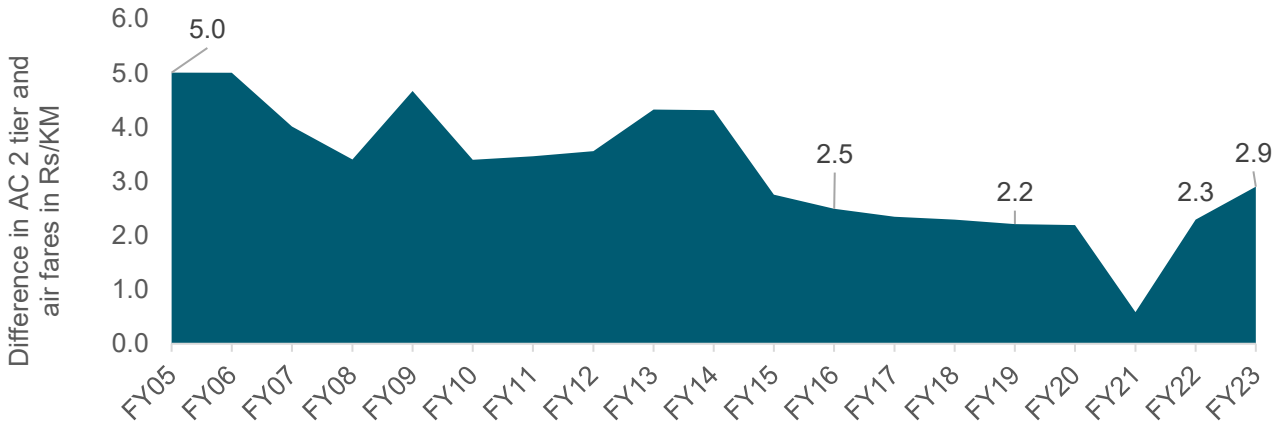
Note: Based on RPK
Source: DGCA, Crisil Intelligence

The increasing popularity of LCCs and intense competition have led to a drop in airfares on both domestic and international routes, leading to higher number of price-elastic Indian passengers taking to the air.

2. Narrowing price differential between air tickets and AC 2 tier fares

Increased competition between Indian airlines, a higher market share of LCCs (Low-Cost Carriers), and technological advancements in aircraft and efficiency have led to airfares falling over the years. However, reduced subsidization of passenger fares by Indian Railways and the introduction of dynamic fares on some routes have led to a rise in railway fares per kilometer. The difference between the per kilometer cost of an air-conditioned (AC) 2-tier railway ticket versus airlines reduced to about INR 2.9 in FY23 from ~INR 5.0 in FY05. This, coupled with the time advantage of air travel, is boosting domestic passenger air traffic numbers. Although the difference is expected to have widened again in FY24 and FY25 and is likely to continue this trend into FY26 as airfares continued rising on account of reduced competition and healthy demand while rail fares remained constant, lower availability on Indian Railways coupled with improved connectivity by air continued providing a boost to air travel.

Figure 61: Fare differential narrowing between AC 2 tier and flight tickets

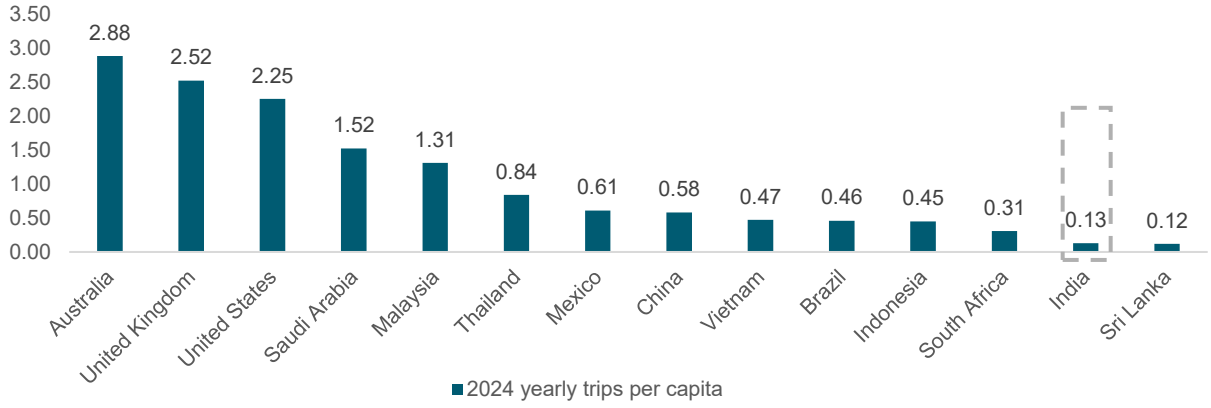


Source: Indian Railways, company reports, Crisil Intelligence

3. Lower air trips per capita

India's air travel per capita, currently lagging its global peers, highlights a significant untapped market potential poised to drive growth in the aviation sector. With a burgeoning middle class, increasing urbanization, and a growing propensity for travel among younger demographics, the demand for air travel is set to rise. Enhanced connectivity, government initiatives like UDAN (Ude Desh ka Aam Nagrik), and investments in airport infrastructure further underscore the potential for exponential growth, positioning India as a pivotal player in the global aviation market.

Figure 62: India among the lowest-ranked developing countries in air trips per capita

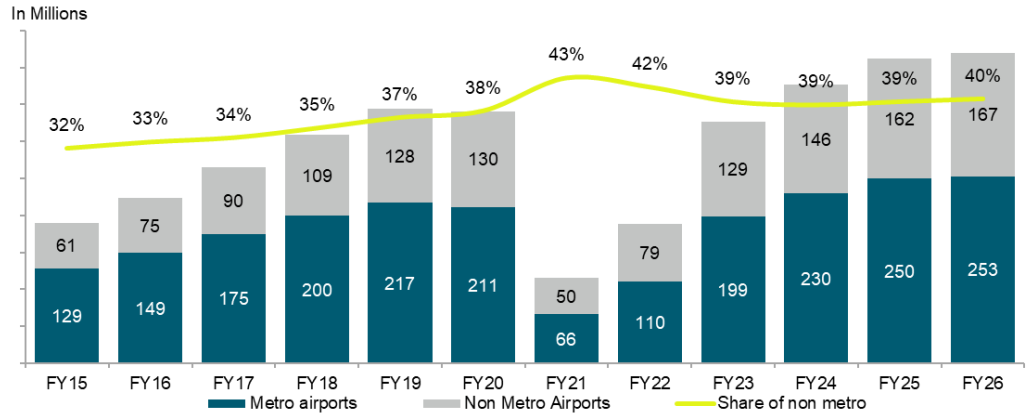


Source: Airbus commercial market forecast 2019, Crisil Intelligence

4. Connectivity beyond metro cities

Airports in metropolitan cities accounted for 68% of air passenger traffic in FY15. However, due to increasing demand for air travel from non-metro destinations, improving airport infrastructure in these cities, availability of high-yielding traffic, and rising congestion at metro airports, airlines have started looking at serving non-metro destinations. The UDAN scheme has also helped popularise air travel in these cities. The share of non-metro passenger traffic has risen to 40% in FY26 from 32.3% in FY15, and the shift is expected to continue as airlines deploy an ever-increasing fleet to newer destinations and new airports come up in non-metro areas.

Figure 63: Share of non-metro airports traffic peaked in FY21 due to migratory travel; metro airports gaining share aided by capacity expansion across major metro airports except Mumbai



Source: AAI, Crisil Intelligence

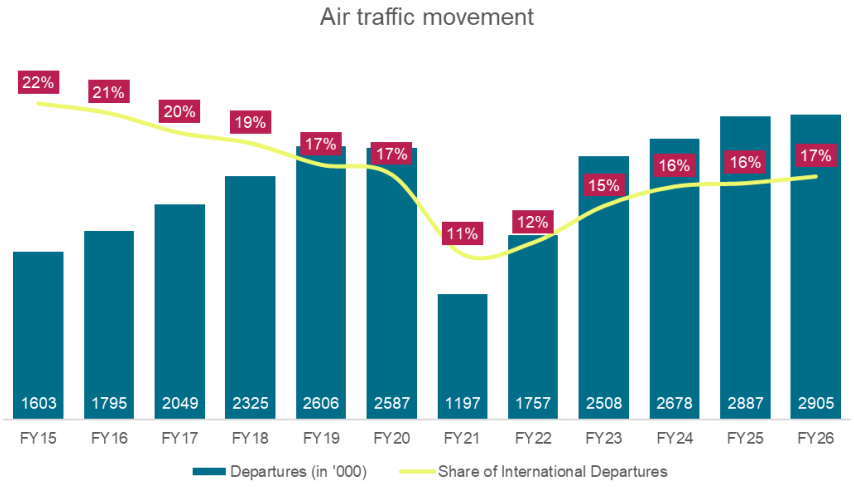
Air traffic movement

India's air traffic movement logged a 3.5% CAGR between fiscal 2017 and fiscal 2026. By fiscal 2026, the flight count reached 2.9 million, 12% above pre-Covid levels of fiscal 2020 with international departures accounting for 16.5% of total aircraft movement.

Domestic ASK in FY27 is projected to record a muted growth of 0-2% on year to 193-197 billion-kms primarily due to supply side constraints, the slowest in 11 years except the pandemic impacted fiscal 2021. Additionally, network maturity and operational prioritisation have played a role. After multiple years of rapid domestic capacity addition, growth has moderated as major trunk routes approach saturation. Airlines have also reallocated scarce aircraft capacity toward international markets, where yields and strategic relevance are higher, further tempering domestic ASKM expansion. Together, these factors explain why domestic capacity growth has slowed despite underlying demand remaining intact.

The outlook for the Indian air travel market appears promising, with several airlines placing significant orders for new aircraft. IndiGo has ordered 500 new narrow-body aircraft, which, combined with existing orders, will elevate its total fleet to approximately 1,000 aircraft. The airline has also agreed to purchase 60 A350-900 aircraft with 40 options, enabling it to expand its international network. Air India has ordered 570 new aircraft to enhance its operational capacity, while Akasa Air has placed an order for 150 aircraft, bringing its total order book to 226 aircraft. With these developments, the Indian air travel market is poised for significant growth, driven by increased fleet capacity, new player entry, and recovering passenger demand. The industry's growth is expected to be further fueled by the expansion of international services, increased connectivity, and the growing demand for air travel in the region.

Figure 64: Air traffic movement



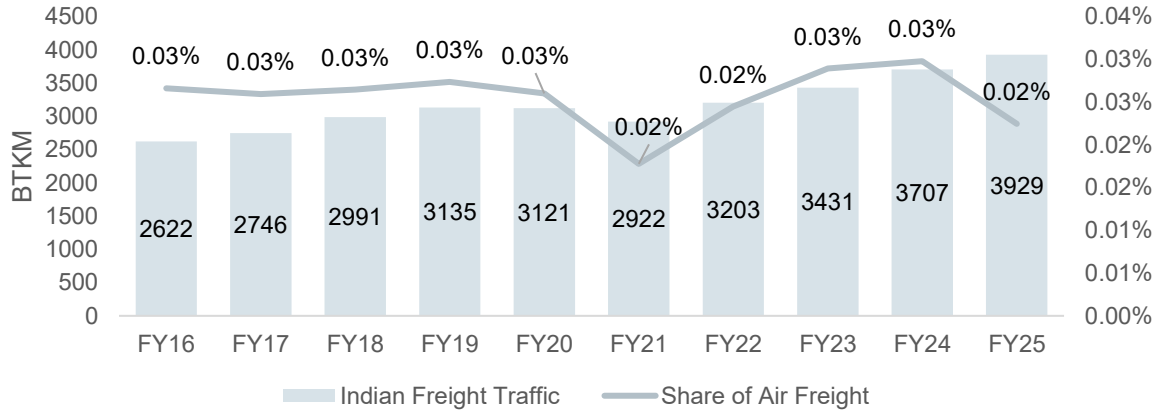
Source: Crisil Intelligence

Freight traffic

The primary modes of freight transportation in India, measured in billion tonne-kilometres (BTKM), include rail, road, coastal shipping, pipelines, and air freight. Among these, road transport holds the dominant position, accounting for approximately 64% of total BTKM as of fiscal 2025. Rail follows with a 26% share, while coastal shipping, pipelines account for the balance with air freight a marginal contributor. The variation in modal share is primarily driven by differences in cost structures and operational suitability. Road and rail are significantly more economical than air freight, making them the preferred choices for the bulk of domestic cargo movement. Road transport offers high flexibility and door-to-door connectivity, which is especially advantageous for short- to medium-haul deliveries. Rail, on the other hand, is more cost-effective for transporting heavy and bulk commodities over long distances, owing to its fuel efficiency and economies of scale.

In contrast, air freight, though the fastest mode, is the most expensive due to higher fuel costs, limited payload capacity, and greater infrastructure and security requirements. As a result, it is typically used for time-sensitive, high-value, or perishable goods rather than for large-scale cargo movement. This cost disparity significantly limits the share of air freight in the overall BTKM, despite its speed advantage.

Figure 65: Modal distribution of Indian domestic freight traffic



Source: Crisil Intelligence

Freight traffic at Indian airports

India's freight traffic logged an 3.2% CAGR between FY 2016 and FY 2026. Freight traffic was 11.7% above pre-Covid levels at the end of FY 2025. Freight traffic in FY26 stood at 3718 thousand tonnes, marking an 10.5% year-on-year increase. Fiscal 2027 is projected to grow at 5-7% on year to 4050-4200 thousand tonnes attributable to capacity push by airlines adding dedicated freighters, growing e-commerce activity, increasing capacity deployments with fleet addition and network expansion of airlines to tier II cities, driven by improving capacity by operationalisation and ramp up of the Navi Mumbai and Jewar airports.

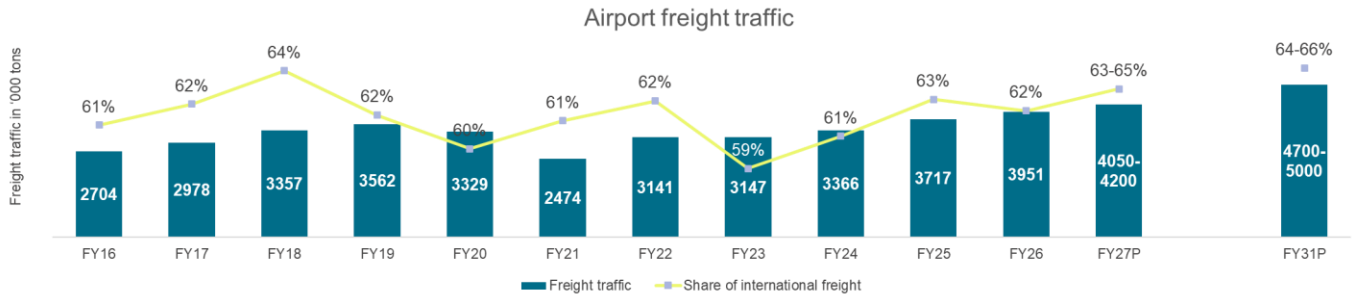
However, the outlook for FY27 is sensitive to rising ATF prices. Higher fuel costs increase freight rates, which may reduce demand for low-value, price-sensitive goods, though premium cargo is likely to remain resilient. The middle east crisis is projected dampening international freight traffic on account of increased fuel prices along with impacted airline network and schedule with the Middle east accounting for more than 1/3rd of the freight throughput from India. The region plays a critical role as a transshipment hub for Indian cargo, especially to Europe, Africa, and North America. With reduced operations by Gulf carriers, and rerouting of flights, capacity has tightened significantly, leading to delays and inefficiencies across key trade lanes.

As a result, cargo volumes have softened in the near term, not due to weak demand but because of constrained supply. At the same time, freight rates have surged sharply, driven by higher fuel costs, and reduced belly cargo capacity. While rates have started to stabilize as some operations resume, they remain elevated compared to normal levels. From a fiscal perspective, this creates a mixed impact - higher yields support revenues, but increased operating costs and volume pressures weigh on margins. Structurally, Indian carriers are gradually increasing their share in international cargo, supported capacity additions. However, Gulf carriers continue to dominate due to their scale and network strength.

Freight traffic was recorded at 3951 thousand tonnes in fiscal 2026, recording a growth of 5.7% over last year driven by domestic freight traffic growth.

This growth was driven by rapid growth of e commerce platforms, requiring faster logistics solutions, pharmaceutical and healthcare exports, improving manufacturing activity in India driving exports through air and growth in international trade and post covid supply chain shifts – basically diversification of global supply chains.

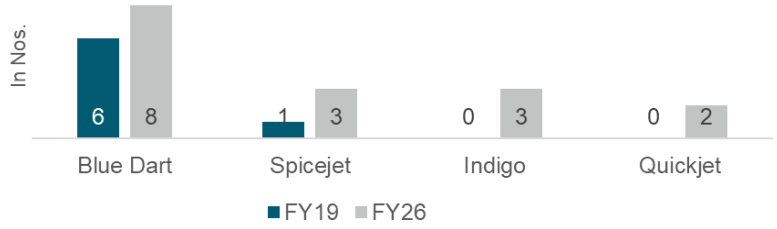
Figure 66: Airport freight traffic



Source: AAI, Crisil Intelligence

The domestic air freight market in India experienced significant growth prior to the Covid-19 pandemic, driven by factors such as the rise of e-commerce, increasing demand for time-sensitive shipments, and growth in the pharmaceutical sector. The share of international freight has inched up from 61% in fiscal 2015 to 63% in fiscal 2025. By fiscal 2031, it is projected to be between 64-66%. Freight traffic over the medium term i.e. by fiscal 2031 will be driven by both demand and supply factors. On the demand side, rising trade to and from India aided by the manufacturing push as India becomes embedded in Global value chains including electronics and rising share of perishables while on the supply side, improving airport infrastructure, increasing focus of airlines on freight traffic and India acting as an air transit hub for neighbouring and south Asian countries. The surge in e-commerce played a crucial role in driving the demand for air freight services, as it requires fast and reliable transportation of goods.

Figure 67: Dedicated freighters were only operated by a single passenger airline till fiscal 2020



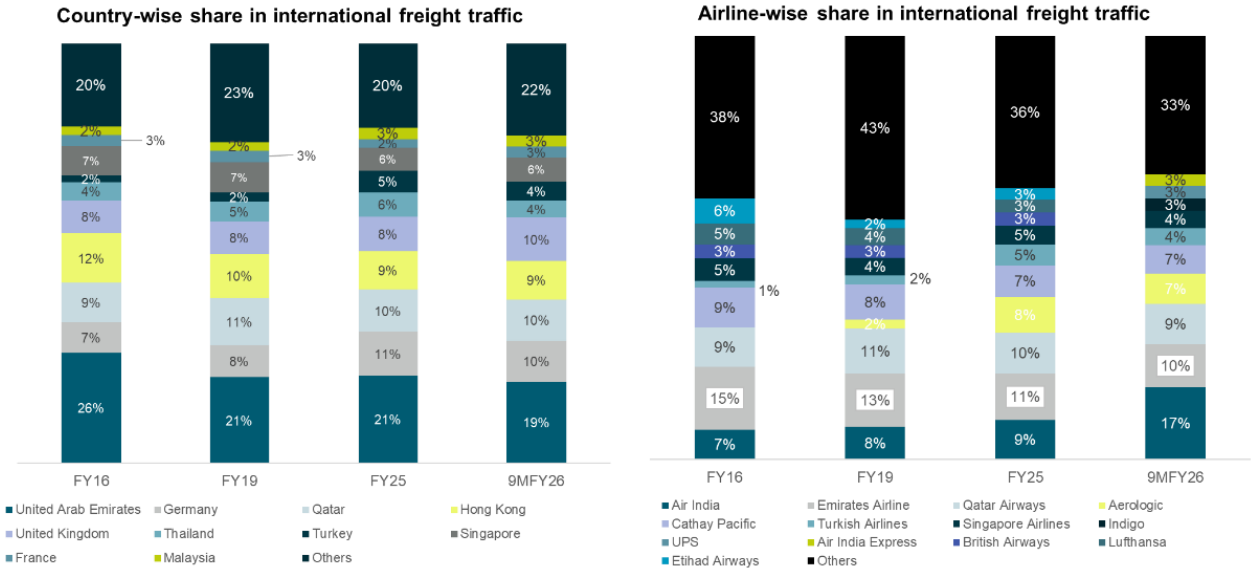
Source: DGCA, Crisil Intelligence

On the international front, while there were no dedicated freighter services operated by Indian carriers ever since Air India halted its air cargo operations in 2012 due to losses, the pandemic witnessed SpiceXpress, IndiGo and Air India operate cargo only flights. SpiceJet leased 3 widebody A340 aircraft to serve destinations in Africa, Europe and CIS countries non-stop. Several foreign carriers operate dedicated freighters to and from India and in order to provide a boost to the cargo operations of Indian carriers and in line with its Aatmanirbhar Bharat Abhiyan, the DGCA has restricted unscheduled and charter operations of foreign carriers to 6 metro airports only. This would aid cargo carriage by Indian carriers from the remaining airports as cargo transshipment is not as common as pax travel via hubs. Further, these foreign operators have also been restricted from operating cargo flights within the country which they were allowed to prior the pandemic which would enable domestic cargo operators and airlines to capture a larger share of the air cargo market.

The interest in freighter operations can be attributed to their higher realisations when compared with realisations of cargo carried by airlines. This differentiation is mainly due to the type and urgency of the cargo, as the belly capacity of airlines

cannot accommodate cargo with large and odd dimensions. Moreover, freighters incur significant costs to operate, which needs to be offset through their higher yields.

Figure 68: UAE maintains significant market share in-line with passenger traffic



Source: DGCA, MoCA, Crisil Intelligence

The Middle East continues to dominate India's international air freight market as well, accounting for roughly one-third of total cargo volumes, driven by strong bilateral trade, geographic proximity, and robust hub connectivity through key transit points such as Dubai and Doha. Advanced logistics infrastructure and high freighter capacity further reinforce the region's position as a global cargo hub.

Among key corridors, the UAE leads freight throughput, supported by its strategic location and major hubs. Germany ranks second, primarily due to the strong presence of AeroLogic (DHL's freight arm), which serves as a key distribution link between India and Europe. Qatar follows closely, with Qatar Airways leveraging its extensive network and dedicated freighter fleet to connect India with long-haul markets across Europe and the Americas. Hong Kong remains an important Asian gateway, led by Cathay Pacific, facilitating trade flows linked to China.

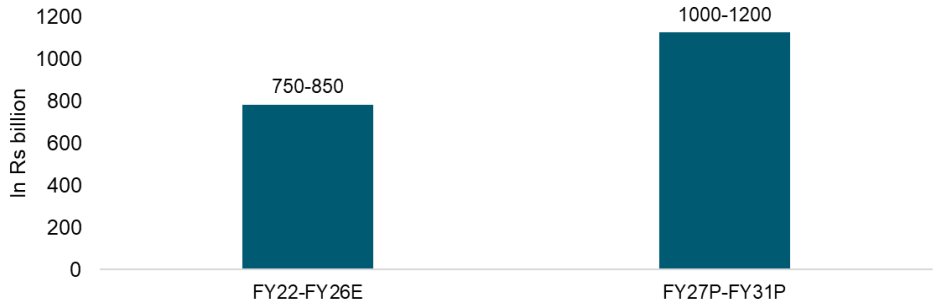
However, ongoing geopolitical tensions in the Middle East have led to a sharp rise in fuel prices, increasing operating costs and pushing up air freight rates. This is beginning to weigh on demand at the margin, particularly for price-sensitive commodities, while also pressuring yields where cost pass-through remains limited.

Amid this, Air India remains the only Indian carrier to sustain its international freight market share at ~9%, above pre-COVID levels, supported by its network strength and ongoing operational improvements. Among foreign carriers, AeroLogic and Qatar Airways lead in freight volumes, followed by Emirates, with capacity distributed across multiple UAE-based airlines.

Overall, while the Middle East retains structural dominance, rising fuel costs and geopolitical uncertainties are creating near-term pressure on volumes, underscoring the importance of efficient hub networks and cost management.

Review of investments by various players in airport infrastructure

Figure 69: Airport capex projected to cross 1 trillion over fiscals 202-30 driven by healthy passenger and investor demand



Source: Crisil Intelligence

Crisil Intelligence forecasts investments exceeding Rs 1 trillion in airport infrastructure from fiscals 2027-31, surpassing the ₹750-850 billion invested from fiscals 2022-26.

Notable upcoming projects include the second phases of Jewar and Navi Mumbai International Airport (NMIA), the redevelopment of Mumbai Airport's Terminal 1, and the commencement of construction for Hyderabad Airport's Phase 3. Several new airport projects are slated for completion or commencement, including the Dholera greenfield airport, which is expected to be completed by FY26. Additionally, expansion projects will begin for new integrated terminal buildings at Ahmedabad and Mangalore airports. The Government of India has also granted 'In-Principle' approval for 21 new greenfield airports, with 12 already operational, further bolstering the country's airport infrastructure.

Limited revenue risk driving participation towards PPP airports

The airport sector is one of the few infrastructure sectors in India where the PPP model has achieved maturity, receiving acceptance from all stakeholders, including the regulator, ministry, operators and lenders.

The salient features of the PPP model contributing to rising participation of private entities in the airport sector are:

i. Regulated fixed return-based structure for aeronautical revenue, with upside potential from non-aeronautical revenue

ii. Assured return on regulatory assets through cost plus model

iii. Inclusion of capex for aeronautical revenue determination

iv. Clarity on applicability of 30% hybrid till model at airports with pax greater than 3.5 million

v. Rising penetration of air travel in India

vi. Increasing propensity to spend of the Indian consumer

vii. Stable regulatory mechanism with AERA regulating tariffs and fees, and TDSAT identified as a dedicated appellate tribunal responsible for addressing disputes with AERA and other related issues

viii. Clarity on end-use of real estate

   a. Clarity on National Civil Aviation Policy's (2016) liberalised end-use of airport Real estate land endorsed by the Supreme Court

   b. Real estate deposits (RSD) of commercial property development can be used to finance project capex

History of privatisation

The first Indian airport to be privatised in India was Cochin airport in 1999, followed by Hyderabad in 2002 and Bengaluru in 2004.

In 2003, the AAI Board approved the modernisation proposal for the two largest airports in the country — Delhi and Mumbai. The government announced the modernisation plan in 2004 and offered 74% of the ownership stake in Mumbai and Delhi Airports to private players, keeping 26% for itself. Foreign direct investment (FDI) was allowed up to 49% of the 74% private ownership. Post the privatisation of Delhi, Mumbai, Bangalore, Hyderabad and Cochin airports, Kannur airport was developed on a PPP basis.

The AAI outlined six airports for privatisation, which were ultimately won by Adani Enterprises in 2019.

Table 9: List of bidders for past airport monetisations

Mumbai	Delhi	Ahmedabad	Mangalore	Guwahati	Thiruvananthapuram	Jewar	Bhogapuram
GVK Group / Adani Enterprises*	**GMR Consortium**	**Adani Enterprises**	**Adani Enterprises**	**Adani Enterprises**	**Adani Enterprises**	**Zurich Airports**	**GMR Group**
GMR Consortium	Reliance Consortium	GMR Group	GMR Group	GMR Group	GMR Group	Delhi International Airport Ltd**	DOIT Smart Infra
Essel-TAV Consortium	Essel-TAV Consortium	AMP Capital	Cochin International Airport Ltd	AMP Capital	KSIDC	Adani Enterprises	GVK Group
DS Construction Consortium	DS Construction Consortium	Autostrade	-	PNC Infrastructure	-	Anchorage Infrastructure	
Macquarie Consortium	Macquarie Consortium.	Fairfax India Holding	-	Autostrade	-		
Reliance Consortium	-	PNC Infrastructure	-	Fairfax India Holding	-		
-	-	NIIF and Zurich AG Consortium	-	-	-		

**Adani Enterprises took over management of Mumbai airport from GVK Group in July 2021*
***GMR Group-led consortium comprising Delhi International Airport Ltd (DIAL)*
Source: Crisil Intelligence

As part of the National Monetisation Pipeline announced in 2021, the government has identified 25 airports for monetisation. Some of these airports are loss-making and, hence, bundling them with those making profit may be considered, according to the NMP document.

Table 10: List of airports identified for monetisation

Sr. No.	Airport	Capacity as of FY20 (in million)	Pax Traffic in FY25 (in Million)
1	Chennai	23.0	20.5
2	Bhubaneswar	4.5	4.4
3	Varanasi	2.5	3.6

4	Patna	2.5	3.4
5	Indore	4.0	3.4
6	Kohzikode	3.5	3.4
7	Amritsar	4.0	3.2
8	Coimbatore	2.5	3.0
9	Nagpur	2.5	2.6
10	Raipur	2.5	2.3
11	Ranchi	2.0	2.3
12	Trichy	1.5	1.8
13	Surat	0.4	1.6
14	Dehradun	0.4	1.6
15	Udaipur	1.2	1.5
16	Bhopal	2.5	1.5
17	Agartala	1.0	1.3
18	Imphal	1.3	1.3
19	Madurai	2.9	1.3
20	Vijayawada	1.8	1.3
21	Vadodara	2.0	1.2
22	Jodhpur	0.4	0.9
23	Tirupati	2.5	0.9
24	Rajahmundry	0.4	0.4
25	Hubli	0.5	0.3

Source: National Monetisation Pipeline document, AAI, Crisil Intelligence

However, the asset monetisation programme has moved with a glacial pace with minimal updates and developments pertaining to the monetisation plans over four years since announcement. Monetisation Pipeline over FY 2022-2025 for Civil Aviation had been approximated at Rs 20,782 crores.

Figure 70: 25 airports identified for monetization under NMP

Source: National Monetisation Pipeline, NITI Aayog

Apart from the 25 airports, monetisation of the Airport Authority of India (AAI)'s residual stake in the four PPP airports was also to be considered under the NMP. The AAI currently holds 13% stake in the two greenfield airports and 26% in two brownfield ones.

New models of private sector participation

New airport tariff model

AERA is responsible for creating a level-playing field and fostering healthy competition among all major airports; encouraging investment for building new airport infrastructure; regulating tariffs of aeronautical services; protecting the interest of fliers; operating efficient, economically viable airports; fixing tariffs for aeronautical services; funding airport expansion projects; and ensuring timely completion of connectivity projects. Also, airport operators need to be proactive in explaining their point of view to the authorities in fixing tariffs for all regulated charges and charges such as user development fees.

AERA follows a 'fixed return on equity'-based model to determine tariffs. Under the current tariff model, the regulator has significantly reduced the risk for airport operators by accommodating under- and over-recoveries in revenues compared with pre-determined levels. These lower/higher revenues are adjusted (called as true ups) accordingly during the determination of tariff in subsequent control periods. AERA considers the following areas for true ups:

ix. Operating and maintenance expenses

x. Cost of debt, subject to a certain ceiling in interest rate

xi. Corporate taxes on aeronautical services

xii. Change in allocation mix of aeronautical and non-aeronautical assets for additions

xiii. Delay in tariff implementation

xiv. Change in mix of debt and equity

As per the National Civil Aviation Policy, 2016, all major airports operate under a 30% hybrid-till tariff model, where aggregate revenue requirement (ARR) from aeronautical activity is cross-subsidised with 30% revenue from non-aeronautical activities.

Aeronautical tariffs are set by AERA after considering the following:

xv. Weighted average cost of capital (WACC)

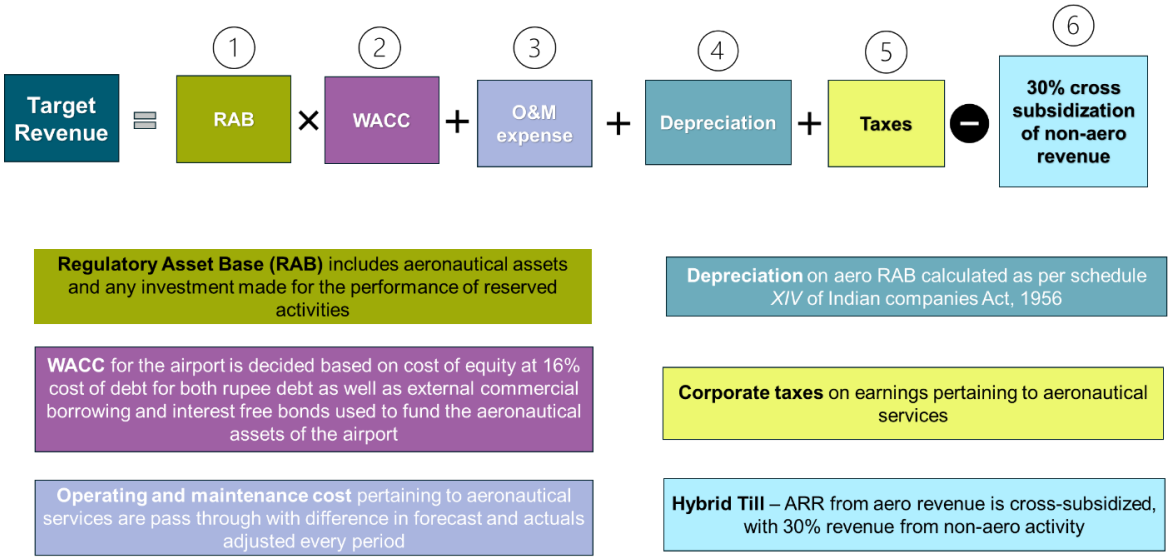
xvi. Project cost and means of finance

xvii. Regulatory asset base (RAB) on which returns will be calculated

xviii. Passenger traffic forecast for the next control period

xix. Aeronautical revenue over/under-recovery for the previous control period

Figure 71: Aggregate revenue requirement for an airport



Note: WACC is decided on cost of debt and cost of equity basis normalised debt-equity ratio
Source: Crisil Intelligence

AERA orders 30% hybrid till model for tariff setting

In the 30% hybrid till model, ARR from aeronautical revenue is cross-subsidised, with 30% of revenue from non-aeronautical activity.

Figure 72: Change in new bidding model

	New Model	Old Model
Bid parameter	Per passenger fee	Revenue share
ARR calculation	30% Hybrid Till	30% Hybrid Till
Return on Equity	Regulated: Fixed (16%)	Regulated: Fixed (16%)
Risk	Project risk, cash flow mismatch due to delay in true-up	Project risk, cash flow mismatch due to delay in true-up
Short comings	High bid impacting returns	Ambiguity in determining gross revenue
Advantages	Clarity due to fixed fee, faster settlement and increased sensitivity to non-aero revenue	

Source: Crisil Intelligence

Airports bid out (New Model)

- **Greenfield**
  - Jewar
  - Bhogapuram
- **Brownfield**
  - Ahmedabad
  - Mangaluru
  - Guwahati
  - Lucknow
  - Trivandrum
  - Jaipur

What remains the same?

Source: Crisil Intelligence

Table 11: Key revenue streams for airports

Aeronautical revenue	Non-aeronautical revenue
Landing charges	Retail – including duty free, lounges
Parking charges	Car park
Housing charges	Space rentals
User development fees	Food and beverages
Fuel farm	Advertising
X-ray baggage charges	Cargo
	Ground handling
	Others

Source: Crisil Intelligence

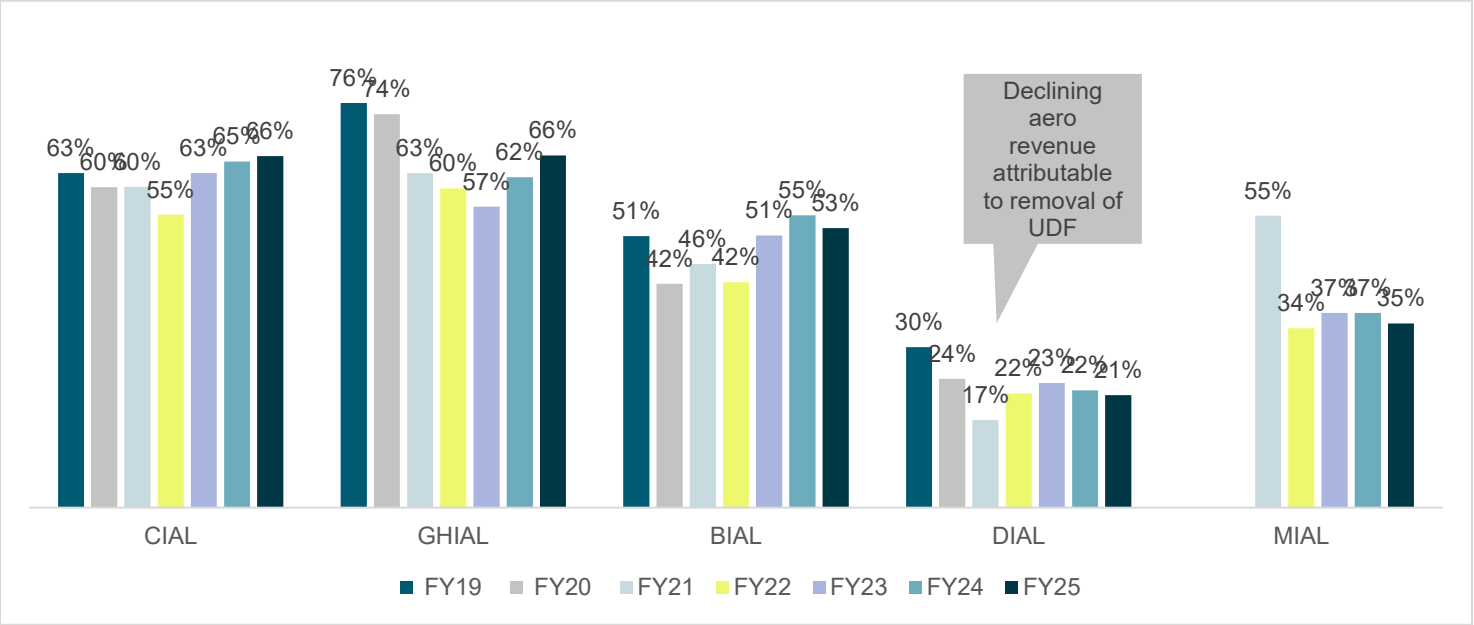
Aeronautical revenue

Aeronautical revenue is generated from an array of charges and fees that are levied on aircraft operators and passengers for airport facilities and services. Aeronautical charges are determined by the AERA for major airports, airports with annual passenger traffic of more than 3.5 million passengers or any other airport notified as major airport by the central government and also a group of airports notified by the central government.

- For aircraft operators – These charges are usually based on an aircraft weight formula and include landing, parking and housing charges

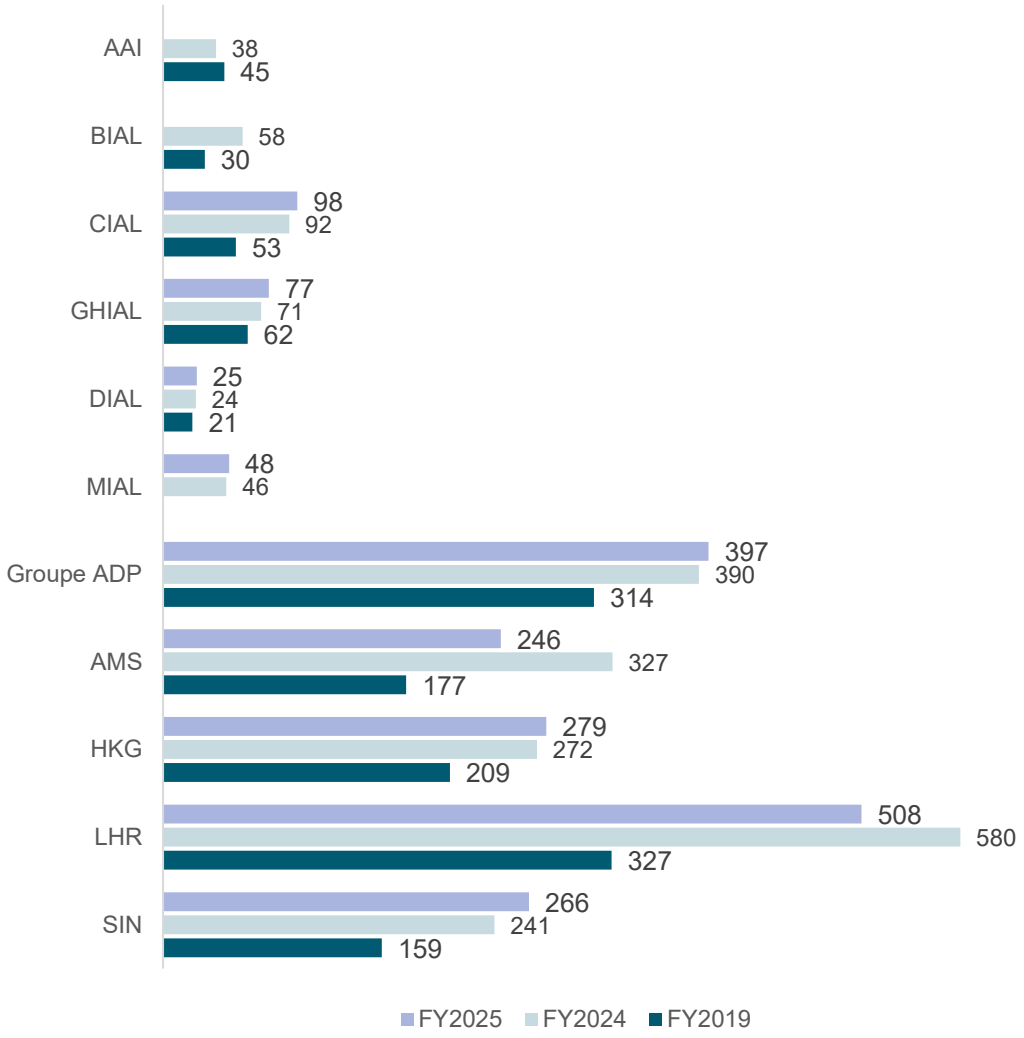
- For passengers – Collected by carriers for the airport, these include aviation security fee, user development fee and are accrued on a per passenger basis

Figure 73: Aeronautical revenue share across Indian airports



Note: 1. Data for GHIAL for FY19 and FY20 not comparable to earlier years due to discontinuation of Fuel through put charges and subsequent restating of non-aero revenues
2. MIAL- Aero / Non-aero revenue split prior to FY21 is not available
3. BIAL FY25 data is currently not available
Source: Company reports, Crisil Intelligence

Aero Revenue per ATM('000)



HKG: Hong Kong Airport; LHR: London Heathrow Airport; SIN: Singapore Airport; AMS: Amsterdam Airport; ADP: Paris Airports; DIAL: Delhi International Airport; GHIAL: Hyderabad International Airport; BIAL: Bangalore International Airport; MIAL: Mumbai International Airport; CIAL: Cochin International Airport; AAI: Airports Authority of India

Note: Data for all Indian airports and Asia Pacific airports is as of fiscal year. Remaining data is as of calendar year

MIAL- Aero / Non-aero revenue split prior to FY21 is not available

BIAL FY25 data is currently not available

Source: Company Reports and Crisil Intelligence

Non-aeronautical revenue

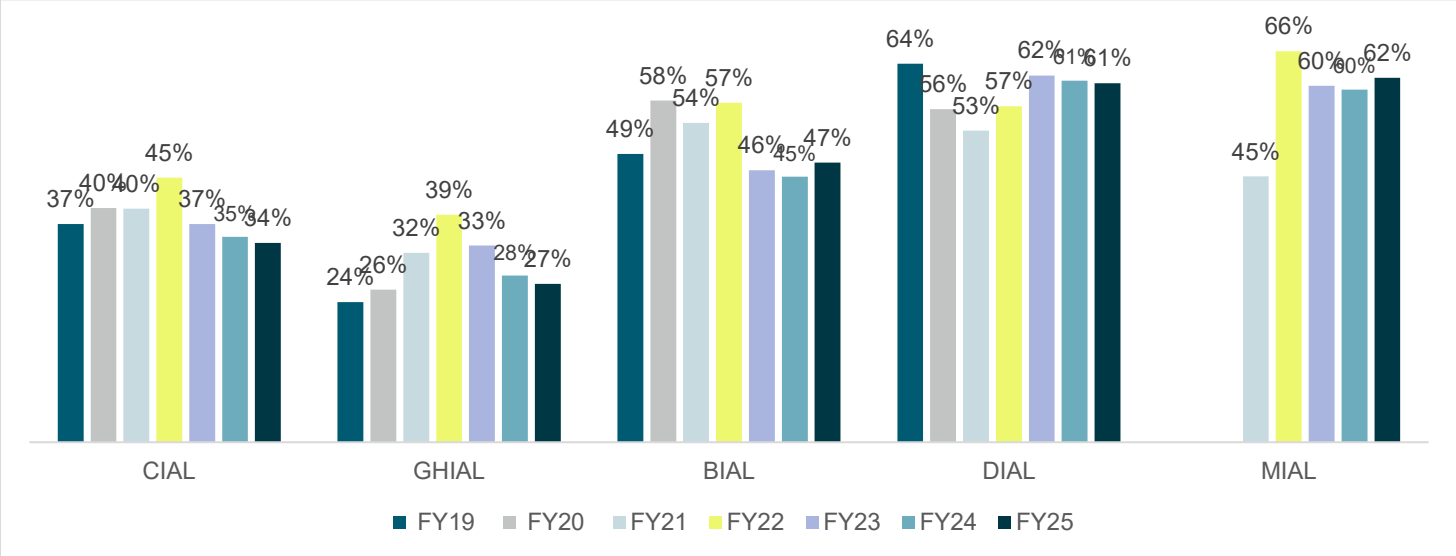
Non-aeronautical revenue collections play a significant role in the profitability of Indian airports as only 30% of non-aeronautical revenue is used to subsidise aeronautical revenue to arrive at the aggregate revenue requirement and airport operators have pricing freedom in non-aeronautical revenue heads.

Non-aeronautical revenue can be broadly divided into the following heads

1. Duty-free
2. Retail
3. Food and Beverages (F&B)
4. Advertisement
5. Space Rentals
6. Cargo
7. Ground Handling
8. Others

Others include car park, taxi, ground transportation, lounges, foreign exchange counters, banks, etc.

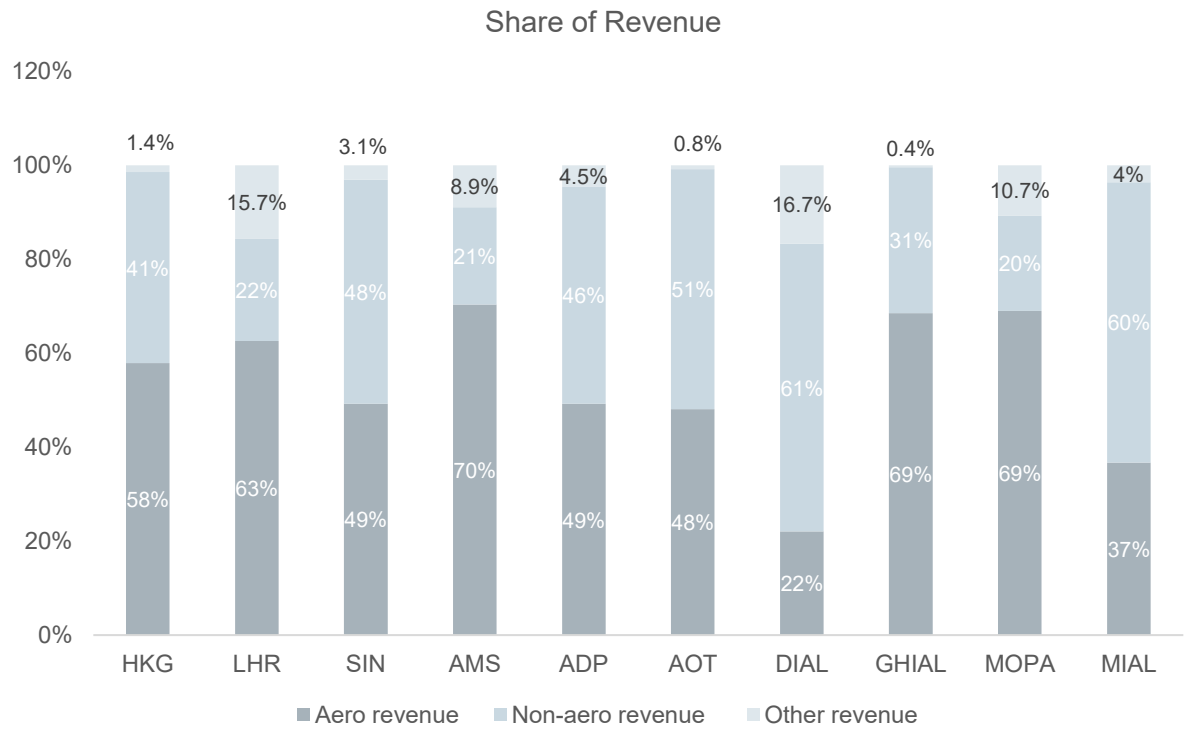
Figure 74: Non-aeronautical revenue contribution across Indian airports



Note: 1. Cargo and GH have been considered under non-aeronautical revenue across all airports
2. ANS and revenue share from PPP airports have not been considered
3. FY25 data for BIAL is not available
Source: Company reports, Crisil Intelligence

The contribution of non-aeronautical revenue heads for Indian airports is similar to global airports.

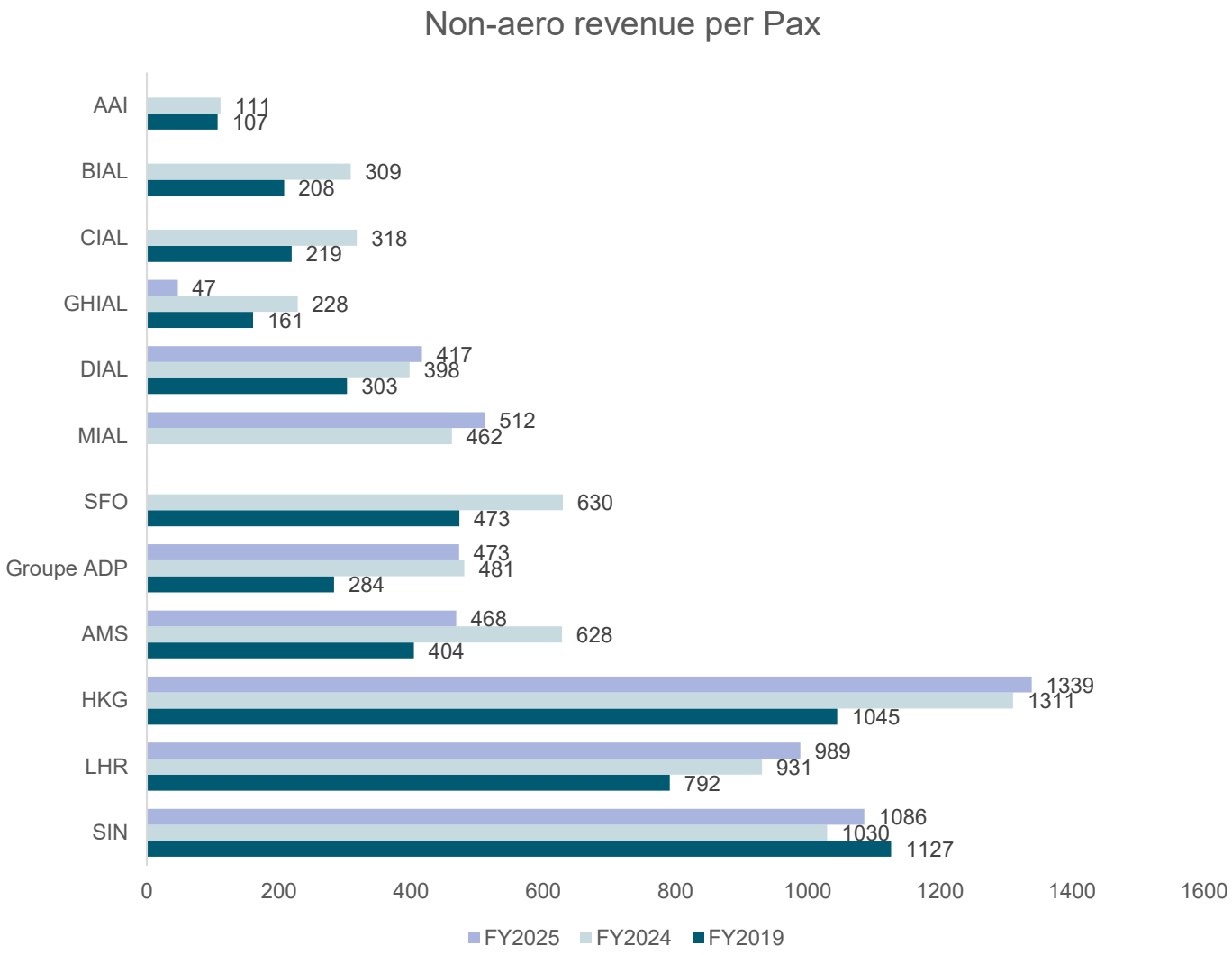
Figure 75: Revenue share comparison across Indian and global airports



Note: FY2024 considered for all airports;
HKG: Hong Kong Airport; LHR: London Heathrow Airport; SIN: Singapore Airport; AMS: Amsterdam Airport; ADP: Paris Airports;
AOT: Airports of Thailand, DIAL: Delhi Airport; GHIAL: Hyderabad Airport; MOPA: Goa Airport; MIAL: Mumbai Airport
Financial year 1st April -31st March – HKG, SIN, AOT, DIAL, GHIAL, MOPA, MIAL
Financial Year 1st Jan to 31st December – LHR, AMS, ADP
Source: Company reports, Crisil Intelligence

While the share of non-aeronautical revenue may be in line for Indian airports when compared with global airports, the difference in spending power per passenger is visible when comparing non-aeronautical spends per passenger.

Figure 76: Non-aeronautical revenue per passenger



SFO: San Francisco International Airport; HKG: Hong Kong Airport; LHR: London Heathrow Airport; SIN: Singapore Airport; AMS: Amsterdam Airport; ADP: Paris Airports; DIAL: Delhi International Airport; GHIAL: Hyderabad International Airport; BIAL: Bangalore International Airport; MIAL: Mumbai International Airport; CIAL: Cochin International Airport; AAI: Airports Authority of India

Note: Data for all Indian airports and Asia Pacific airports is as of fiscal year. Remaining data is as of calendar year

MIAL- Aero / Non-aero revenue split prior to FY21 is not available
BIAL FY25 data is currently not available

Source: Company Reports and Crisil Intelligence

Table 12: 4% growth in number of Non-Aero Stores opened at all airports which was 15% last year

Airport	Stores as on Mar-24	Stores as on Mar-25	Change in FY25 to 24	September 2025
MIAL	384	393	2%	444
AMD	107	138	29%	168
LKO	75	76	1%	85
IXE	57	63	11%	65
JAI	68	68	0%	68
GAU	79	73	-8%	68
TRV	93	84	-10%	83
Total	863	895	4%	981

In Non-Aero segment the growth can be accessed through growth in ATV and SPP which is the benchmark in determining the future growth of the segment. These ATV and SPP are increased by factors like Increase in passengers, number of stores and the area monetized for Non-Aero.

As on March 24, the Total area was 40,336 Sq mt which has increased by 17% to 47,091 sq mt in March 25, same as September 2025 Total area was 48,840 Sq mt increased by 4%.

The Non-Aero Segment Shows Strong operational growth with a 4% increase in stores between March 2024 and March 2025, reaching 981 stores by September 2025.

Table 13: The Average ATV and Area of the various segments for FY 2025 & Sep 25

Segment	ATV (INR) FY 2025	Area (In Sq Mt)	ATV (INR) Sep 2025	Area (In Sq Mt) Sep 2025
Retail	1,584	9,103	1,448	10,962
F&B	342	15,687	345	16,338
Services	4,452	2,171	3,742	3,028
Lounge	1,500	9,480	1,642	9,637
Duty paid	1,911	2,070	1,620	-

Duty Free	7,219	8,581	7,005	8,875
GTB - Arrival	148	-	-	-
Pranaam	2,308	-	2,806	-

3. City Side Development Business

Airports globally are evolving into business and retail hub, expanding beyond core air travel. Airports are increasingly developing commercial real estate/Aero cities to expand the addressable market and revenue potential. These developments focus on multiple uses ranging from hotels, convention centers, shopping malls, office spaces etc which are accessible to passengers and non-passengers of all age groups. Such developments enhance the overall airport revenue, and not just passenger driven income.

Examples include:

- Jewel Changi Airport is an example of a cityside development which has been successful in boosting non-aeronautical revenues despite the outbreak of COVID-19
- One more example of CSD is India is the Aerocity at IGI Airport which is developed as a “Smart and Sustainable Commercial District”. Aerocity is being planned to have a world class commercial zone with well-developed infrastructure, multi modal transit connectivity and mixed use of space, including an array of international brand hotels, retail spaces and Grade A office

Challenges faced by the aviation sector and airport operators

Airlines

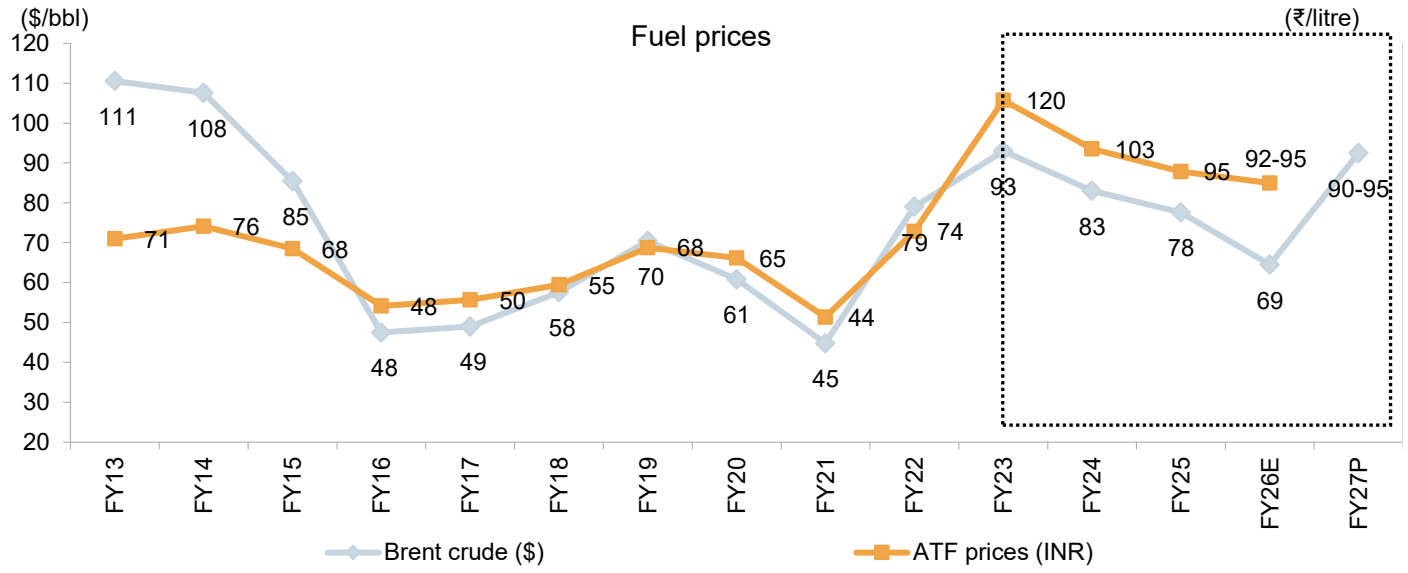
Aviation turbine fuel (ATF) accounts for 25-40% of an airlines cost base. Since fiscal 2023, ATF prices have been gradually decreasing from 120 in fiscal 2023 to 95 in fiscal 2025. However, due to the geopolitical volatility in the middle east crisis, it is seen to moving up in FY2027.

Airline profitability is inversely proportional to ATF rates.

The government has limited the pass-through of ATF price hikes for domestic scheduled carriers, capping increases to 25% for domestic routes to prevent severe financial strain.

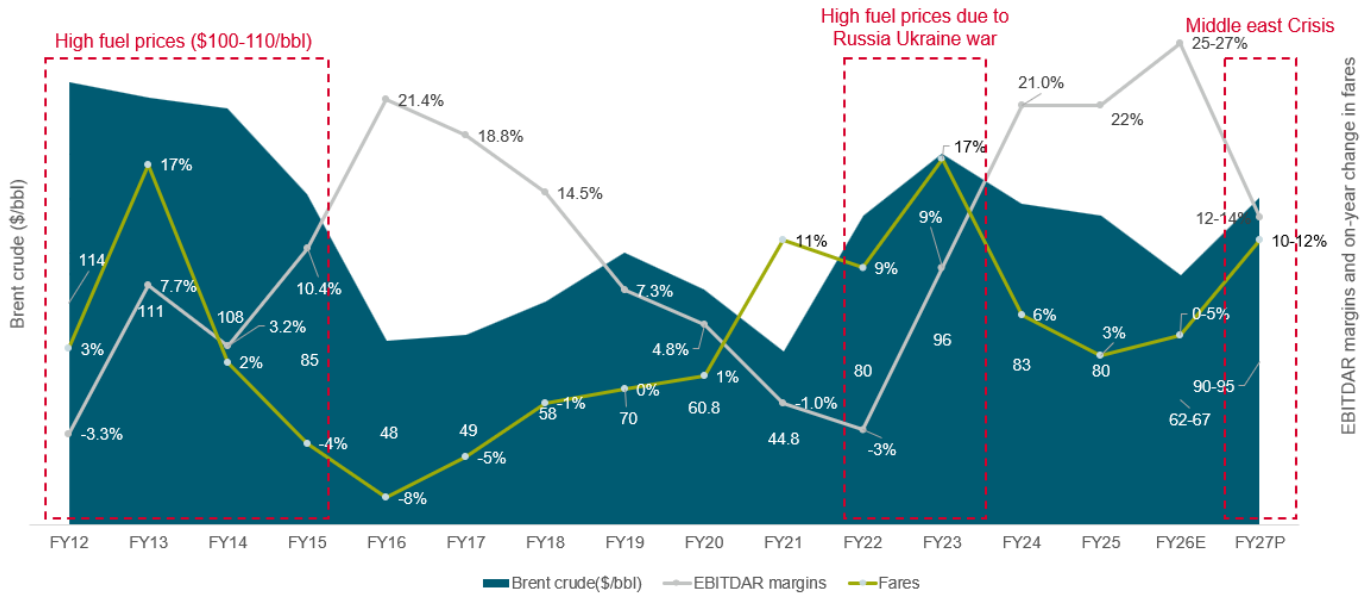
The Ministry of Civil Aviation and the Ministry of Petroleum and Natural Gas implemented the 25% cap to decouple the domestic aviation sector from extreme volatility in international oil markets. The cap applies exclusively to domestic routes. International carriers and non-scheduled operations are subject to the full brunt of global oil market spikes.

Figure 77: Annual change in ATF prices per litre



Note: Due to geopolitical volatility in the market, the there's no visibility on the ATF prices for FY27
Source: Crisil Intelligence

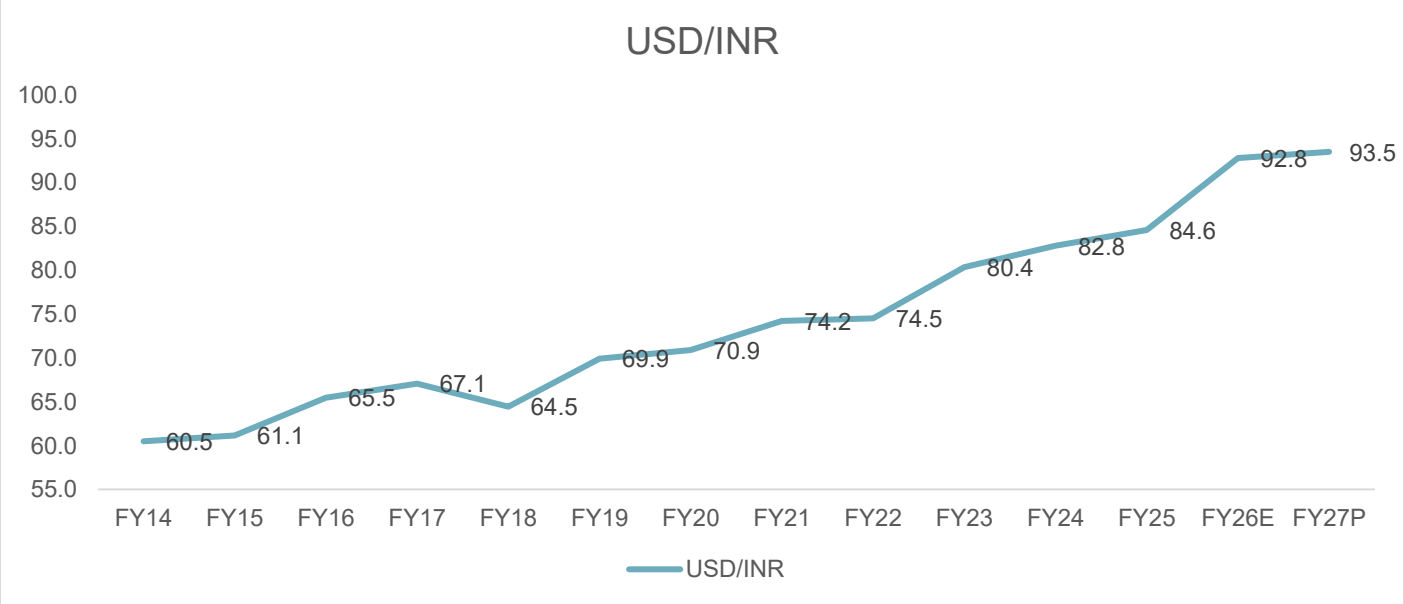
Figure 78: Higher fuel cost and adverse forex movement to weigh on operating margins



Note: P: Projected; E: Expected

Source: Company reports, Crisil Intelligence

Figure 79: Annual change in forex rates



Source: Crisil Intelligence

Crisil Intelligence expects the rupee to average 93.5 a dollar in March 2027 compared with 92.8 in March 2026 amid high volatility. The strengthening of the dollar will lead to an additional outgo for airlines further straining margins. The

rising dollar vs the rupee is a negative for airlines as nearly 70% of an airline's costs are dollar denominated. The Rupee is seen falling by 4% in fiscal 2026 over the level in fiscal 2025 which would affect margins for players.

Airlines have limited pricing power due to intense domestic competition from new entrants and high elastic demand.

In recent years, technical issues resulting in grounding of aircraft (for example, 737 Max, A320 neo engines and 787 engine issue) have impacted network planning and route deployment, leading to a shortfall in planned capacity. Airlines explore short-term leasing of aircraft from the secondary market often at higher rates to meet the shortfall, impacting profitability.

Airports

Government policies, competition and cash-flow mismatch are the key risk factors impacting profitability of the airport sector.

Airport operators face delays in tariff determination and passing of control orders by AERA, which leads to over/under-recovery of revenues and cash-flow mismatches.

Competition in the sector is growing with upcoming secondary airports, while establishment of new airports is also reducing the catchment area of an airport. The upcoming Jewar Airport would provide stiff competition to Delhi Airport with traffic likely to be weaned away by Jewar. Operationalisation of Kannur Airport adds added competition in the southern airports in Tamil Nadu and Kerala, while smaller AAI airports opening up under UDAN would wean away traffic from the larger established PPP airports.

The development of super expressways would also see some passenger and freight traffic shifting away from airlines.

There have been cost escalations at BOT airports compared with initial costs when they started their construction. However, AERA considers the project cost escalation in the tariff model determination provided it is not related to the delays on account of the concessionaire. Moreover, most of the difference in operating expenses is trued up based on such rise. On account of true ups, there is no impact on returns, but cash flows get impacted.

Change in government policy

Change in the government’s stance on the model of operation for airports will impact profitability of airports as it will change the regulated and unregulated part of revenue.

Earlier, airports in India operated on a single- or hybrid-till model. During allocation of four PPP airports, Delhi and Mumbai airports were offered under a 30% hybrid-till model; Bengaluru under a 40% hybrid-till model; and Hyderabad under a single-till model.

As per the National Civil Aviation Policy, 2016, the government has standardised the 30% hybrid-till model across all major airports in India.

Delays in land monetisation

Typically, non-aeronautical revenue accounts for 30-40% of the total revenue depending on various factors. During allocation of airports under the PPP model, the government earmarked certain areas of land for commercialisation by airports. The earnings were unregulated. However, there has been a significant delay in monetising land, impacting the overall return generated by airports. For instance, in the case of DIAL, about 55% of the land has been monetised to date. For GHIAL, about 6% of the land has been monetised to date, while in the case of MIAL, only 3% has been monetised so far. No land has been monetised to date in the case of BIAL.

Short-term cash-flow mismatch due to delays in true-ups

AERA has defined control period as a period of five years to determine tariffs based on actual financials vis-à-vis projected financials. Most of the regulated revenue for airports is subject to a true-up based on the shortfall or excess collections compared with forecast revenue for that period. This true-up is considered to determine the tariff for future control period.

Risks such as fall in passenger traffic below forecasts, discontinuance of airline operations, change in hub airports and cost overruns (which are beyond the control of management) are considered in the true-up. However, the true-up is done on a five-year basis during the determination of tariffs. This can lead to a mismatch in cash flows for airports during intermittent periods based on the level of over/under-recovery in revenue during the previous control period, expansions planned and passenger traffic.

Airport Name	Control period		Effective date of tariff order
Bangalore International Airport	3rd Control	01.04.2021 - 31.03.2026	22 June, 2021
Delhi International Airport	4th Control	01.04.2024 - 31.03.2029	31 January, 2025
Mumbai International Airport	4th Control	01.04.2024 - 31.03.2029	10 March, 2025
Cochin International Airport	3rd Control	01.04.2021 - 31.03.2026	15 June, 2021
Hyderabad International Airport	3rd Control	01.04.2021 - 31.03.2026	02 July, 2021
Ahmedabad International Airport	3rd Control	01.04.2021 - 31.03.2026	20 October, 2022
Jaipur International Airport	3rd Control	01.04.2022 - 31.03.2027	11 March, 2024
Guwahati International Airport	3rd Control	01.04.2022 - 31.03.2027	06 June, 2024
Thiruvananthapuram International Airport	3rd Control	01.04.2022 - 31.03.2027	12 February, 2024
Mangalore International Airport	1st control	01.04.2021 - 31.03.2026	05 August, 2022
Lucknow International Airport	3rd Control	01.04.2021 - 31.03.2026	20 February,2023

Source: AERA, Crisil Intelligence

Current trends in competition — airport infrastructure

Multiple airport systems

Professor Richard de Neufville of MIT, a world leader in airport systems, defines a multi-airport system (MAS) as “a set of two or more significant airports that serve commercial traffic within a metropolitan region.” Multiple airport systems are critical when the sole airport serving a catchment area has reached its capacity and is unable to expand. In the absence of a second airport, the city would see diversion of air traffic to neighbouring airports and would lose the opportunity to provide better connectivity to its passengers.

Different airports in a city are meant to cater to different kinds of passengers. Globally, LCCs were able to bloom because of their ability to fly to secondary airports — these were typically no-frills airports and had lower airport charges than primary airports, which served as a transit hub and a full-service carrier base. Airlines were able to pass on lower charges to passengers. However, in India, no multi-airport systems exist as of now. As aviation traffic grows over the next decade, many cities in India may see a move towards multiple airports. Such plans have already been announced in at least three cities, viz. NCR, Mumbai and Goa, where we expect to have two airports operational by fiscal 2026. Goa may be an outlier given that one of the airports is a defence airport. However, apart from Delhi and Mumbai, it is likely that other metro cities such as Bangalore and Chennai may see demand for more than one airport, similar to global examples such as London, Istanbul and New York.

London, for example, is served by five airports: Heathrow, London City, Gatwick, Stanstead and Luton. Heathrow is the base of British Airways and is home to foreign carriers and facilitates both originating and transit traffic. London City,

despite being the smallest airport, has the highest percentage of business travellers, who value its in-city location, compact size, speedy processing and maximum productivity. Gatwick is the home to ultra-low-cost carriers such as EasyJet and has the lowest percentage of business passengers. Stanstead is home to ultra-low-cost Ryanair, while Luton caters to those living in the north-west suburbs around London. The same person may choose to use London City for a European business trip, Heathrow for a trans-continental business trip, and Gatwick or Stanstead for a family vacation. Similarly, airlines tend to offer flights from Gatwick to primarily leisure destinations, and from Heathrow to business destinations. Even in the economically bracketed BRIC (Brazil, Russia, India and China), similar patterns are observed. Shanghai's distant airport, Pudong, caters to international flights, and in-city airport, Hongqiao, flies domestic and regional routes. In the Brazilian capital, Sao Paulo, in-city Congo has catered to domestic flights, while out-of-city Guarulhos handles all the international traffic and some domestic connections. Similarly, New York-Newark, San Francisco, Los Angeles, Chicago, Dallas Fort Worth, Bangkok, Tokyo, Osaka and others operate multi-airport systems — fostering competition and enabling choice and affordability for their citizens.

Brief on institutional framework (AERA regulations) for aviation sector by the central government

Airports Economic Regulatory Authority (AERA) Regulator for tariff fixation

AERA is a statutory body constituted under the Airports Economic Regulatory Authority of India Act, 2008, notified vide a gazette notification dated December 5, 2008. AERA was established by the government in 2009 and is headquartered in New Delhi.

Key functions

- To determine tariff for aeronautical services
- To determine development fees to be charged at major airports
- To determine passengers service fees to be levied
- To monitor set performance standards in airports relating to quality, continuity and reliability of service, as may be specified by the government or any authority authorised by it in this regard
- To perform such other functions relating to tariff structures for airport operators, as may be entrusted to it by the government or as may be necessary to carry out the provisions of this Act

Powers of AERA

- Penalise airports for failure to comply with its orders and directions of the AERA Act
- Penalise for offences by government departments
- Appeals in the AERA's rulings can be filed only in the Supreme Court
- AERA has been constituted to fix, review and approve the tariff structure for aeronautical services, and monitor pre-set performance standards at Indian airports, but with no regulation over army and paramilitary airports
- The prime objective of AERA is to create a level-playing field and foster healthy competition among all major airports, encourage investment for building greenfield airports, protect reasonable interest of fliers, and operate efficient, economic and viable airports.

Overview of the MRO industry

The Maintenance, Repair, and Overhaul (MRO) industry is a critical component of the global aviation sector, providing essential services to ensure the airworthiness and safety of aircraft. MRO involves a range of activities, including routine maintenance, repairs, and modifications to aircraft, engines, and components. The industry plays a vital role in maintaining the efficiency, reliability, and safety of aircraft operations, thereby supporting the growth of the aviation sector as a whole.

The global MRO industry is driven by factors such as the increasing demand for air travel, the growing fleet of aircraft, and the need for regular maintenance to ensure compliance with regulatory requirements. The industry is highly competitive, with many players operating globally, including original equipment manufacturers (OEMs), independent MRO providers, and airlines' in-house maintenance facilities.

The MRO industry can be broadly categorized into several segments, including:

1. **Airframe MRO**: Maintenance and repair of aircraft structures, including fuselage, wings, and control surfaces.
2. **Engine MRO**: Maintenance and repair of aircraft engines, including engine overhauls and component repairs.
3. **Component MRO**: Maintenance and repair of aircraft components, such as avionics, electrical, and hydraulic systems.
4. **Line Maintenance**: Routine maintenance activities, such as daily checks, performed on aircraft while they are still in service.

The global MRO industry is expected to grow significantly in the coming years, driven by the increasing demand for air travel and the need for regular maintenance to ensure safety and efficiency.

Indian MRO Industry

The Indian MRO industry has been growing rapidly in recent years, driven by the country's growing aviation sector and the government's efforts to promote the industry. Indian carriers used to use global MRO hubs/players for the repair and maintenance of aircraft due to a limited fleet size, lack of skilled manpower, equipment and dedicated MRO players. However, post policy tweaks by the government, MRO players in India are growing and offering expanded services to both domestic and international airlines.

The Indian aviation sector has been experiencing rapid growth in recent years, driven by increasing demand for air travel and the government's efforts to promote the industry. The growing fleet of aircraft in Indian airspace has significant implications for the MRO industry, as airlines require regular maintenance and repair services to ensure the airworthiness and safety of their aircraft.

The Indian MRO industry is driven by factors such as:

Figure 80: India leads global aircraft buying spree with unprecedent orders

Pending deliveries by airlines		
Airline/Manufacturer	Airbus	Boeing
Indigo	905	-
Air India group	344	169
Akasa	-	195
SpiceJet	-	129

Manufacturer	Order book	Deliveries
Airbus	1897	567
Boeing	601	108

Source: DGCA, Crisil Intelligence

Note: Order update as of January 2026

With India's fleet expected to triple in the medium to long term, the demand for local MRO services has gone up as it aids airlines in reducing time and also saves forex.

Maintenance cost as a share of total cost has gone up from 6% in FY19 to 16% in FY24. As the number of aircraft in the country increases, the demand for maintenance and repair services will also rise. This will create new opportunities for Indian MRO providers, including:

1. **Increased Demand for Maintenance Services**: The growing fleet of aircraft will require regular maintenance and repair services, driving demand for MRO services.
2. **New Business Opportunities**: The influx of new aircraft will create opportunities for Indian MRO providers to offer specialized services, such as aircraft painting, interior refurbishment, and avionics upgrades.
3. **Investment in Infrastructure**: The growth of the MRO industry will require investment in infrastructure, including hangars, workshops, and testing facilities, creating new opportunities for investors and entrepreneurs.
4. **Job Creation**: The expansion of the MRO industry will create new job opportunities for skilled technicians, engineers, and other professionals, contributing to the growth of the Indian economy.

The massive aircraft orders placed by Indian airlines will have a profound impact on the Indian MRO industry, driving growth and creating new opportunities. As the Indian aviation sector continues to expand, the demand for MRO services will increase, making India an attractive destination for MRO providers and investors. With the right infrastructure, skilled workforce, and regulatory framework, India is poised to become a major hub for MRO services in the region.

Adani portfolio - Airports

Adani Enterprises won the mandate to modernise and operate six airports — Ahmedabad, Lucknow, Mangaluru, Jaipur, Guwahati and Thiruvananthapuram — through the AAI's globally competitive tendering process. Adani Enterprises also

acquired MIAL in 2021 and thereby won the contract for Navi Mumbai International Airport, a greenfield international airport project. As of 31 March, 2026, its portfolio comprises seven operational airports and one greenfield international airport inaugurated on 08.10.2025. The company has emerged as the largest private operator of airports based on the number of airports. Airports under Adani Enterprises serviced 95.3 million passengers, 619 thousand air traffic movements and 1.16 million tonnes of cargo across airports in fiscal 2026.

Table 14: Comparison by market share with other private airport operators

The Adani Enterprises owned airports rank second across operational parameters among PPP/ JVC airports.

FY26	Adani Enterprises	GMR Group	BIAL
Passenger	22.7%	27.3%	10.6%
ATM	21.3%	24.8%	9.6%
Cargo	29.3%	33.7%	13.3%

Source: AAI, Crisil Intelligence

The following table gives the ranking of the 8 operational airports under AEL across passenger traffic, freight traffic and aircraft movement.

Table 15: Positioning of Adani Airports holding limited airports on passenger traffic across years

Pax traffic (domestic + International)	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-2026
Mumbai								
in million	48.8	45.9	11.1	21.7	43.9	52.8	55.1	55.3
Rank	2	2	2	2	2	2	2	2
Ahmedabad								
in million	11.2	11.4	3.6	5.7	10.1	11.7	13.4	13.8
Rank	7	7	7	7	7	7	7	7
Lucknow								
in million	5.5	5.4	2.4	3.3	5.2	6.2	6.4	6.1
Rank	12	12	11	11	11	11	11	12
Mangalore								
in million	2.2	1.9	0.6	1	1.8	2	2.3	2.5
Rank	27	29	31	31	29	30	30	30
Jaipur								
in million	5.5	5	1.9	2.9	4.8	5.5	6.1	5.6
Rank	13	13	14	15	13	13	13	13
Guwahati								
in million	5.7	5.5	2.2	3.1	5.1	6	6.2	6.9
Rank	11	11	12	13	12	12	12	10
Trivandrum								
in million	4.4	3.9	0.9	1.7	3.5	4.4	4.9	4.7
Rank	14	15	24	22	18	16	14	16
Navi Mumbai								
in million								0.8
Rank								54

Note: Rank is based on pan-India airports

Ahmedabad Airport is the seventh largest airport in India in terms of passenger traffic, air traffic movement and freight traffic as of March 31, 2026. The Chhatrapati Shivaji Maharaj International Airport ("Mumbai Airport") is the second largest airport in India in terms of passenger traffic, air traffic movement and freight traffic as of March 31, 2026.

Source: AAI, Crisil Intelligence

Table 16: Positioning of Adani Airports holding limited airports on freight traffic across years

Freight traffic (domestic + International)	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26
Mumbai								
in Tons	963460	863782	592966	770953	776934	822977	889900	927499
Rank	2	2	2	2	2	2	2	2
Ahmedabad								
in Tons	101731	103741	60749	90634	92337	106905	103051	126188
Rank	7	7	7	7	7	7	7	7
Lucknow								
in Tons	6111	14882	9968	14942	15840	20983	22102	22566
Rank	24	14	14	12	13	10	12	12
Mangalore								
in Tons	3287	4605	2186	3521	3815	2174	2213	2414
Rank	32	31	34	32	34	39	39	40
Jaipur								
in Tons	18513	17499	12204	14180	16441	19420	21762	28039
Rank	12	13	12	13	12	11	13	11
Guwahati								
in Tons	23840	21270	15951	21858	22823	18851	26607	30164
Rank	11	12	10	10	10	12	10	10
Trivandrum								
in Tons	25167	25511	14799	16579	16722	18392	22913	20775
Rank	10	11	11	11	11	13	11	13
Navi Mumbai								
in Tons								561
Rank								53

Note: Rank is based on pan-India airports
Source: AAI, Crisil Intelligence

Table 17: Positioning of Adani Airports holding limited airports on air traffic movement across years

Air traffic movements (Domestic + International)	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-2026
Mumbai								
in Numbers	321263	304675	115864	186186	290387	324986	330063	331756
Rank	2	2	2	2	2	2	2	2
Ahmedabad								
in Numbers	78412	84577	40209	51157	80026	87025	101119	103475
Rank	7	7	7	7	7	7	7	7
Lucknow								
in Numbers	41752	38494	22954	30005	42276	45549	49662	40276
Rank	13	13	10	12	12	11	10	13
Mangalore								
in Numbers	19365	15685	6664	9980	14382	15042	16763	17923
Rank	25	32	34	34	34	33	34	34
Jaipur								
in Numbers	46185	39484	18933	27157	41156	44863	48407	43451
Rank	12	12	14	13	13	12	11	12
Guwahati								
in Numbers	50488	45539	23442	33572	45909	46148	45984	47439
Rank	11	11	9	10	11	10	12	10
Trivandrum								
in Numbers	33093	28842	9313	15356	11905	30141	31798	30018
Rank	14	15	24	22	19	16	17	19
Navi Mumbai								
in Numbers								4501
Rank								61

Note: Rank is based on pan-India airports
Source: AAI, Crisil Intelligence

Table 18: ASQ ratings before acquisition and post acquisition of airports

Airport name	Pre-acquisition (March 2020)	**Post-acquisition ASQ Rating (January – March 2026)**
Ahmedabad	4.87	4.99

Mangalore	4.75	4.98
Lucknow	4.92	5
Jaipur	4.47	5
Guwahati	4.9	4.9
Trivandrum	4.95	4.93
Mumbai	4.98	5
Navi Mumbai		4.9

Source: ACI World, Crisil Intelligence

Module 7: Roads

Review of roads infrastructure in India

Road sectors contribution to India's GDP

India boasts the second-largest road network globally, covering approximately 6.3 Mn kilometres (km) as of March 2026.This extensive network serves as the backbone of the country's transportation system, facilitating the movement of 71% of freight and 90% of passenger traffic. Over the past several years, the road sector has attracted the highest investments among infrastructure segments, driven by innovative financing models such as the Hybrid Annuity Model (HAM). Given its success, HAM is now being adapted for other infrastructure sectors like ports and water treatment plants, enhancing their viability and investment appeal. Build-Operate-Transfer (BOT) projects are also expected to play a crucial role in attracting private investments, allowing developers to recover costs through toll collection over a fixed concession period. Moreover, the road sector has led the way in asset monetization, generating significant revenue through toll-operate-transfer (TOT) models and infrastructure investment trusts (InvITs), further reinforcing its position as a key driver of economic growth and infrastructure development. Additionally, reforms in concession agreements—such as improved risk allocation, longer concession periods, and revenue-sharing models—have enhanced investor confidence. The widespread adoption of electronic toll collection systems like FASTag has further improved revenue predictability and reduced leakages, making road projects more financially viable. These advancements, coupled with streamlined regulatory frameworks and increased government support, have collectively contributed to the sector's attractiveness for both domestic and international investors.

Figure 81: Existing roads network across India

Road classification	Length (in Km)
National Highways	1,46,572
State Highways	1,79,535
Rural and other roads	60,48,260
TOTAL:	**63,74,367**

Note: State highways length is as of March 2025, national highways and rural and other roads length are as of March 2026
Source: PIB, Crisil Intelligence

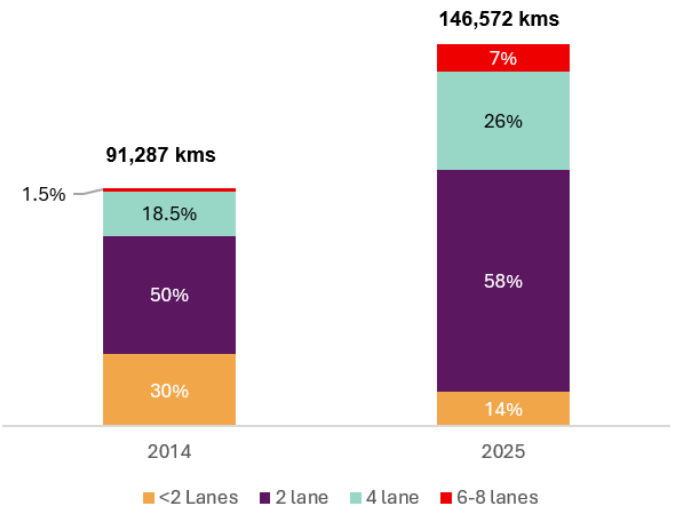
- National Highways (NHs) – These highways form the primary road network, connecting major cities, ports, industrial hubs, and state capitals. Managed by the National Highways Authority of India (NHAI) and the Ministry of Road Transport and Highways (MoRTH), NHs are developed through public funding, Public-Private Partnerships (PPP), and foreign investments. Key programs such as Bharatmala pariyojana Pariyojana and the National Highways Development Project (NHDP) have played a crucial role in expanding and modernizing NHs.

- State Highways (SHs) – These highways connect state capitals with district headquarters, major towns, and economic zones. SHs are primarily maintained by state governments, with funding sourced from state budgets, central assistance, and infrastructure bonds. Some states have also adopted PPP models to upgrade and maintain high-traffic corridors.

- Rural Roads – These roads ensure last-mile connectivity, linking villages to nearby towns and urban centres. The Pradhan Mantri Gram Sadak Yojana (PMGSY), launched by the central government, has been instrumental in constructing and upgrading rural roads, with funding shared between the central and state governments.

This vast and expanding network not only facilitates efficient transportation of goods and services but also serves as a catalyst for employment, manufacturing, and regional development. Over the past decade, the length of national highways has grown by 60%, rising from 91,287 km in 2014 to 1,46,572 km. Notably, the development of four-lane and above national highways has increased more than 2.5 times, reaching approximately 48,000 km, significantly improving connectivity and logistics efficiency.

Figure 82: National highways witness significant expansion in last decade



Source: MoRTH, Crisil Intelligence

Recognising the crucial role of road infrastructure in economic growth, the Indian government has placed heavy emphasis on expanding and modernizing the road network to reduce logistics costs, which currently account for 7.97% as per latest estimates. Key initiatives such as expressway development to enhance connectivity and development of multi-modal logistics parks (MMLP) to support freight aggregation and distribution have resulted in reducing logistics cost, time and traffic congestion. Further implementation of technology-driven tolling systems like FASTag and proposed implementation of Global navigation satellite system (GNSS)-based tolling will minimize leakages in toll collection and

reduce waiting time at toll plazas. GST implementation resulted in abolishment of octroi posts thereby reducing transportation costs. By focusing on seamless connectivity between industrial corridors, ports, and economic zones, the government aims to boost trade competitiveness, attract private investments, and enhance supply chain efficiency, positioning India as a global manufacturing and logistics hub.

Institutional framework for roads at central level & for specific states

Road infrastructure is governed by a multi-tiered institutional framework that delineates responsibilities between the central and state governments. This framework ensures a coordinated approach to road development, maintenance, and policy implementation across the country.

Central-level institutions

At the national level, the Ministry of Road Transport and Highways (MoRTH) serve as the nodal authority responsible for formulating policies, overseeing the planning and development of the road sector, and allocating central funds. MoRTH plays a pivotal role in setting technical standards and ensuring uniformity in road construction and safety norms across the country.

Working under the administrative control of MoRTH is the National Highways Authority of India (NHAI), established under the NHAI Act of 1988. NHAI is the primary agency responsible for the development, maintenance, and management of National Highways entrusted to it. It is also the implementation authority for major highway development programmes such as Bharatmala Pariyojana and the National Highways Development Project (NHDP). While MoRTH retains policymaking and funding responsibilities, NHAI operates as the executing arm, handling tendering, contracting, and project monitoring.

Additionally, other central institutions like the National Highways and Infrastructure Development Corporation Limited (NHIDCL) focus on highway development in strategic and remote regions, particularly in the Northeast, hilly, and border states.

State-level institutions

At the state level, the responsibility for developing, maintaining, and upgrading State Highways, Major District Roads, and rural roads lies with the respective State Public Works Departments (PWDs) or specially constituted road development authorities. These agencies operate under the administrative control of the state governments and are funded through state budgets, central assistance, and institutional financing.

Each state has its own institutional mechanisms to manage road infrastructure. For instance:

- Maharashtra State Road Development Corporation (MSRDC) plays a key role in executing large-scale highway and expressway projects in Maharashtra.
- Tamil Nadu Road Infrastructure Development Corporation (TNRIDC) supports the state's PWD in developing key road corridors and industrial connectivity.
- Uttar Pradesh State Highways Authority (UPSHA) is responsible for the development and maintenance of high-capacity state highways through public-private partnership models.
- Karnataka Road Development Corporation Limited (KRDCL) undertakes state highway and bridge development in Karnataka, supplementing the work of the state's PWD.

These institutions often collaborate with central agencies for co-funded projects or projects of national importance traversing multiple states. They also act as key stakeholders in implementing centrally sponsored schemes such as the Pradhan Mantri Gram Sadak Yojana (PMGSY) for rural roads.

Share of roads in Indian freight traffic

Logistics plays a crucial role in the smooth functioning of an economy, facilitating the flow of goods and services from raw materials to end customers. Efficient logistics management is essential for businesses to remain competitive, reduce costs, and improve customer satisfaction. In today's fast-paced and interconnected world, logistics has become a key differentiator for companies seeking to gain a competitive edge.

- Economic growth - Logistics is a significant contributor to a country's GDP, creating jobs, and stimulating economic growth. According to the World Bank, the logistics industry accounts for around 10-15% of a country's GDP. The growth of the logistics industry has a direct impact on the overall economy, driving economic development and prosperity.
- Supply chain efficiency - Logistics ensures the timely and cost-effective movement of goods, reducing inventory costs, and improving supply chain efficiency. By streamlining logistics operations, businesses can reduce transportation costs, minimize inventory holding costs, and improve delivery times. This, in turn, enables companies to respond quickly to changing market demands, improving their overall competitiveness.
- Competitiveness - Businesses with efficient logistics systems can respond quickly to changing market demands, gaining a competitive edge over rivals. In today's fast-paced business environment, companies need to be agile and responsive to customer needs. Logistics enables businesses to do just that, providing them with the flexibility to adapt to changing market conditions and customer preferences.
- Customer satisfaction - Logistics enables businesses to deliver products to customers quickly and reliably, leading to increased customer satisfaction and loyalty. In today's digital age, customers expect fast and convenient delivery options. Logistics plays a critical role in meeting these expectations, ensuring that products are delivered on time and in good condition.
- Reduced costs - Effective logistics management helps reduce transportation costs, inventory costs, and other related expenses. By optimizing logistics operations, businesses can reduce waste, minimize inefficiencies, and lower their overall costs. This, in turn, enables companies to invest in other areas of their business, driving growth and innovation.
- Increased productivity - Logistics automation and technology enable businesses to process orders faster, reducing labor costs and increasing productivity. The use of automation and technology in logistics has revolutionized the industry, enabling businesses to process orders quickly and efficiently. This, in turn, has led to increased productivity, reduced labor costs, and improved customer satisfaction.
- Improved inventory management - Logistics helps businesses maintain optimal inventory levels, reducing stockouts and overstocking. By optimizing inventory levels, businesses can reduce waste, minimize inventory holding costs, and improve their overall supply chain efficiency.
- Enhanced visibility - Logistics provides real-time visibility into the supply chain, enabling businesses to track shipments, manage inventory, and respond to disruptions. The use of technology and data analytics in logistics has provided businesses with real-time visibility into their supply chain operations. This, in turn, has enabled companies to respond quickly to disruptions, improve their supply chain efficiency, and reduce costs.
- Risk management - Logistics helps businesses mitigate risks associated with supply chain disruptions, natural disasters, and other unforeseen events. The use of logistics management systems enables businesses to identify

potential risks, develop contingency plans, and respond quickly to disruptions. This, in turn, has helped companies minimize the impact of disruptions, reduce costs, and improve their overall supply chain resilience.

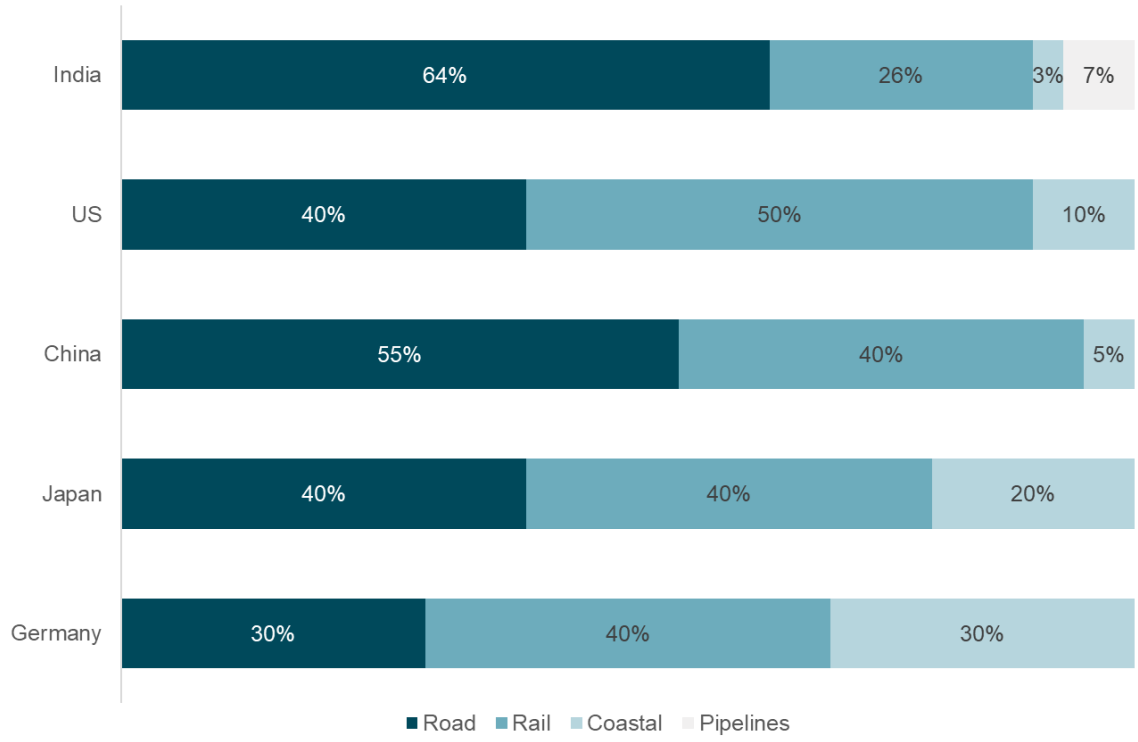
- Environmental sustainability - Efficient logistics management can reduce carbon emissions, minimize waste, and promote sustainable practices. The logistics industry is a significant contributor to greenhouse gas emissions, with transportation accounting for around 10% of global emissions. However, by optimizing logistics operations, businesses can reduce their carbon footprint, minimize waste, and promote sustainable practices.

Factors influencing modal split

The modal split is influenced by the type of goods, the value of goods as well as expected timeline for transit. This plays a critical role in modal choice and thereby modal share. The modal split of goods movement is also influenced by a range of factors, including infrastructure, geography, and economic development. Infrastructure, such as road and rail network, plays a critical role in determining the modal split. Geography, including terrain and climate, also influences the modal split, with certain modes being more suitable for certain regions. Economic development, including trade patterns and industrialization, also plays a role in shaping the modal split.

The modal split of goods movement is a complex and dynamic phenomenon, influenced by a range of factors, including infrastructure, geography, and economic development. Understanding the modal split is essential for policymakers, businesses, and logistics providers, as it can inform investments in infrastructure, logistics strategies, and environmental policies. By recognizing the strengths and weaknesses of each mode, economies can optimize their transportation systems, improving efficiency, reducing costs, and minimizing environmental impacts.

Figure 83: Global modal share

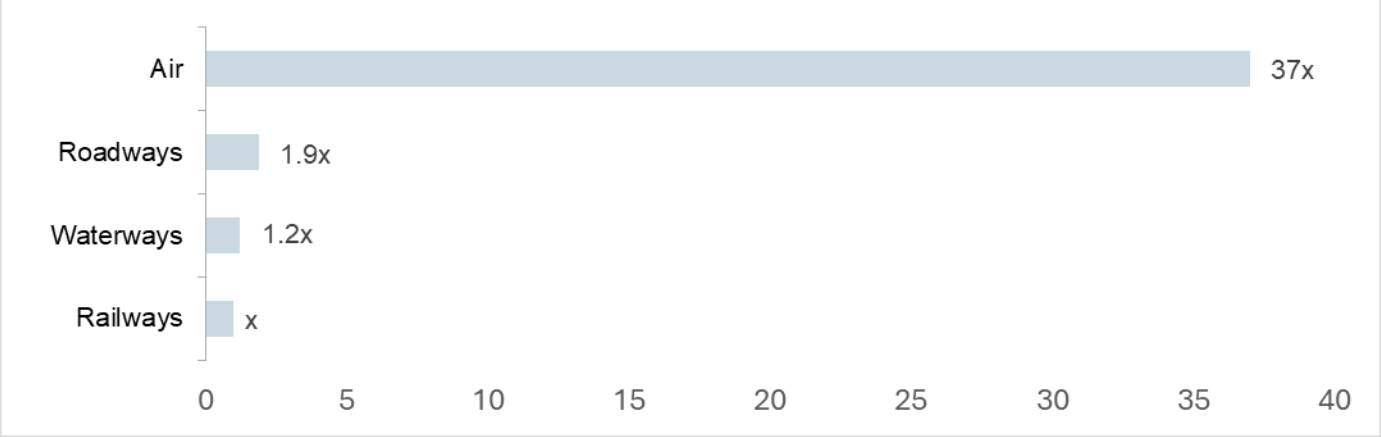


Note: The above chart represents comparison between roads, rail and coastal only (pipelines are not included for the global comparison)
Source: Industry, Crisil Intelligence

India's domestic freight transport system is heavily reliant on road transport, which accounts for around 64% of the modal share, followed by railways at 26%, and the rest covered by coastal shipping and pipelines. This contrasts sharply with countries like Germany, the United States, China, and Japan, where the share of road transport is significantly lower, and railways play a more prominent role in freight movement. For instance, railways account for approximately 50% of freight transport in the U.S. and 40% in China. This greater reliance on railways in these countries is due to their efficiency in handling bulk commodities over long distances at a lower cost compared to road transport.

Road transport, while flexible, is often more expensive due to higher fuel consumption, maintenance costs, and congestion on highways. Additionally, India's road infrastructure faces challenges like poor quality in rural areas, which further inflates costs. In contrast, rail and coastal modes are more cost-efficient, especially for bulk goods, offering economies of scale and reducing overall logistics expenses. This disparity in modal share and cost structure underlines the need for India to diversify its freight transport mix towards more cost-effective rail and coastal shipping solutions to enhance its logistics competitiveness globally.

Figure 84: Freight rate comparison



Source: Industry, Crisil Intelligence

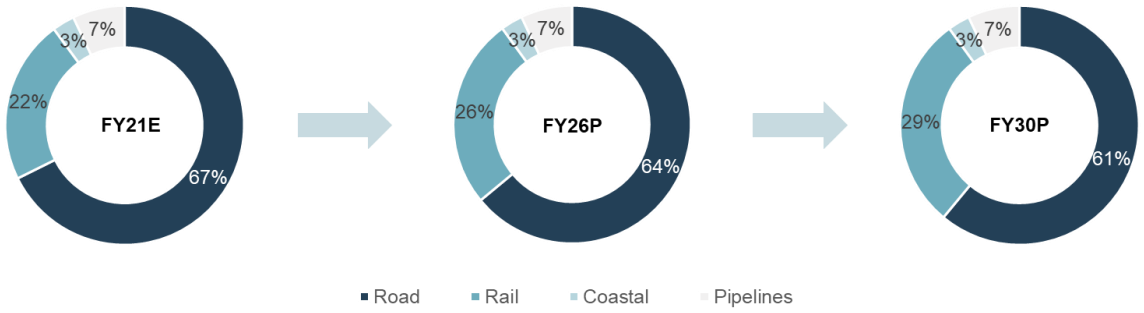
The cost of freight transportation varies widely across railways, waterways, roadways, and air, influenced by differences in energy efficiency, infrastructure, capacity, and speed. Railways are the most economical mode of transport. Their efficiency stems from the ability to move large volumes of cargo over long distances using relatively low energy and manpower. Trains can carry bulk goods like coal, cement, and grains at a much lower cost per ton-kilometer due to economies of scale and streamlined infrastructure. Additionally, railway tracks and systems are designed for durability and longevity, minimizing per-unit maintenance costs.

Waterways, at 1.2 times the cost of railways, are also highly cost-efficient, particularly for transporting bulk commodities over long distances. Ships and barges can carry significantly larger loads compared to trains or trucks, and water transportation consumes less fuel per ton-kilometer. However, the slightly higher cost compared to railways arises from slower transit times, port handling fees, and the need for specialized infrastructure like docks and cranes. Waterways often lack the flexibility of rail or road transport, necessitating additional costs for connecting ports to inland destinations via other modes of transport.

Roadways, costing 1.9 times as much as railways, are less efficient for long-distance freight movement. Trucks have lower payload capacities, and fuel consumption per ton-kilometer is significantly higher than trains or ships. Road transport also faces challenges like tolls, higher wear-and-tear on vehicles, and the need for frequent maintenance of road infrastructure. Despite these costs, roadways remain crucial for their flexibility and ability to handle last-mile delivery, which neither railways nor waterways can achieve directly.

Air freight, at a steep 37 times the cost of rail transport, is the most expensive mode of freight movement. Aircraft prioritize speed over capacity, which inherently limits their cost efficiency. Aviation fuel is substantially more expensive, and airplanes have high operational and maintenance costs. Additionally, specialized infrastructure such as cargo terminals, handling equipment, and stringent security measures further drive-up costs. Air freight is typically reserved for high-value, time-sensitive goods where speed justifies the expense, such as perishable goods, pharmaceuticals, or electronics.

Figure 85: Road to continue being the most preferred mode of transportation



Source: Industry, Crisil Intelligence

Roads account for a significant share in non-bulk commodity transportation such as:

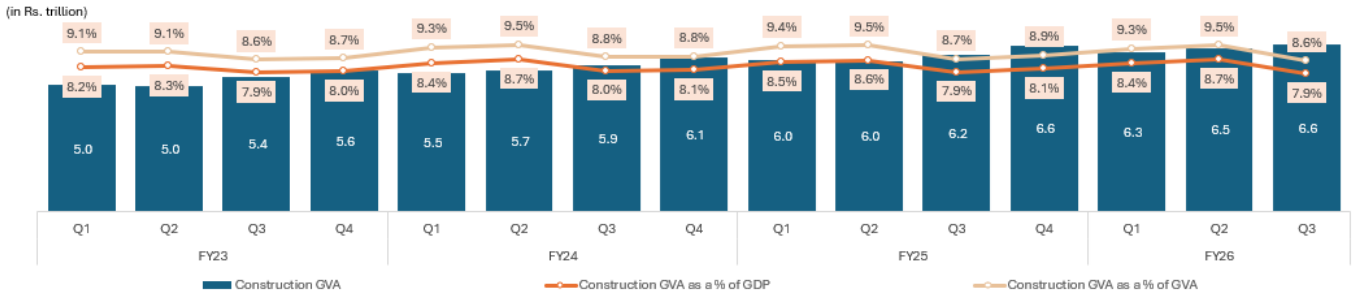
- Rail does not cater to piecemeal freight transportation. Entire rakes are provided for transportation and not just single wagons (although the Indian Railways is looking into multi-point loading, it would still not attract small-sized cargo).
- Road transport has better quality service and is more reliable.
- Road transporters operate on a much smaller scale. Also, given the large number of road-transport operators, customers have better bargaining power. These transporters also add a personal touch to their service, which is important, as these commodities are typically expensive and fragile.
- Roads provide end-to-end connectivity and safer handling, which is an important factor while transporting low-volume, but high-value commodities.

Table 19: Challenges faced by the roads sector

Risk	Challenge
Land Acquisition 	Delays in road projects lead to time and cost overruns. Sector-specific policies are being introduced to mitigate these issues.
Environmental clearances 	Delays in environmental clearances remain a challenge for the road sector, though initiatives like PM Gati Shakti aim to streamline approvals. Projects under construction must also adapt to evolving environmental regulations.
Approval delays 	Road projects often face delays due to the need for multiple approvals from local bodies, many of which work independently with limited coordination, slowing regulatory clearances.
Political risk 	Road projects often face delays due to the need for multiple approvals from local bodies, many of which work independently with limited coordination, slowing regulatory clearances.
Geographical risk 	Natural calamities such as flooding, landslide, excessive rains, local hinderances, terrorism, and unavailability/ low availability of raw material could have an adverse impact on any project.

Source: Industry, Crisil Intelligence

Figure 86: Construction GVA share in GDP decreases to 8.6% in Q3 fiscal 2026



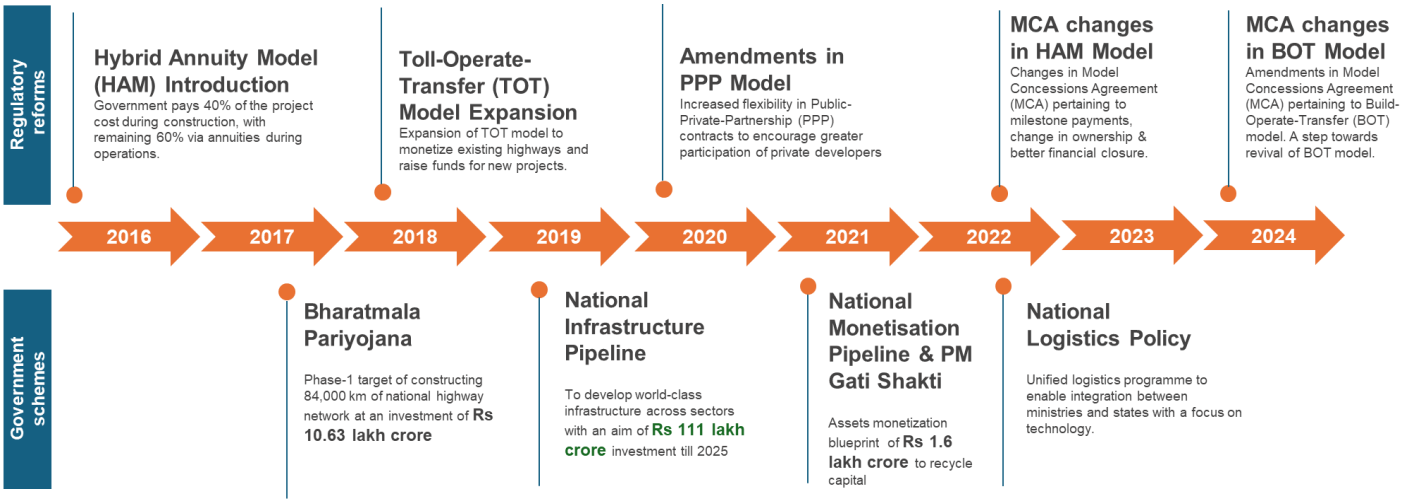
Source: Industry, Crisil Intelligence

Government focuses towards roads infrastructure development

The Government of India has played a major role in shaping the growth trajectory of the road infrastructure sector through a combination of policy reforms, innovative financing mechanisms, and large-scale infrastructure programs. The introduction of Hybrid Annuity Model (HAM) has provided a balanced risk-sharing mechanism between the government and private players, ensuring better financial security for investors. Additionally, the government has actively promoted asset monetization through the Toll-Operate-Transfer (TOT) model and Infrastructure Investment Trusts (InvITs), enabling private sector participation while unlocking capital for further infrastructure development. Moreover, favourable amendments in HAM and Build-Operate-Transfer (BOT) models have addressed investor concerns, offering improved financial terms and risk mitigation measures.

Schemes and initiatives such as the National Infrastructure Pipeline (NIP), National Monetization Pipeline (NMP), PM Gati Shakti, and the National Logistics Policy (NLP) have strengthened multi-modal connectivity and logistics efficiency. These measures collectively aim to reduce logistics costs, enhance project execution, and attract private investments.

Figure 87: Key government schemes and initiatives



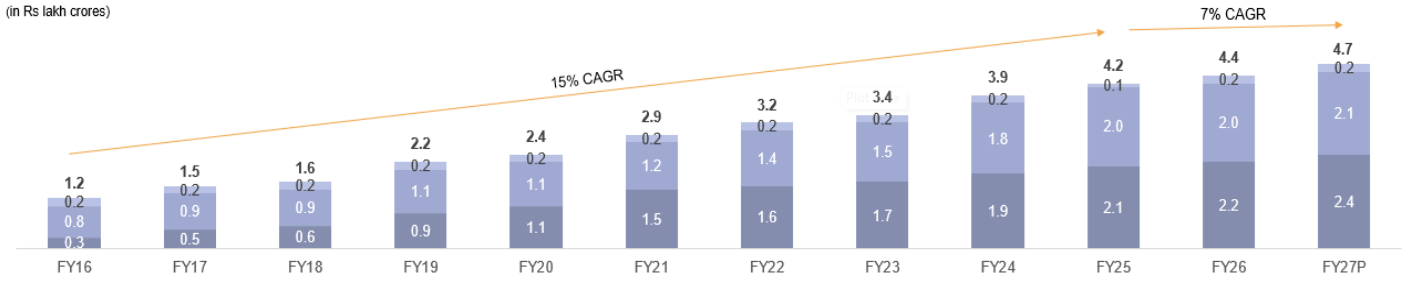
Source: Industry, Crisil Intelligence

Spending on roads to remain elevated, grow at 6% CAGR fiscal 2024-26, *Sharper focus on construction of high-speed corridors likely*

The Indian government has unveiled plans to develop 20,000 km of high-speed corridors (HSCs) over the next 5-6 years, with a long-term goal of establishing a 50,000 km-long HSC network by 2040. This strategic focus is expected to significantly improve logistics efficiency, reducing travel time and boosting the competitiveness of Indian industries. The road sector is anticipated to maintain its strong growth momentum, driven by a robust pipeline of HSC projects and sustained state spending on infrastructure, which has grown at a 10% compound annual growth rate over the past five years.

Despite some challenges, the sector remains on a strong growth trajectory, with a 12% compound annual growth rate in state capital expenditure on roads between 2015 and 2026. However, the pace of capital expenditure on roads and bridges has slowed in recent years, and the share of roads and bridges in states' overall capital outlay has declined. The Bharatmala Pariyojana, a flagship programme aimed at enhancing national connectivity, has faced delays and cost escalations, while the Pradhan Mantri Gramin Sadak Yojana (PMGSY) rural road construction programme continues to make progress, with a new phase sanctioned in 2024 to construct 62,500 km of new roads at an investment of Rs 70,125 crore.

Figure 92: Key government schemes and initiatives



Source: Crisil Intelligence

National Highways: Review and Outlook

Overview of PPP framework and models in operation

National highways authority of India (NHAI) has adopted a robust Public-Private Partnership (PPP) framework to augment investments and improve efficiency in the development and operation of National Highways. The framework allows private sector participation through multiple models, balancing risk-sharing and public benefit. The key implementation models include Build-Operate-Transfer (BOT), Hybrid Annuity Model (HAM), Engineering-Procurement-Construction (EPC), and operation-focused models such as Toll Collection, Operation-Maintenance-Transfer (OMT), and Toll-Operate-Transfer (TOT).

BOT (Toll, Annuity and HAM)

BOT is one of the earliest PPP models adopted for National Highways, involving private sector participation in financing, designing, constructing, and operating highway projects for a specified concession period. There are three major variants under BOT:

- BOT (Toll)

In this model, the private concessionaire finances, constructs, and operates the road and is allowed to recover investments through user toll collections over the concession period (typically 20–30 years). Traffic risk is fully borne by the private player. This model is viable in high-traffic corridors and incentivizes performance and efficiency.

- BOT (Annuity)

In this model the private party constructs and maintains the highway, but instead of toll collection, the government pays the developer fixed semi-annual annuity payments. The traffic risk is borne by the government, making this model suitable for stretches with moderate or uncertain traffic. BOT (Annuity) is no longer widely used, having been largely replaced by HAM.

- Hybrid Annuity Model (HAM)

HAM was introduced in 2016 to address the limitations of pure BOT and EPC models. Under this model, the government contributes 40% of the project cost during the construction phase, while the remaining 60% is financed by the developer. The developer is paid back through fixed semi-annual annuities along with interest and operation & maintenance payments over 15 years. Traffic risk remains with the government, while construction risk is shared. HAM is now the dominant mode for awarding highway projects in India.

EPC (Engineering-Procurement-Construction)

Under the EPC model, the government fully funds the project and appoints a contractor to design, construct, and deliver the road within a stipulated time and cost. The private contractor does not bear traffic or revenue risk and is not involved in long-term operation or maintenance.

EPC is typically used for strategically important, low-traffic or difficult terrain projects where PPP participation is limited. While it reduces the cost of borrowing and ensures timely project delivery, the entire financial burden rests on public funds.

Toll Collection/OMT/TOT

To ensure efficiency in toll operations and long-term asset monetization, the Ministry of Road Transport and Highways (MoRTH) and National Highways Authority of India (NHAI) have adopted models focusing on operations, maintenance, and revenue rights:

- Toll collection contracts

Under these short-term contracts, private firms are appointed through competitive bidding to collect tolls on behalf of NHAI for a fixed period (typically 1–2 years). The contractor pays an upfront or periodic fee to NHAI and retains toll revenues.

- Operate-Maintain-Transfer (OMT)

In this model, private players are granted concession rights to operate, maintain, and collect tolls from existing highway stretches for a medium-term period (typically 4–9 years). The concessionaire is responsible for maintaining road quality and collecting tolls, in return for a fixed concession fee or revenue share with NHAI.

- Toll-Operate-Transfer (TOT)

TOT is a long-term monetization model for completed highway assets. NHAI bundles operational road assets with established toll revenue streams and auctions them to private investors (typically for 20–30 years). The successful bidder

makes an upfront payment to NHAI and gains the right to operate, maintain, and collect tolls. TOT enables asset recycling and attracts long-term institutional investment, including foreign infrastructure funds.

Overview Bharatmala Pariyojana (including subsumed National highways development project (NHDP))

Bharatmala Pariyojana is the Government of India's ambitious highway development programme aimed at transforming the road infrastructure landscape of the country. Launched in October 2017 as a successor to the National Highways Development Project (NHDP), Bharatmala adopts a corridor-based approach to develop an integrated and efficient national highway network. The programme is designed to address critical infrastructure gaps in the movement of freight and passengers, enhance connectivity to remote, border, and economically backward regions, and reduce overall logistics costs. The overarching aim is to facilitate economic integration, improve supply chain efficiency, and support India's long-term growth by strengthening road-based connectivity between key production and consumption centers.

Total aggregate length of 26,425 km with a total capital cost of ` 8,53,656 crore has been approved and awarded till date under Bharatmala Pariyojana (including 6,758 km length of residual NHDP). No further projects are now being taken up under Bharatmala Pariyojana.

Table 20: The status of various components of Bharatmala Pariyojana as on 30 November 2025 is as under:

Component	Length (km)	Total Length Completed (in km)
Economic corridors	8,737	6,896
Inter corridors roads	2,889	2,397
Feeder roads	973	702
National corridors	1,777	1,516
National corridor efficiency improvement	824	767
Expressways	2,422	1,994
Border roads & international connectivity roads	1,619	1,466
Coastal roads	77	72
Port connectivity roads	348	154
Balance road works under NHDP	6,758	5,633
Total – Bharatmala	**26,425**	**21, 597**

Source: MoRTH, Crisil Intelligence

The funding model for Bharatmala is a blend of multiple sources, including budgetary support, borrowings by the National Highways Authority of India (NHAI), private sector participation through BOT and HAM models, and asset monetisation avenues such as the Toll-Operate-Transfer (TOT) model and Infrastructure Investment Trusts (InvITs). While NHAI is the principal implementing agency, the Ministry of Road Transport and Highways (MoRTH), state public works departments (PWDs), and other central agencies are also involved in executing specific segments of the programme.

Table 21: Mode wise status of works awarded under Bharatmala Pariyojana is as under:

Mode of Implementation	Length (km)	Awarded Total Capital Cost (Rs Cr)	% Length
EPC	14,748	4,06,024	55.81%
HAM	11,269	4,36,522	42.64%

BOT Toll	408	11,111	1.55%
Grand total	**26,425**	**8,53,656**	**100%**

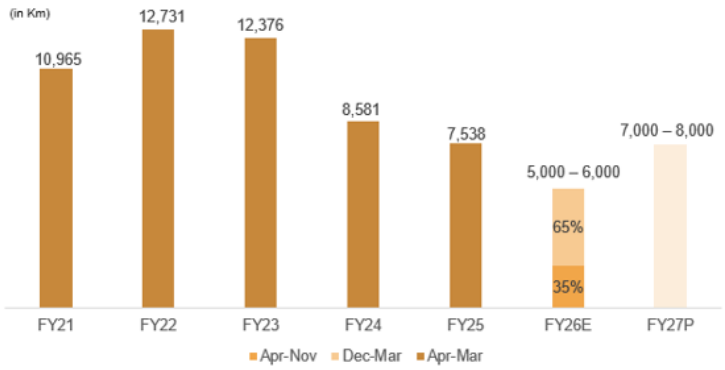
Source: MoRTH, Crisil Intelligence

Progress under Bharatmala Phase I has been significant, however, the programme has faced notable implementation challenges. Chief among them are delays in land acquisition, which have driven up costs substantially due to higher compensation rates. Additionally, procedural delays in securing environmental and forest clearances, as well as difficulties in mobilising private investment for public-private partnership (PPP) projects, have impacted timelines. As a result, the original deadline for Phase I completion has been extended to FY28. Projects were not awarded under Bhartmala Pariyojana in fiscal 2025. NHAI has shifted focus towards completion of ongoing projects and identifying individual road corridors for implementation.

National highway awarding and construction outlook

Awarding of national highways in India declined by a significant 31% on year in fiscal 2024 to 8,581 km. This subdued momentum continued into fiscal 2025, with awards further declining by 12% on year to 7,538 km. National highway awards for fiscal 2026 are expected to remain at 5,000-6,000 km due to slower progress made on NHAI's 124 announced projects, primarily caused by delays in land acquisitions.

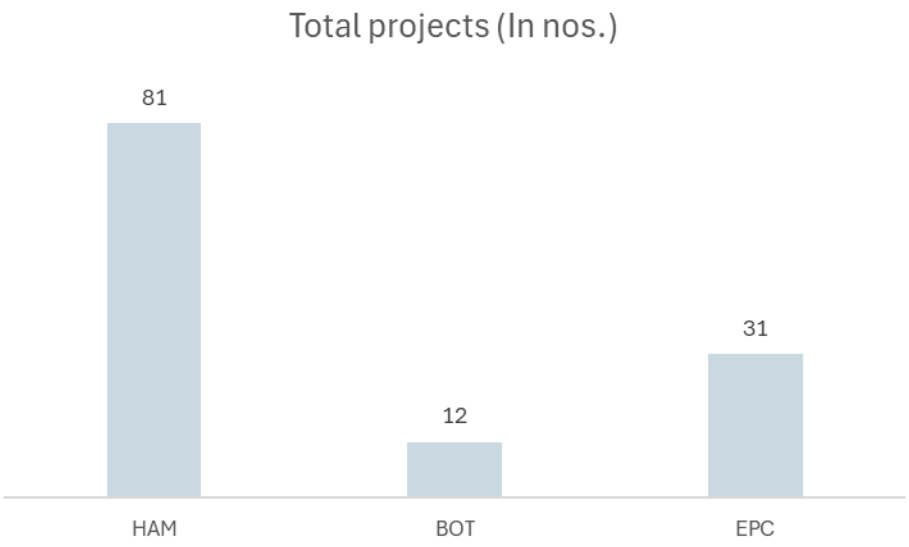
Figure 88: NH awarding in FY26 is expected to remain at similar levels as of previous fiscals



Source: MoRTH, Crisil Intelligence

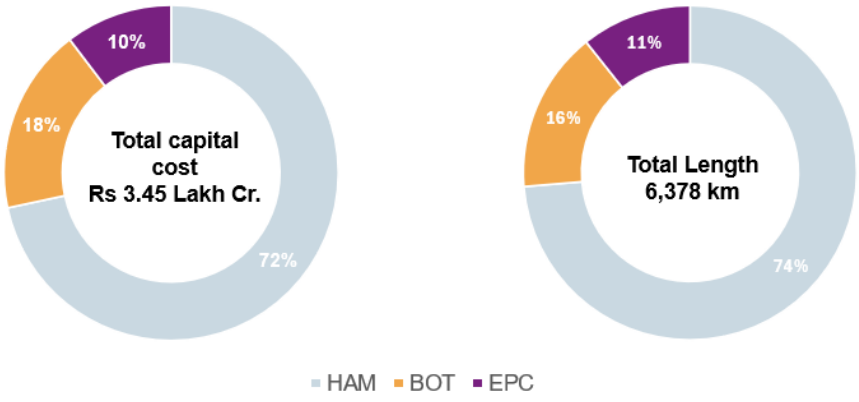
There is typically an execution lag of 18 to 24 months between the awarding of national highway projects and the commencement of on-ground construction activity. As a result, the slowdown in project awards observed during fiscal 2024 and fiscal 2025 is expected to weigh on construction activity in the subsequent year. Consequently, the total length of national highways constructed in fiscal 2026 is likely to decline and is estimated to be in the range of 7,000 to 8,000 km. Construction activity is projected to be at similar levels of 7,000-8,000 km in fiscal 2027.

Figure 93: NHAI released list of 124 projects to be awarded under HAM, BOT & EPC model in fiscal 2026



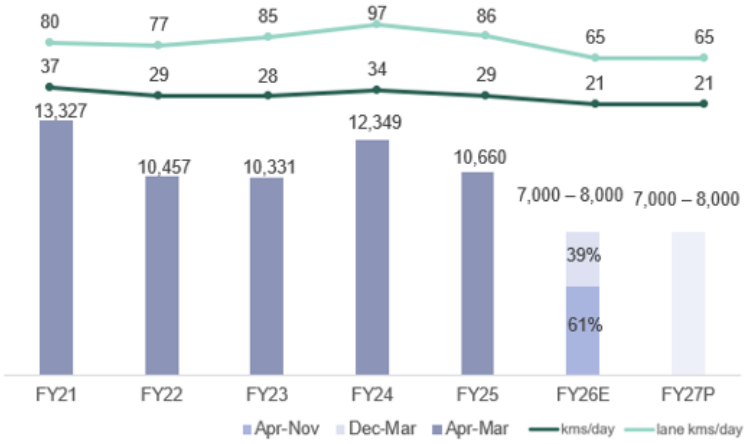
Source: NHAI, Crisil Intelligence

Figure 94: Share of projects by capital cost and length



Source: NHAI, Crisil Intelligence

Figure 95: Lower pace in construction in FY26 is expected due to lower awarding previous fiscals

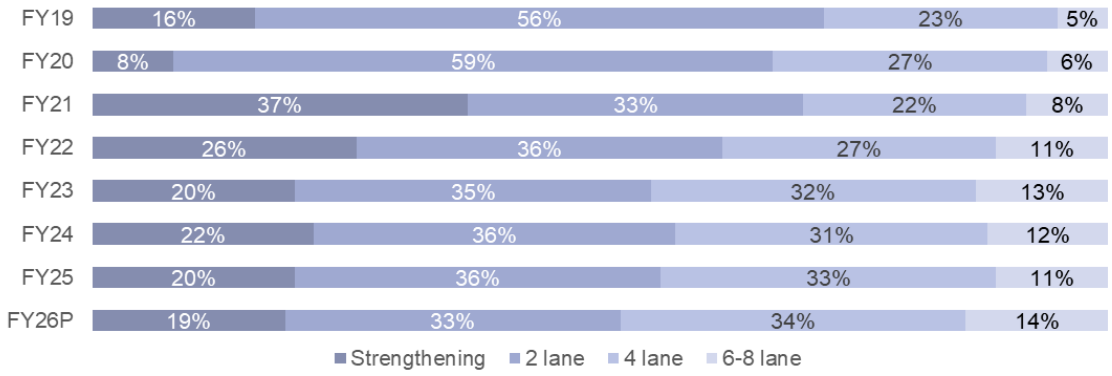


Source: MoRTH, Crisil Intelligence

However, there has been significant transformation in India's national highways in recent years, with a notable shift towards the development of wider highways. The annual national highway construction data reveals the share of four-lane, and more highways have increased steadily, from 28% in fiscal 2019 to 44 % in fiscal 2025, while the share of two-lane highways has decreased from 56% to 36%. This trend indicates the government's deliberate effort to focus on developing broader highways, which would enhance the overall efficiency and safety of the transportation network.

The data also highlights the impressive pace of national highway construction in India, with the average daily lane-kilometre built increasing from 76 lane-km/day in fiscal 2020 to 80 lane-kms/day in fiscal 2021, when the absolute national highway construction reached a peak of 13,327 km. Notably, even though the absolute national highway construction is expected to decline to around 7,000-8,000 km in fiscal 2026, the pace of lane-km is expected to remain high at 65 lane-km/day, driven by the higher share of four-lane and more highways being constructed. This suggests despite a decline in the absolute kilometres of national highways built, the sector's spending is expected to remain elevated, driven by the focus on wider highways.

Figure 89: Construction of wider 4-8 lane national highways have gathered momentum



Source: MoRTH, Crisil Intelligence

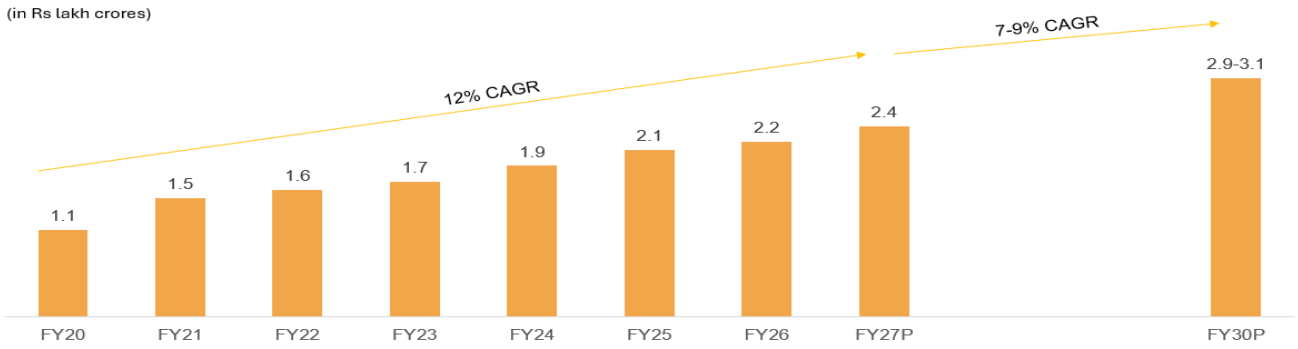
National highway capital expenditure outlook

As the sector enters a new phase of identifying and developing broader highways and expressways, the government has announced plans to develop 20,000 km of high-speed corridors (HSCs) over the next 5-6 years. It aims to establish a 50,000 km-long HSC network by 2040. This focused approach is expected to significantly enhance logistics efficiency, reducing travel time and increasing the competitiveness of Indian industries.

The road sector is expected to maintain its strong growth momentum, driven by a robust pipeline of HSC projects and sustained state spending on infrastructure, which has been growing at 14% compound annual growth rate over fiscal 2020-25.

Although the pace of national highway construction may slow down, the overall capital expenditure (capex) is expected to normalise in growth rate this fiscal. Notably, the capex is expected to remain elevated due to the need for broader highways, which will offset the potential decline in the absolute kilometres of highways being built. This suggests investment in the sector will continue to be significant, albeit growing at a more moderate pace with the government prioritising the development of high-quality transportation infrastructure. The post-pandemic surge in road capex, which grew in double digits on-year, is expected to stabilize to 7-9% CAGR between fiscals 2027-30P. However, the sector's growth trajectory will remain positive, driven by the government's ongoing focus on improving the country's transportation network.

Figure 90: National highway's capex growth to normalise to 7-9% between fiscal 2026-30



Source: Crisil Intelligence

Note: Capital expenditure includes spending on development and maintenance of National highways by NHAI, MoRTH and private concessionaires

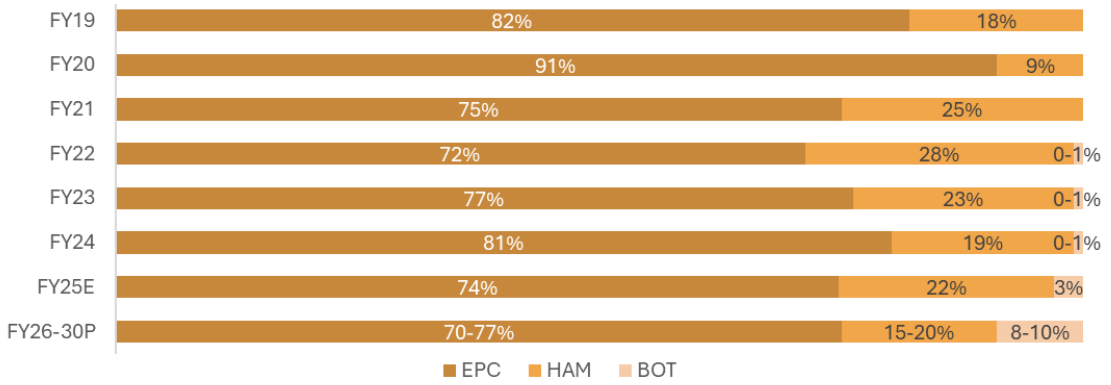
BOT mode of execution on track for revival, HAM to maintain significant share

National highways have also undergone significant changes in the mode of project execution over the years. Between 2007 and 2014, build-operate-transfer (BOT) projects accounted for ~50% of total project awards, indicating their popularity during that period. However, post-2014, the popularity of BOT projects declined due to various challenges such as aggressive bidding, unrealistic traffic projections, land acquisition delays and disputes, which led to project failures and non-performing assets (NPAs) for banks.

In response to these challenges, the government introduced the hybrid annuity model (HAM) in 2016, which subsequently became a popular mode of execution. HAM allowed for a more balanced risk-sharing mechanism between the government and private developers, making it a more attractive option for investors.

However, in fiscal 2025, the share of BOT projects ticked upwards, driven by favorable changes made in the model concession agreement (MCA) for developers. The MCA amendments have made BOT projects more attractive to developers, and the share of BOT projects is forecast to rise to 8-10% in the near future. This is also driven by a strong pipeline of projects and further amendments in the MCA, which are expected to make BOT projects more viable and attractive to investors.

Figure 91: BOT share to improve over long term with amendments in MCA & strong project pipeline



Source: MoRTH, Crisil Intelligence

The resurgence of BOT projects is a positive development for the sector since it indicates a renewed interest in private sector participation and investment in road and highway development. The government's efforts to revamp the MCA and make it more favourable for developers have paid off, and the sector is expected to benefit from increased private sector investment and participation.

Amendments in BOT MCA: A boost for investment by large corporates

The government has introduced significant amendments to the MCA for BOT projects, aiming to address the concerns of large corporates, creating a lucrative investment environment for them in the road and highway sector.

Key amendments include:

1. Change in ownership: The requirement for each consortium member to maintain a 26% equity stake in the concessionaire/ project SPV during construction and for a year after completing the Punch List. Each member must now hold 26% equity in the concessionaire, amounting to no less than 5% of the total project cost.

2. Performance security: Concessionaires can provide performance security through insurance surety bonds, accounts payee demand drafts, banker's cheques or e-bank guarantees, in addition to bank guarantees. The performance security amount has been reduced to 3% of the estimated project cost.

3. Change of scope: NHAI can modify the existing scope of work as part of the change of scope. Concessionaires are required to submit a detailed proposal and essential information, including a breakdown of quantities, unit rates and costs for different work items.

4. Construction and equity support: Support will be provided during the construction period. In addition, equity and construction support will be extended up to 40% of the total project cost.

5. Buyback of the project by NHAI: The buyback provision allows NHAI to repurchase the project from the concessionaire if the average daily traffic in PCUs reaches the design capacity in any two fiscals within a block of three consecutive accounting years.

6. Obligations of authority regarding competing roads: NHAI is required to extend the concession period if it breaches its obligation to not construct or facilitate the construction of any competing road before the 10-year completion of the appointed date.

7. Modifications in concession period due to construction of additional tollway: The amendment extends the restriction on constructing an additional tollway to cover the entire concession period. If NHAI or a government authority constructs an additional tollway, the extension of the concession period will be based on the traffic shortfall caused by it.

8. Compensation for default by authority: Distinct compensation mechanisms for two periods have been introduced as: (i) from the appointed date until commercial operation date (COD) and (ii) after COD.

9. Termination payments: The payment is defined as the sum of debt due and adjusted equity limited to the total project cost at any point during the concession period.

The government is set to introduce additional changes to the BOT concession agreement for greenfield highways in fiscal 2026, aiming to reduce disputes and boost private sector investment in the sector. The proposed reforms are a follow-up to the amendments made in fiscal 2025, which were designed to make the BOT model more lucrative to large corporates.

One of the key amendments is to mandate that all pre-construction activities be completed before issuing the Letter of Award. The move is expected to reduce the risk of potential delays and disputes during the construction phase and provide a more stable environment for private sector investors.

Table 22: Strong BOT pipeline to support private sector participation

BOT project (State)	Project cost (Rs Crore)	Length (in Km)
Karmala-Tembhurni **(Maharashtra)**	983	60
Sangli – Kolhapur **(Maharashtra)**	749	33.8
Kasarwadi (Nashik Phata)-Rajgurunagar **(Maharashtra)**	5,954	30
Ahmendnagar Solapur section of Surat Chennai expressway - Pkg 1 **(Maharashtra)**	2,289	62
Ahmendnagar Solapur section of Surat Chennai expressway - Pkg 2 **(Maharashtra)**	2,026	65.5
Ahmendnagar Solapur section of Surat Chennai expressway - Pkg 3 **(Maharashtra)**	2,193	70.5
Ahmendnagar Solapur section of Surat Chennai expressway - Pkg 4 **(Maharashtra)**	1,574	56.1
Pune-Shirur **(Maharashtra)**	6,170	56
Talegaon-Chakan-Shikarapur **(Maharashtra)**	4,202	54
Chennai - Tirupathi section & 6 laning tirupathi bypass **(Tamil Nadu)**	2,500	83
Armoor – Mancherial **(Telangana)**	3,175	131.3
Aligarh-Palwal-Tappal section of NH334D **(Uttar Pradesh)**	1,479	72.4
Chennani - Nashri Tunnel **(Jammu & Kashmir)**	1,880	9

TOTAL	35,174	783.6

Source: NHAI, Crisil Intelligence

Table 23: 2 BOT projects successfully awarded in FY25

Project Name	# of bidders	Project cost (in Km)	Bid premium	Project length (in Km)	Concession period (in years)	Highway lanes
Agra – Gwalior Expressway	10	3,738	23%	88	20	6
Guwahati ring road	4	5,500	(11)%	121	30	4/6

Source: Industry reports, Crisil Intelligence

Additionally, long-term project pipeline of **53 highway projects worth Rs 2.1 lakh crore** is being prepared under the BOT model. In fiscal years 2026, NHAI has also invited bid for 52 highway projects spanning 2,188 Km with a capital cost of Rs 1.15 Lakh crore.

Amendments in HAM model concession agreement

Annuity payments
Interest on annuity payment linked to average of one-year marginal cost of funds-based lending rate (MCLR) of the top five Scheduled Commercial Banks + 1.25%
Impact - Differential between cost of borrowing and interest on annuity reduced, thereby preventing erosion of developers' returns due to the RBI's repo rate changes

Milestone payments
10 instalments, each equal to **4%** of the bid project cost
Impact - Quicker payments helping developers' liquidity

Change in ownership
Original sponsor/ concessionaire shall hold at least 26% of equity during construction period and **six months thereafter**
Impact - Quicker stake sell-off would ease up developers' balance sheets to bid for new projects

Financial closure
Financial Closure to be undertaken for an amount no lower than either:

1. Total project cost (60% of BPC); or
2. 10% less than estimated project cost minus 40% of bid project cost

Impact - Would prevent termination of projects due to inadequate financing

Dispute resolution board
Failing mediation by the Independent Engineer, either party may require such dispute to be referred to the **Dispute Resolution Board (DRB)**
Impact - Quicker dispute resolution mechanism to prevent stuck projects

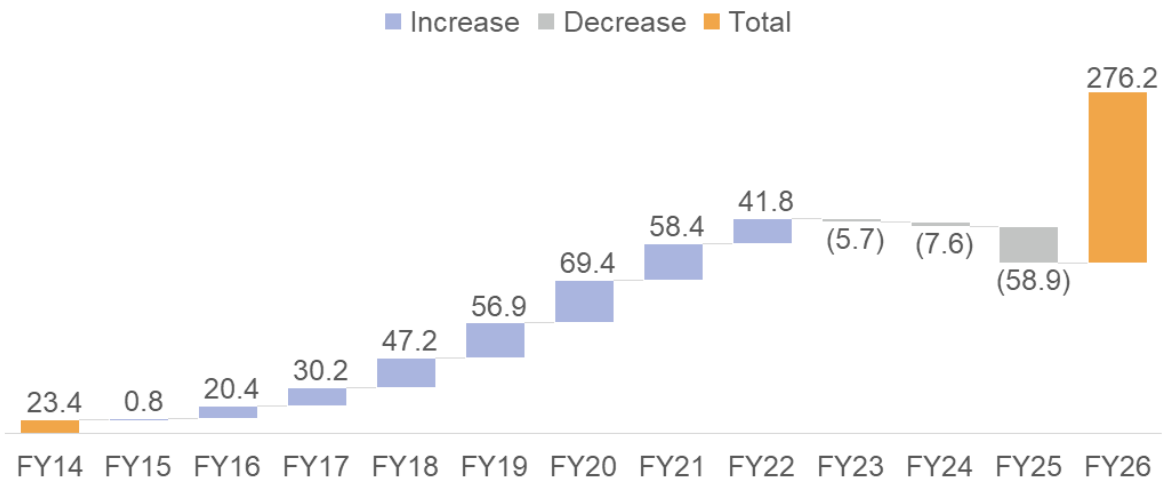
The ministry in July 2025, also revised the bidding criteria for developers for HAM projects. The government has tightened the eligibility norms for HAM developers to ensure only financially strong and technically capable players take up projects. The minimum net worth requirement has been increased to 20% of project cost (from 15%) and will now be calculated after deducting 20% of the value of ongoing PPP projects.
On the technical front, developers must demonstrate a stronger execution track record—having completed at least 35% of one similar project or 25% of two similar projects, compared to the earlier 20% requirement. Additional parameters, such as project timelines and road length completed, have also been raised.

These changes are expected to bring more discipline in bidding, ensure developers have adequate resources, and improve overall construction quality.

Asset monetisation to play a key role in supporting the sector's balanced growth

The National Highways Authority of India (NHAI) has been grappling with burgeoning debt, which has been a major concern for the authority's financial sustainability. As of March 2025, the NHAI's outstanding debt was ~Rs 2.7 lakh crore. This significant debt burden has been a result of the authority's aggressive highway development programme, which has led to a substantial increase in its borrowing requirements. However, in a positive development, the NHAI has recently made significant repayments of ~Rs 58,900 crore, which has been supported by the successful implementation of asset monetisation initiatives.

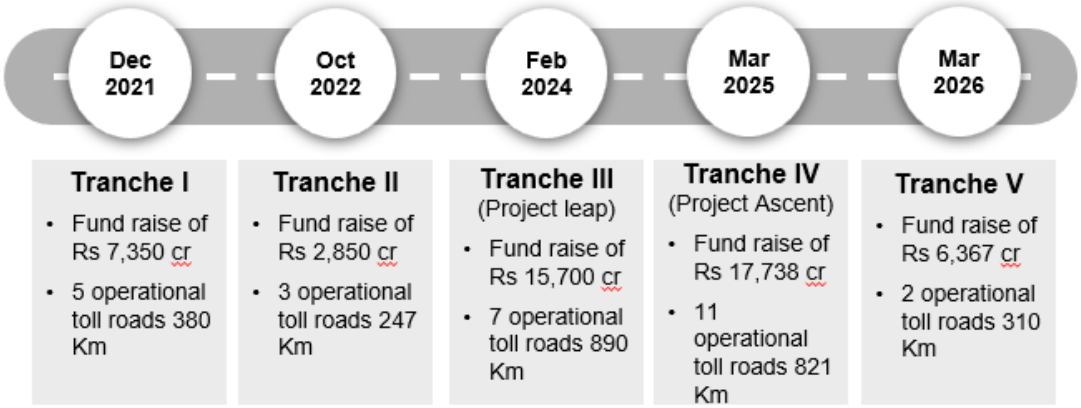
Figure 92: Rising NHAI debt underscores need for monetization



Source: NHAI, Crisil Intelligence

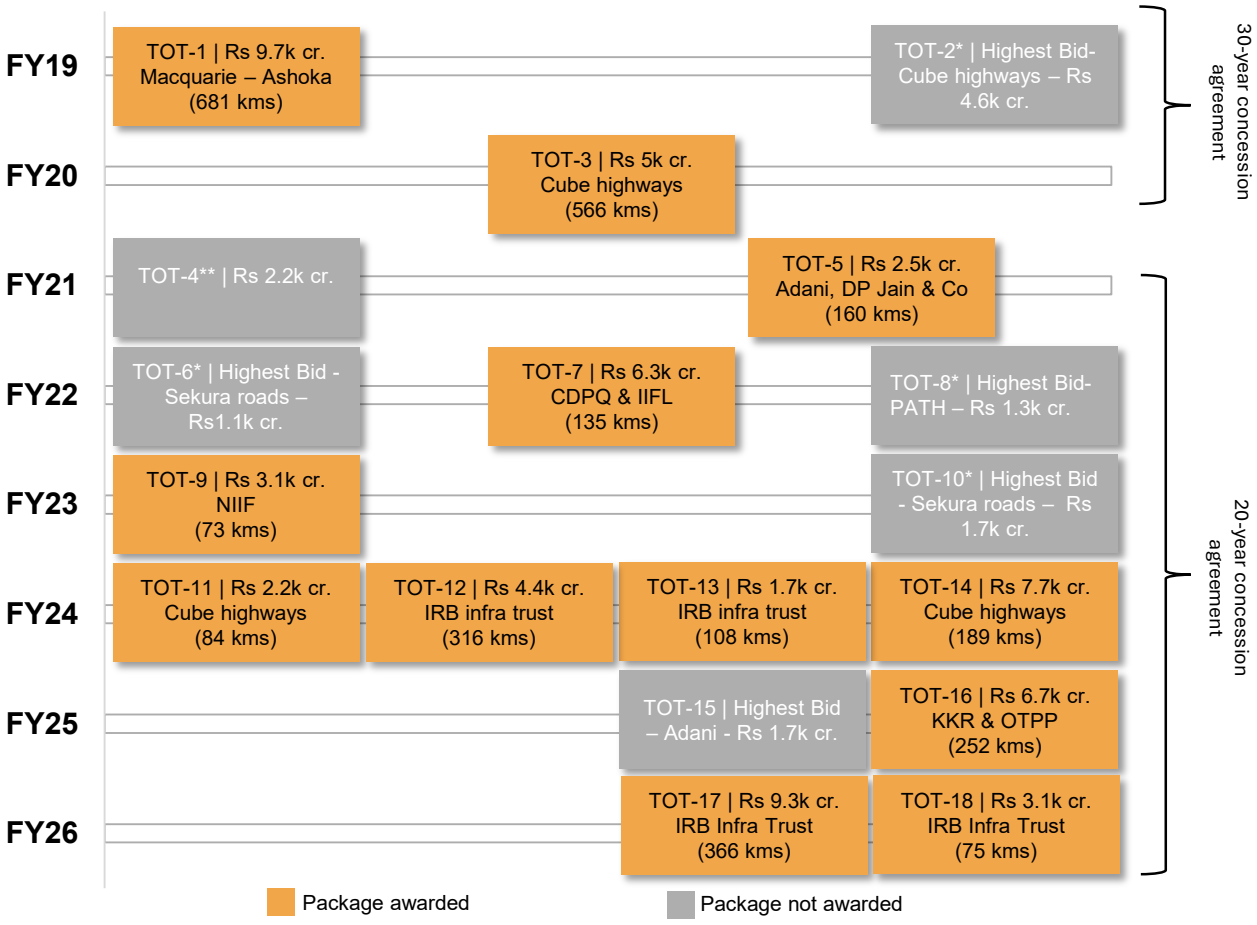
MoRTH has already achieved a significant milestone by raising ~Rs 1.6 lakh crore through various modes of monetisation. This initial success is expected to be further bolstered by the National Monetisation Pipeline (NMP) 2.0, which will likely provide an additional opportunity of Rs 4.14 lakh crore for road asset monetisation over the next 5-6 years. The steady growth in traffic and toll collection is also expected to support investment momentum in the sector, ensuring a stable revenue stream for investors. The asset monetisation programme is likely to play a crucial role in supporting the sector's balanced growth by unlocking the value of existing infrastructure assets, attracting private sector investment, and enabling the development of new projects. As a result, the road and highway sector is well-positioned to achieve sustainable growth, driven by a combination of government support, private sector investment and increasing demand for infrastructure development.

Figure 93: NHAI InvIT have raised total of 50,005 crores through 5 tranches until fiscal 26



Source: NHAI, Crisil Intelligence

Figure 94: ToT have raised a total of Rs 61,352 crores until fiscal 26

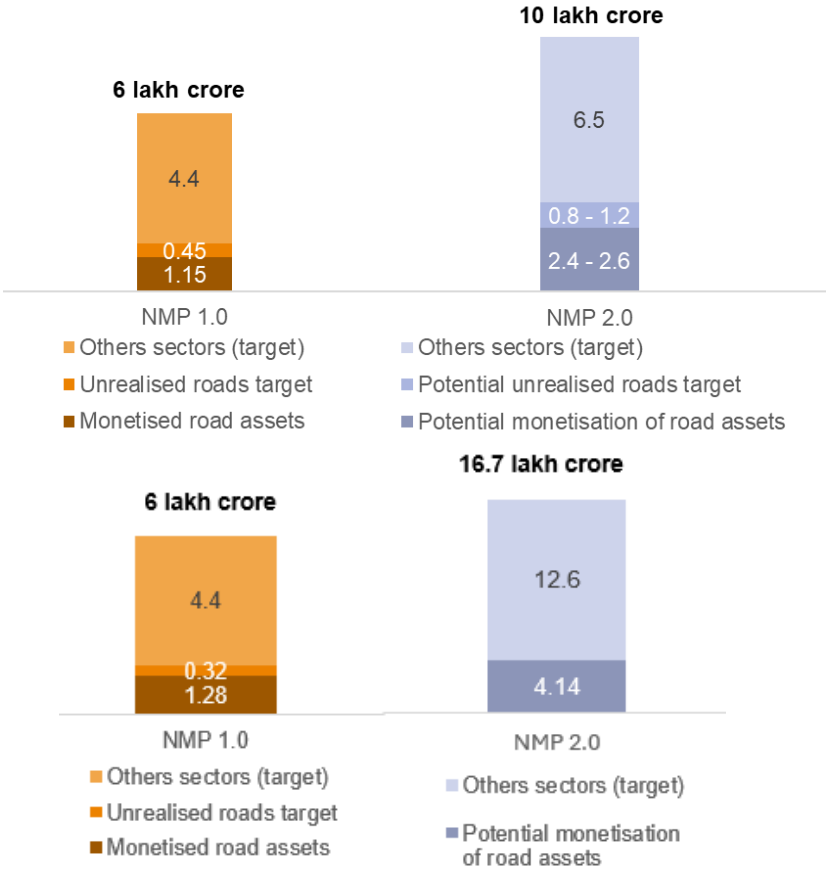


Source: NHAI, Crisil Intelligence

*Note: * Annulled due to highest bid being lower than the Initial estimated concession value (IECV)*

*** Withdrawn as per the decision for non-disclosure of IECV*

Figure 95: Rs 4.14 lakh crore is envisaged to be raised through monetisation in the next 5 years

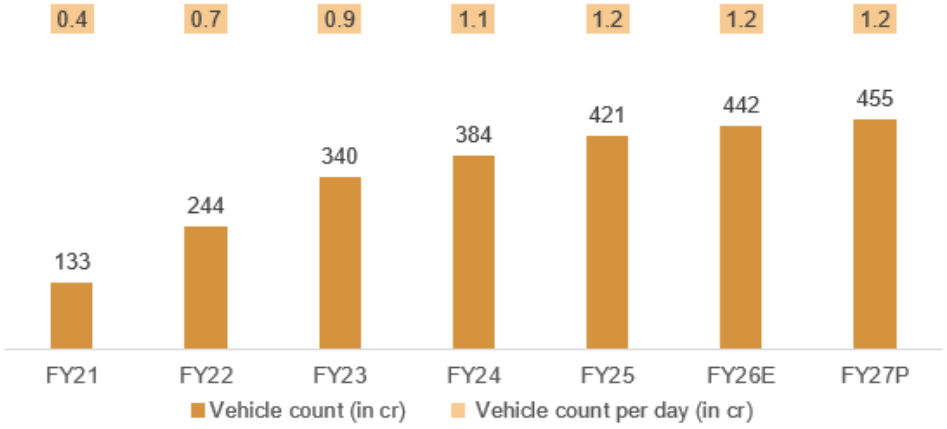


Source: Crisil Intelligence

Traffic volume and toll collection on firm footing

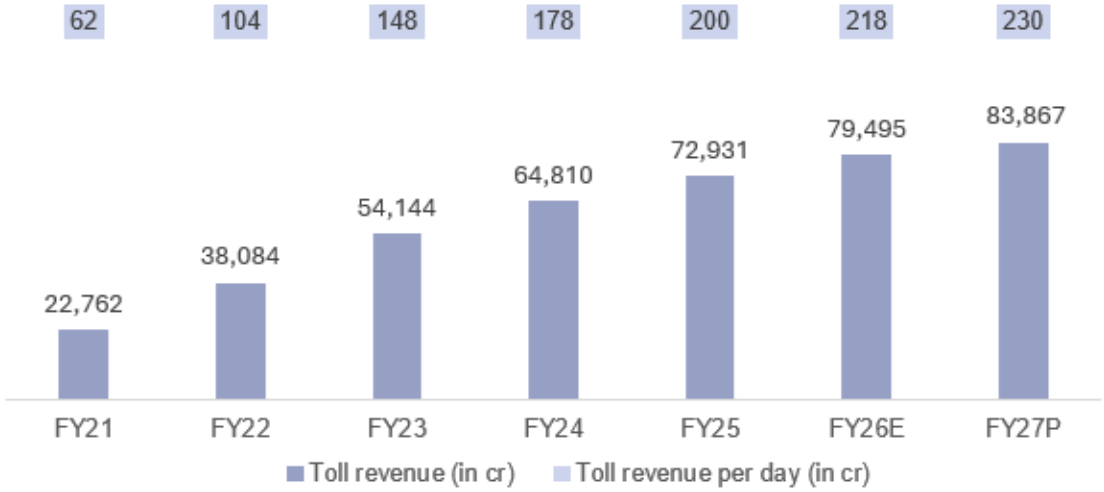
Rising vehicular traffic and toll rates have led toll collection to jump to ~Rs 200 crore/day in fiscal 2025 from Rs 62 crore/day in fiscal 2021, indicating a strong revenue growth trajectory for the sector.

Figure 96: Vehicle traffic grew at a CAGR of 33% during the period of FY21-25



Source: NETC, Crisil Intelligence

Figure 97: Toll revenue grew at a CAGR of 34% during the period of FY21-25



Source: NETC, Crisil Intelligence

The rise in toll collection is expected to continue, with rates expected to surge 4-5% in fiscal 2026. The increase in toll rates is likely to support revenue visibility and investor confidence in the sector, attracting private sector investment.

The steady growth in toll collection and the expected increase in toll rates provide a stable revenue stream for investors and support the financial sustainability of projects. The surge in toll collections is also a testament to the increasing demand for highway infrastructure in India, driven by rapid economic growth and urbanisation.

Key growth drivers for toll traffic at national highways

Toll traffic on national highways is witnessing steady growth, supported by multiple structural drivers.

- A key factor is the rapid rise in vehicle ownership, both in the passenger and commercial segments, which has led to higher movement of people and goods across the country.

- India's robust economic expansion has played a critical role, as increased industrial activity and trade translate into greater freight movement on highways.
- This trend is further supported by significant improvements in road infrastructure, with the construction of new expressways and the widening of existing corridors into four- and six-lane highways, which has enhanced connectivity and reduced travel times.
- Urbanisation and changing lifestyle patterns have contributed to a surge in inter-city travel, whether for work, leisure, or business, adding to the traffic volumes on toll roads.
- The growth of e-commerce and organised logistics has created more consistent and large-scale truck movements across key corridors.
- The introduction of FASTag and a more stable tolling framework have improved efficiency, ensured smoother traffic flow, and reduced revenue leakages.

Impact of Middle east crisis on Road's sector

The ongoing Middle East oil crisis would exert cost pressures on the roads and highways sector. The escalation in crude oil prices directly inflates the cost of bitumen and increases fuel expenses for construction equipment. Together, bitumen and fuel account for approximately 12-16% of total project construction costs, making project economics sensitive to oil price volatility.

In the near term, this would create margin compression for contractors, particularly under fixed-price EPC and HAM contracts where cost pass-through is limited or delayed. Indirectly, higher fuel prices also raise logistics and transportation costs for materials such as aggregates and cement, further amplifying cost overruns.

Competition profile and AEL's positioning

Dilip Buildcon

Dilip Buildcon undertakes road construction under EPC, BOT and HAM. It also provides EPC services for bridges, buildings, dams, canals, water supply, and mining. The company has a presence across 21 states and has an outstanding order book of Rs 29,400 crores as of Q3 FY2026. Roads constitute ~19% of the orderbook while irrigation (16%) and mining (20%) also have major shares. Standalone revenue from operations stood at Rs 5,150 crores in Q3 FY2026.

KNR Constructions

KNR Constructions Ltd (KNRCL) is a construction company with expertise in EPC services across roads and highways, irrigation and urban water infrastructure management. Its order book is dominated by mining projects (-40%), followed by irrigation projects (~31%) and road projects (29%). The company is an established player in the south, especially in Andhra Pradesh, Karnataka, Kerala, Telangana, and Tamil Nadu. As of December 2025, it had an outstanding order book of Rs 8,848.8 crores and total revenue of Rs 585.1 crores in Q3 FY2026 .

PNC Infratech

PNC Infratech executes infrastructure projects, including highways, bridges, flyovers, power transmission lines, airport runways, and industrial area development. It has expertise in EPC projects on roads and highways. As of December 2025, it had an outstanding order book of Rs 19,346 crores. Road highway, road expressway, railway, airport runway and canal EPC projects constitute 71% of total order-book. In 9M of FY2026, the company clocked revenue of Rs 3,176 crores.

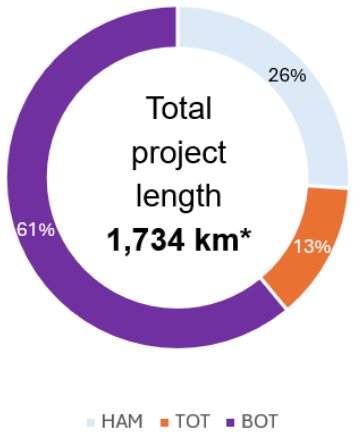
Ashoka Buildcon

Ashoka Buildcon (ABL) is an infrastructure development company with projects in roads, railways, buildings and power transmission & distribution segments. Roads EPC constitute the majority 44.1% of its order book followed roads HAM – 10.8%. As of December 2025, it had an outstanding order book of Rs 15,927 crores and revenue from operations of Rs 1,492 crores in Q3 FY2026 .

Adani Enterprises

Adani Enterprises Ltd. is a leading infrastructure developer with a successful track record in delivering large-scale, high-impact projects. Focused on PPP opportunities under BOT (Build-operate-transfer), TOT (Toll-operate-transfer), and HAM (Hybrid annuity model) models.

Figure 103: Project model breakup of Adani's road portfolio



*Note: *excludes BOT- Maharashtra Border Check Post Network Ltd (MBCPNL) of 24 BPCs*

Source: Company filings, Crisil Intelligence

Table 24: The **company has secured following 21 strategic road projects to date.**

Project Model	Project SPV / Location	Length (KMs)	Concession Period (in Yrs) (Const. + O&M)

HAM	Bilaspur Pathrapali Road Pvt Ltd (BPRPL) / Chhattisgarh	53.3	2 + 15
	Suryapet Khammam Road Pvt Ltd (SKRPL) / Telangana	58.6	2.5 + 15
	Mancherial Repallewada Road Pvt Ltd (MRRPL) / Telangana	42.0	2 + 15
	Vijayawada Bypass Project Pvt Ltd (VBPPL) / Andhra Pradesh	17.9	2.5 + 15
	Nanasa Pidgaon Road Pvt Ltd (NPRPL) / Madhya Pradesh	47.4	2 + 15
	Azhiyur Vengalam Road Pvt Ltd (AVRPL) / Kerala	40.8	2.5 + 15
	Kodad Khammam Road Pvt Ltd (KKRPL) / Telangana	31.8	2 + 15
	Badakumari Karki Road Pvt Ltd (BKRPL) / Odisha	47.5	2.5 + 15
	Munger Sultanganj Road Ltd (MSRL) / Bihar	41.8	4 + 15
	Sultanganj Sabour Road Ltd (SSRL) / Bihar	41.1	4 + 15
	Sree Vishwa Varadhi Private Limited/ Bihar	35.22	4+15
TOT	DPJ TOT Road Private Limited	105.9	0 + 20
	PRS Tolls Pvt Ltd / Gujarat	49.5	0 + 20
	CORR Tollways Limited (CTL)	60.15	0 + 25
BOT	Panagarh Palsit Road Pvt Ltd (PPRPL) / West Bengal	67.8	2.5 + 18
	Kagal Satara Road Pvt Ltd (KSRPL) / Maharashtra	65.1	2 + 16
	Maharashtra Border Check Post Network Ltd (MBCPNL) / Maharashtra	24 BCPs	1.5 + 23
	Ganga Expressway, Uttar Pradesh	464.2	-
	Budaun Hardoi Road Pvt Ltd (BHRPL)	151.7	3 + 27
	Hardoi Unnao Road Pvt Ltd (HURPL)	155.7	3 + 27
	Unnao Prayagraj Road Pvt Ltd (UPRPL)	156.8	3 + 27

Source: Company filings, Crisil Intelligence

"On April 29, 2026, AEL officially inaugurated the 464-km access-controlled Greenfield Ganga Expressway from Budaun to Prayagraj in Uttar Pradesh, representing 80% of the total expressway project."

Module 8: Data centres

Overview of Data centre in India

Data centres are infrastructure facilities for computing, storage, and networking. This infrastructure is essential for processing, storing, and disseminating huge amounts of digital data. These facilities are centralised hubs forming the backbone of digital economy, supporting a wide array of services ranging from cloud computing, enterprise IT operations, content delivery networks and government database.

The exponential growth of data driven by increasing internet penetration, proliferation of connected devices and surge in cloud-based applications, the demand for reliable and scalable data centres has surged globally. Modern data centres are designed with high standards of redundancy, security, and energy efficiency to ensure continuous uptime and protect sensitive information from cyber threats and physical disruptions.

In addition to their role as digital infrastructure hubs, data centres serve as the physical foundation for virtually all modern technologies like e-commerce, social media, financial transactions and public services. These hubs are operated in highly controlled environment, ensuring optimal conditions such as temperature, humidity and power supply for uninterrupted functioning of servers and associated systems. Data centres are increasingly integrating sustainable practices, such as renewable energy use and advanced cooling technologies, to address environmental concerns associated with their high energy consumption.

Historic evolution of the Data centre industry

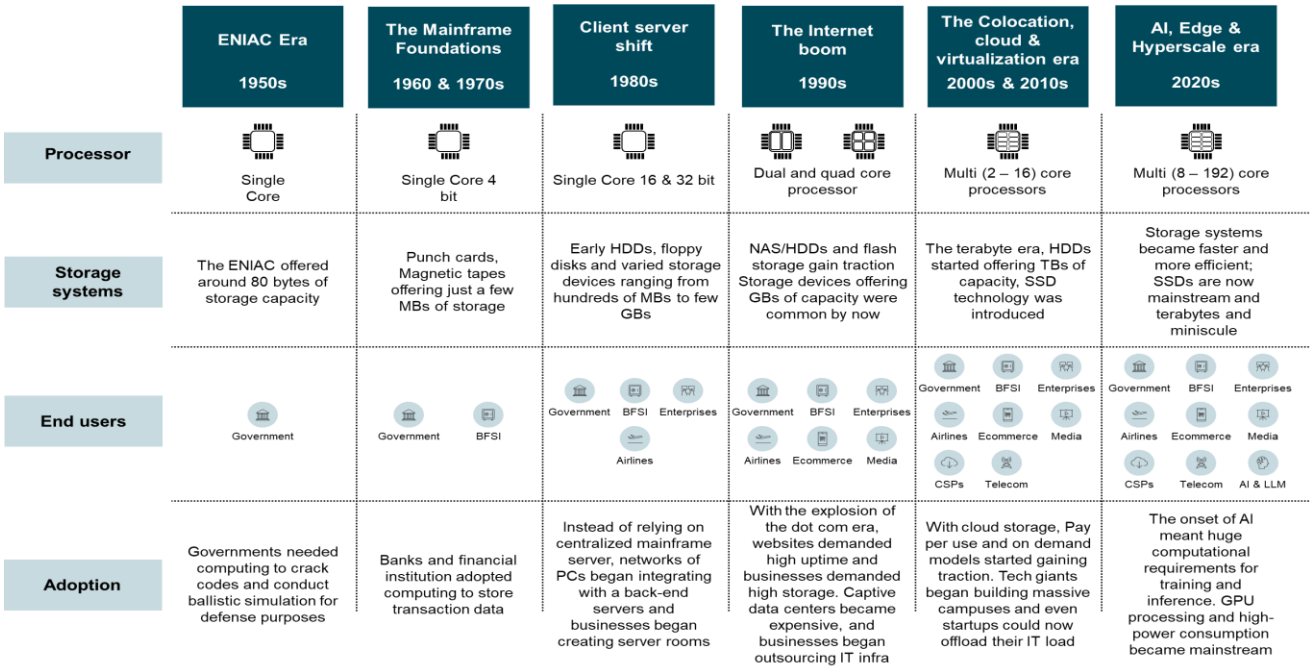
The evolution of data centres has mirrored the rapid advancement in computing technology, beginning with the ENIAC era in the 1950s, where the focus was on massive, government-driven computing for defense simulations. These early systems had single-core processors and offered minuscule storage capacities, around 80 bytes, mainly relying on physical storage formats. The 1960s and 1970s saw the rise of mainframe computers, powered by single-core 4-bit processors and using punch cards and magnetic tapes to handle just a few megabytes of data. Financial institutions and government bodies were the primary users, leveraging computing to process transactions and maintain records.

By the 1980s, the client-server model emerged with 16- and 32-bit processors, and storage systems advanced to early HDDs and floppy disks, enabling the storage of a few gigabytes. The real transformation began in the 1990s during the internet boom, with dual and quad-core processors and more powerful NAS/HDDs and flash storage systems. Enterprises, banks, e-commerce platforms, and airlines increasingly adopted computing power to support growing web applications and consumer data. As cloud technologies matured in the 2000s and 2010s, multi-core processors (2–16 cores) became standard, and data storage expanded into the terabyte range, with SSD technology gaining traction. This era marked the rise of colocation services, cloud service providers (CSPs), and startups moving to flexible IT load models.

The most recent shift in the 2020s has been fueled by AI, edge computing, and hyperscale infrastructure, powered by processors with up to 192 cores. Storage has become faster and more efficient, with SSDs now mainstream. Enterprises and AI-driven applications like large language models (LLMs) are pushing demand for high-performance computing, massive parallel processing, and low-latency access to data. Data centres today are no

longer just physical server rooms, they are strategic digital infrastructure supporting hyper-connected, intelligent systems on a scale.

Figure 98: Snapshot on evolution of Data centre



Source: Industry, Crisil Intelligence

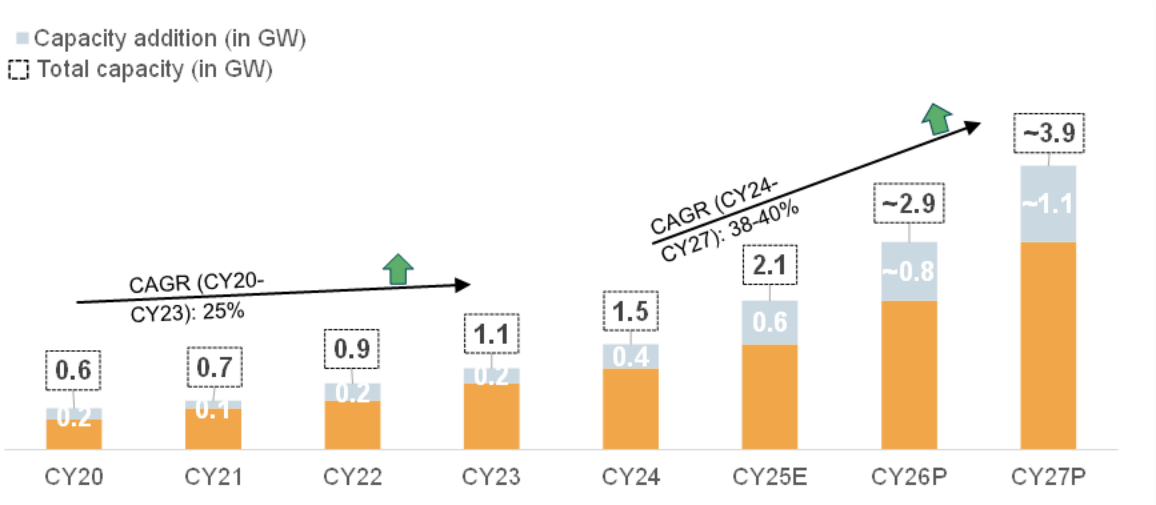
Review and outlook of Data centre capacity addition in India

The Indian data centre industry has experienced remarkable growth since 2020, with a significant addition of approximately 1.7 gigawatts (GW) between 2020 and 2025. This surge has propelled the country's total capacity to reach 2.1 GW. It is anticipated that the industry will surpass the 2.8 GW capacity milestone by 2026.

The driving forces behind this capacity expansion are multifaceted. The introduction of 5G technology, advancements in Artificial Intelligence (AI) and the Internet of Things (IoT), the proliferation of Over-The-Top (OTT) platforms, and the Reserve Bank of India's (RBI) data localisation directives have all contributed to an increase in data generation and storage requirements. Furthermore, favourable state data centre policies and the presence of cable landing stations have also played a significant role in fueling this growth.

As India's demand for data consumption continues to escalate, coupled with the nation's pursuit of digital self-reliance, the data centre industry is poised for sustained growth. It is projected that the industry will reach over 3.5 GW by 2027, with robust capacity addition anticipated in coming years. This projected expansion underscores the significant potential for growth and development in India's data centre sector, driven by the country's increasing appetite for digital services and its commitment to digital transformation.

Figure 99: Total capacity to expand by CAGR 38-40% from 2024 to 2027



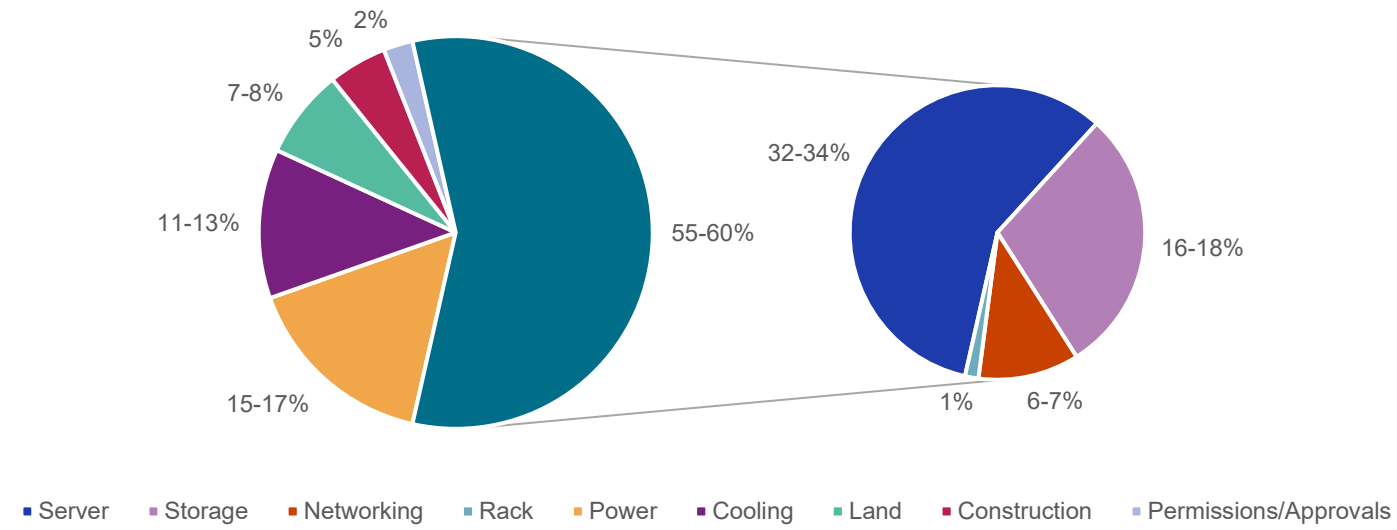
Source: Crisil Intelligence

IT setup constitutes 55-60% spending for data centres with 1 MW capacity

The cost of setting up a data centre with a capacity of 1 MW in India has infrastructure technology costs accounting for 55-60% of the total expenditure. These include the cost of servers, storage, networking and racks, which form the backbone of the facility's operations.

Servers constitute about two-thirds of the IT costs, highlighting their critical role in data processing and storage. The remaining 40-45% of the costs are attributed to supporting infrastructure, which encompasses cooling infrastructure, land acquisition, construction and necessary permissions and approvals. Notably, power and cooling systems form majority of the supporting infrastructure costs, underscoring the importance of efficient and reliable energy management in data centre operations.

Figure 105: Unit cost of setting up a 1 MW data centre in India



Source: Crisil Intelligence

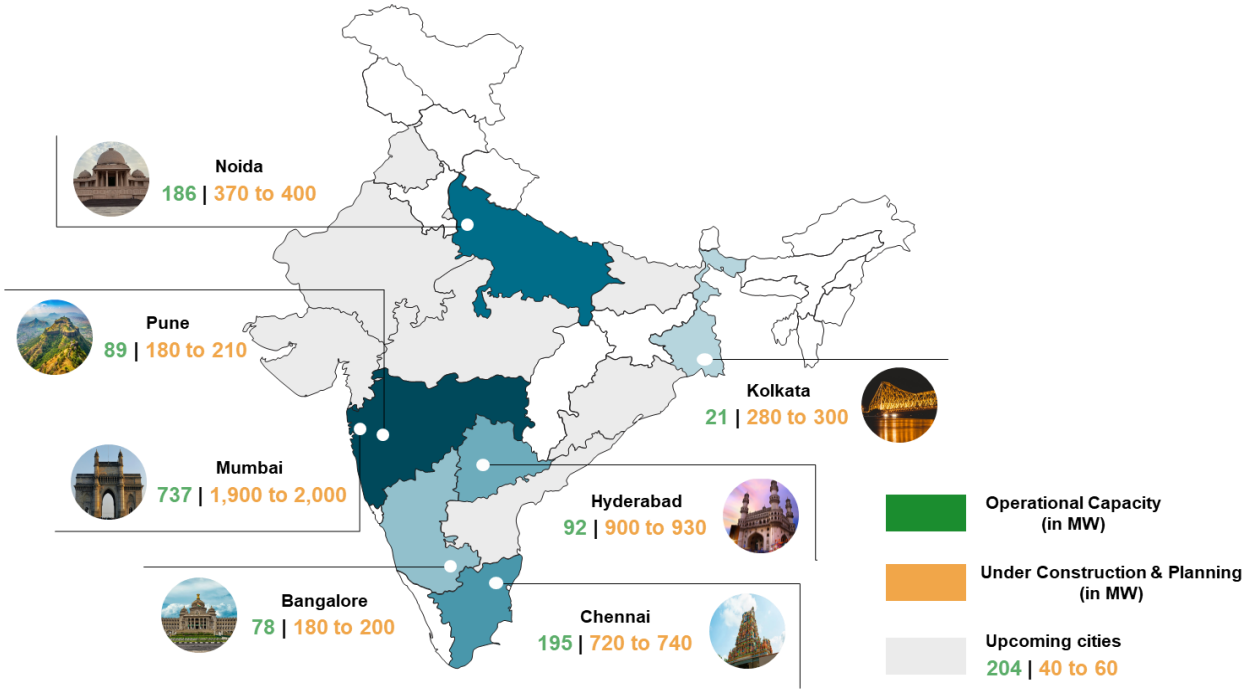
Data centre hotspots: Operational and pipeline capacities by city

Approximately 96% of India's current operational data centre (DC) capacity is concentrated in the top seven cities, with Mumbai boasting the largest share at around 0.7 gigawatts (GW), accounting for a substantial 51%. Noida and Chennai follow closely, each holding a 13% share. Other cities, such as Pune, Bangalore, and Kolkata, are also gaining significant momentum, with several projects currently under construction.

Mumbai is anticipated to reach an operational capacity of approximately 2 GW by 2028, driven by its strategic location near global cable landing stations and its proximity to major corporate entities. The city has over 2 GW of additional capacity in the pipeline, further solidifying its position.

Chennai is expected to emerge as the second major data centre hub in India, driven by the presence of cable landing stations and increasing demand from IT firms and e-commerce giants. Cities like Hyderabad and Bangalore are already home to the Indian headquarters of global hyperscale's, including Microsoft, Amazon, and Google, as well as numerous startups, thereby generating significant demand. Notably, Microsoft and Amazon have established at least three data centre campuses in Hyderabad, with several more in the pipeline, either operational or under construction.

Figure 100: City-wise Data centre capacity distribution



Source: Crisil Intelligence

Global Data centre landscape: Where India stands?

The United States leads the global data centre market, boasting approximately 56 MW of capacity per million internet users, followed by Germany at 25 MW and China at 4 MW per million users. In contrast, India's data centre capacity stands at just 2 MW per million internet users — markedly lower than that of developed nations. This stark gap highlights the considerable potential for growth. With rising data consumption, supportive state-level data centre policies, and regulatory pushes for data localisation, India's data centre capacity is expected to expand significantly in the coming years.

Figure 101: Under penetration in the Indian market indicates massive avenues for growth

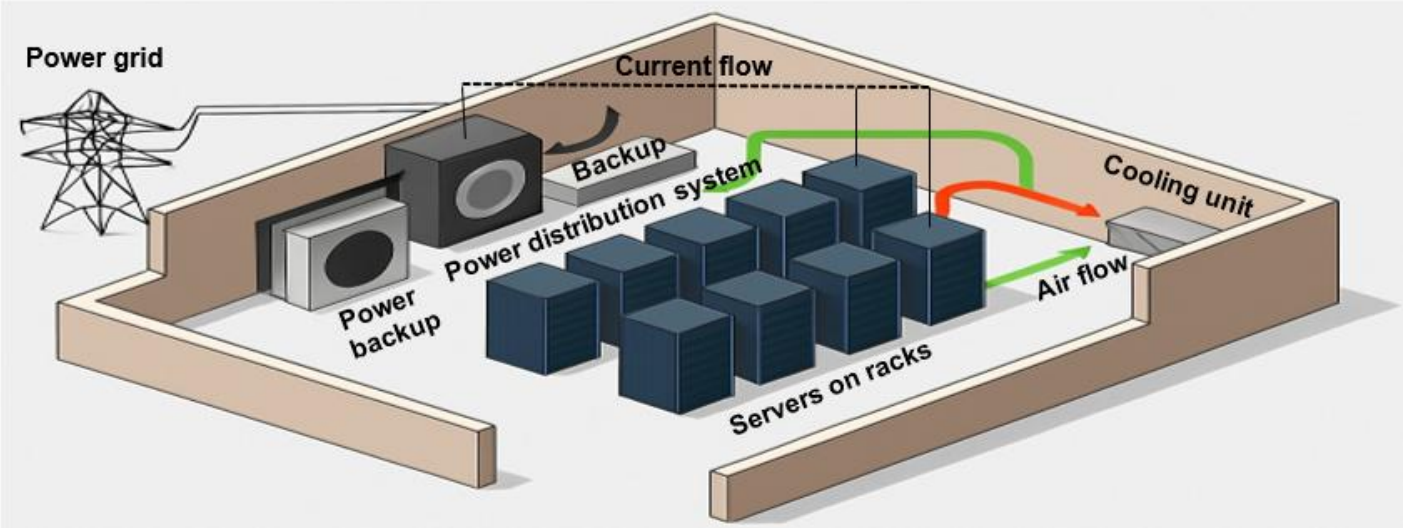
Source: Crisil Intelligence

Structure of a Data centre in India

A typical data centre layout is designed to optimise performance, reliability and efficiency. At the core are stacks of servers on racks, responsible for computing and storage. These are often arranged in hot aisle and cold aisle configurations to enhance airflow and cooling efficiency between the racks. Adjacent to server racks is power distribution systems, this consist of Uninterruptible Power Supplies (UPS) and Power Distribution Units (PDUs), to ensure consistent power delivery and protect against outages and power surges. To protect against redundancy,

there are backup components like generators and battery banks are strategically placed near power distribution systems to maintain uptime during grid failures. This also contain whole set of new components in case of any component failure and thereby reducing redundancy risks and potential downtime in service. Cooling units such as Computer Room Air Conditioning (CRAC) units, chillers or liquid cooling systems are integrated to regulate temperature and humidity levels. This is very crucial for maintaining server health and performance. The layout also includes cabling trays, fire suppression systems, security zones and monitoring stations. These are structured within a highly controlled environment to support continuous operations and data security.

Figure 102: Typical layout of data centre



Source: Crisil Intelligence

Classification of Data Centres

Data centres are typically classified depending on their size and capacity of facility, ownership of infrastructure and operational availability of hubs. Data centres vary widely in terms of scale and computing power. The selection depends on an organization's storage, processing, and networking requirements.

Classification based on size and capacity

In this classification, data centres type is influenced by purpose of their operational requirements and scalability. Category caters typically to distinct end-use industries depending on their data intensity, latency, processing sensitivity and scalability. The selection of a suitable type is driven by the computing load, storage requirements, and nature of service. The location of data centres is also vital. It is often influenced by factors like network connectivity, power availability and climate.

Table 24: Types of data centres and their end use

Type	Description	Capacity	End use industry
Enterprise	Owned and operated by a single organization, typically on-premises or in purpose-built locations	1-20 MW	Government, defence, banking, financial services, telecom

Micro	Very small and compact in size, self-contained and modular; often just a rack-sized	10-30 MW	Retail outlets, manufacturing & industrial, smart factory, healthcare
Edge	Small to medium size, deployed closer to data sources for low-latency processing	30-100 MW	5G telecom network, augmented & virtual reality, power smart grid, OTT & streaming
Hyperscale	Huge and massive in size, highly scalable facility designed to handle enormous data processing, storage, and networking needs	>50 MW	E-commerce, gaming, digital payments, public cloud providers, IT & ITeS, social media

Source: Crisil Intelligence

Classification based on ownership of infrastructure

Under this classification of data centres, it is based on the ownership and management model of the infrastructure. This is determined based on level of control, cost structure and operational responsibilities for corporate. The choice of ownership is typically linked with usage for corporate on data sensitivity, IT strategy and regulatory obligations. Data sovereignty and compliance with data protection laws further underscore the importance of secure and localised data storage.

Table 25: Classification ownership

Type	Description	Usage
Captive	Built, owned and operated by a corporate, for its exclusive use	Suitable for companies needing high security or regulatory compliance
Managed services	A third-party operator manages the data centre's physical and digital infrastructure, while the organization retains data ownership	Ideal for companies that want to focus on core business while outsourcing IT operations
Colocation	Organisation owns and manages its hardware, but power, cooling, and facility maintenance are managed by a third party	Balance of control and cost-efficiency; allows organizations to avoid large capital outlays while retaining hardware control
Cloud	Owned by public cloud service providers; infrastructure is completely virtualized and accessed via the internet	Enables rapid provisioning and pay-as-you-go billing. Ideal for DevOps, testing and scalable web hosting

Source: Crisil Intelligence

Classification based on Tier

Data centres are classified on their level of redundancy, uptime guarantee and fault tolerance. This tier-based classification helps organisations assess the reliability and resilience of a data centre, depending on the criticality of their operations. Each tier represents a different level of infrastructure robustness, ranging from basic setups with no redundancy (Tier I) to fully fault-tolerant systems with minimal downtime (Tier IV).

Table 26: Classification based on Tiers

	Tier I	Tier II	Tier III	Tier IV
Redundancy*	None	Partial (N+1)	Full (N+1)	Full (2N or 2N+1)
Uptime guarantee	99.671%	99.741%	99.982%	99.995%

Maintenance impact	Shutdown	Shutdown	Without downtime	No impact
Fault tolerance	None	Limited	Limited	Full
Power and cooling paths	Single path	Single path with redundant components	Multiple paths with redundant components	Multiple active paths with full redundancy
Max annual downtime	~28.8 hours	~22.0 hours	~1.6 hours	~26.3 minutes

**Redundancy refers to the duplication of critical components (like power, cooling, network, etc.) to ensure continuous operation in case of failure*
Source: Crisil Intelligence

Government Policies to strengthen Industry structure

RBI Data Localization Mandate

The circular mandates all payment system-data to be stores exclusively in India. In case of foreign processing, a complete copy must also be stored in India.

Draft Data Centre Policy (Meity)

Proposes **Infrastructure status, data centre economic zones (DCEZs), DC incentivization schemes (DCIS)** and others to enable ease of doing business, and promote indigenous technology development, research and capacity building

Telecommunications Act

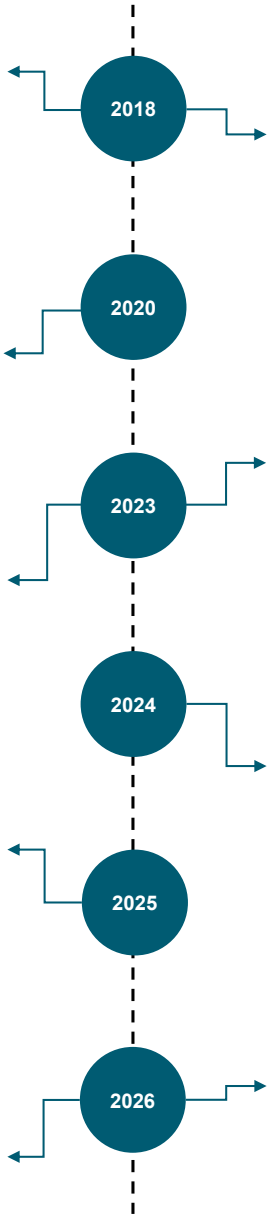
Aims to modernize India's telecom legal framework, reflecting advancements in 5G, fixed broadband, IOT, etc. by introducing a unified authorization regime, right-of-way enabling deployment of dark fiber,

National Broadband Mission 2.0

Aims to achieve the following by FY30: broadband access to all villages by adding **~2.7 lakh km** of optical fibre, have a national average broadband speed of **100 Mbps**, RoW* application average of **30 days**, 60 rural internet subscribers per 100 population, use of **30% sustainable energy** in mobile towers, etc.

Tax holiday till 2047

The government announced a **tax holiday till 2047** for foreign cloud service providers operating thorough India-based data centre infrastructure thus providing a predictable tax environment for global cloud players



National Digital Communications Policy

Aims to provide atleast **50 Mbps** broadband connectivity to every citizen, **10 Gbps** to Gram panchayats, attract **Rs 8.3 Lakh crore** in investments, expand IOT system to **500 crore** connected devices by establishing a National Digital Grid and facilitating open access next generation networks

Digital Personal Data Protection Act

Provides obligations of fiduciaries (data processor), principals (data owners), and financial penalties on breach to promote consent, lawfulness and transparency

India AI Mission

Allocation of over **Rs. 10,300 crore to bolster India's AI ecosystem** through 7 pillars like increasing India's AI computing capacity, support researchers and startups through innovation centres, to promote responsible development of AI, etc.

India Semiconductor Mission (ISM) 2.0

Announced in the Union Budget 2027 with a provision of **Rs. 1,000 crore** in fiscal 2027, it focuses on - design and manufacturing of semiconductor equipment and associated materials in India, expansion of semiconductor design ecosystem, strengthening of talent development initiatives to support the development of India's digital infrastructure

Source: Industry, Crisil Intelligence

Figure 103: State wise DC policy and incentives

	Subsidy on Fixed Capital Investment	Land Incentives		Power Incentives			
		Subsidy on land cost	Stamp duty concession on land	Electricity tariff	Exemption from electricity duty	Subsidy on electricity tax	Dual Power Grid
 Maharashtra IT/ITeS Policy 2023	✗	✗	100%	At industrial rates	100% (permanently)	✗	✗
 Telangana DC Policy 2016	✗	✗	100% (reimbursement)	At industrial rates	✗	✗	Available
 Tamil Nadu DC Policy 2021	✗	50%	50% - 100%*	At industrial rates	✗	100% (for 5 years)	Available (for load > 50 MW)
 Karnataka DC Policy 2022-27	7% (up to INR 10 Cr)	10% or INR 3 Cr (whichever is lower)	100% (up to 10 Acres)	At industrial rates (if >30% renewable energy usage)	100% (for 5 years)	✗	Available
 Uttar Pradesh DC Policy 2021	7% (up to INR 20 Cr)	25% - 50% (based on region)*	50% - 100% (first / second transaction)*	✗	100% (for 10 years)	✗	Available

* Rates vary based on region
Source: Industry, Crisil Intelligence

Importance of data centres in digital economy

Data centres are playing a pivotal role in enabling seamless digital operations, enhancing computational capabilities, and supporting the growing demands of big data analytics and real-time connectivity. With business models becoming increasingly digital-first, the demand for robust and resilient IT infrastructure has made data centres a core component of national and enterprise-level digital strategies. As the digital ecosystem continues to expand, data centres are not just enablers of connectivity and computation, but key drivers of innovation, digital infrastructure, and economic competitiveness.

In response to the latency and bandwidth requirements posed by real-time applications such as autonomous systems, predictive analytics, and immersive media, the design and geographic distribution of data centres are undergoing a paradigm shift. While traditional hyperscale data centres remain critical for centralised processing, edge data centres are gaining prominence by enabling faster and more efficient processing at the source. This reduces latency, enhances throughput, lowers costs, and improves user experience for applications that require instantaneous response times.

As the digital ecosystem continues to expand, data centres are no longer passive enablers of connectivity and computation, but active drivers of innovation, digital infrastructure, and economic competitiveness. They provide

the foundation for critical sectors including finance, healthcare, e-commerce, media, manufacturing, and public governance. Their role is central to the continuity of business operations, the delivery of citizen-centric digital services, and the overall resilience of national digital infrastructure.

Edge data centres—positioned closer to data sources such as mobile networks, industrial IoT devices, and user endpoints—enable real-time data processing and response, significantly reducing latency and bandwidth consumption. This makes them highly suited for use cases in autonomous mobility, AR/VR, smart grids, streaming platforms, and real-time analytics. The ability of data centres to ensure high availability, data sovereignty, regulatory compliance, and cyber resilience has made them indispensable in today's interconnected world.

The evolution of data centres in both form and function is thus central to the growth of the digital economy. Whether it is through hyperscale facilities supporting AI workloads, or modular edge nodes deployed across smart cities, data centres are enabling the digital infrastructure that drives innovation, supports new business models, and sustains economic activity across every major sector.

Powering the digital surge: What's fuelling the data centre growth?

Data centres are now at the heart of the digital world, supporting everything from online services to cloud and AI application. As data consumption rises and digital adoption grows, data centres have become an essential infrastructure. There are several key factors that have been driving the rapid growth and evolution of data centre in India, some of which have been detailed out below

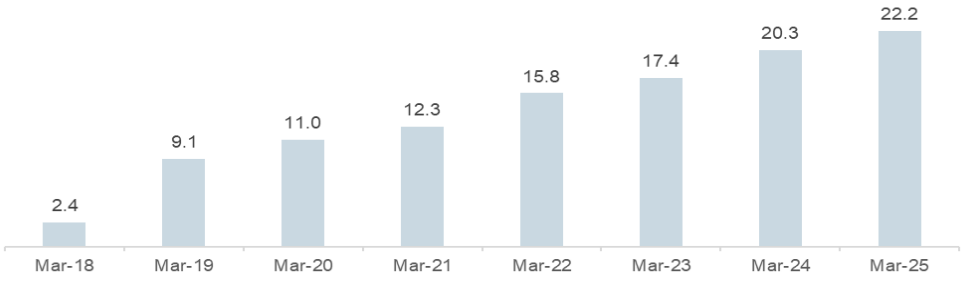
Digitalisation and surge in data consumption

Digitalisation has been the epicentre of India's growth story, the evolution from a paper-based economy to a digital economy has been rapid. With a vast and rapidly growing internet user base, India is seeing a tremendous rise in digital transactions, smartphone usage, and the use of internet services. This shift is creating strong tailwinds for data centre growth. The number of internet subscribers grew from 252 million in March 2014 to 969 million by March 2025—an increase of 284.5%. Of these, 58% are from urban areas, while the remaining 42% are from rural parts of the country. Greater internet access has led to a surge in the use of social media and cloud-based services, boosting data consumption and storage needs across both rural and urban regions.

Furthermore, the rapid adoption of digital payments, especially through the Unified Payments Interface (UPI), has also added to the rise in data traffic. According to the National Payments Corporation of India (NPCI), UPI transactions reached 1,840 crores in June 2025 alone, showing how deeply digital finance is becoming part of everyday life.

One of the most significant outcomes of this digital shift is the sharp rise in data consumption. The monthly data usage per wireless subscriber rose from just 2.4 GB in March 2018 to 22.2 GB in March 2025 This growth is mainly due to wider smartphone access, affordable data plans, and changing user habits that favour constant online connectivity.

Figure 104: India's data consumption per user per month (2018- 2025)



Note: Data for the month of March for each year from 2018 to 2025
Source: TRAI, CRISIL Intelligence

As more individuals, businesses, and government institutions embrace digital platforms, the volume of data being generated, shared, and stored across India is rising sharply. This trend is fuelling the demand for local data hosting and storage infrastructure, highlighting the strategic need to develop and expand data centres across the country.

Government interventions to fastrack industry growth

The government plays a crucial role in the growth of any sector, with policy reforms and strategic initiatives often acting as key enablers. Recognising the rising demand for data and the need for faster, more efficient storage infrastructure, the government has placed emphasis on the development of data centres.

Digital India is a flagship initiative of the Government of India, launched with the vision of transforming the country into a digitally empowered society and knowledge economy. At its core, the programme aims to integrate digital technologies across various government services, thereby reducing the gap between the state and its citizens and eliminating the role of intermediaries. The initiative has made governance more transparent and efficient, and has significantly improved access to services, especially for rural populations.

Over the years, the programme has delivered tangible results. Mobile connectivity has reached nearly every village, while public internet centres have opened digital access for millions. One of the key enablers of rural connectivity has been BharatNet, which, as of January 2025, has connected more than 2.18 lakh Gram Panchayats with high-speed internet. Additionally, platforms such as the Government e-Marketplace (GeM) have revolutionised procurement processes, with GeM recording a Gross Merchandise Value (GMV) of Rs 4.09 lakh crore in the first 10 months of FY 2024–25—a nearly 50% increase over the same period last year. Other key milestones include the generation of 138 crore Aadhaar numbers, the issuance of 981 crore documents via DigiLocker, 8.6 crore registrations under UMANG, and over 18.26 crore enrolments for the DIKSHA education platform.

Building on this digital momentum, the Government launched the India AI Mission on 7 March 2024. With a total outlay of Rs 10,371.92 over five years, the mission aims to create a robust and inclusive AI ecosystem. It focuses on democratising access to computing power, enhancing datasets, encouraging innovation, supporting start-ups, and ensuring the ethical use of AI. By 30 May 2025, India had achieved a major infrastructure milestone, with the country's national compute capacity crossing 34,000 GPUs, underlining its commitment to becoming a global leader in AI-driven innovation.

The Union Budget 2026-27 also aims to position India as a global hub for digital infrastructure by offering a tax holiday until 2047 for foreign cloud service providers operating through Indian data centres. This policy seeks to

attract large-scale investments in AI and cloud computing, which require significant upfront capital, energy, cooling, and skilled manpower. The long-term certainty provided by the tax holiday is designed to bring critical digital infrastructure into India and support the rapid growth in global demand for AI compute capacity.

Additionally, the budget launches India Semiconductor Mission (ISM) 2.0 with a Rs. 1,000 crore allocation for FY 2026-27. This initiative focuses on developing semiconductor design and manufacturing capabilities, producing essential materials, expanding the design ecosystem, and strengthening talent development. These efforts aim to build core electronics manufacturing capability vital for supporting digital infrastructure like data centres and advanced computing systems

These transformative initiatives are not only moving India towards a digital economy but also indicating the need for robust digital infrastructure.

Rollout of 5G and need for edge computing

The rollout of 5G services across the country, which began in 2023, is a key step in India's journey towards digital transformation. As of now, 5G coverage has been extended to a remarkable 99.8% of the country's districts. Furthermore, by July 2024, a total of 486,000 5G Base Transceiver Stations (BTSs) had been installed by telecom operators across the country. Notably, the overall 5G wireless data usage witnessed a substantial increase in the fiscal year 2025, more than doubling from 21,074 PB to 57,042 PB. In contrast, the usage of 3G and 4G data experienced a decline during the same period.

Table 27: Wireless data usage (in PB)

Years	2G	3G	4G	5G
2021-22	507	2057	134895	0
2022-23	251	1598	158206	0
2023-24	184	1314	172201	21074
2024-25	218	915	170603	57042

Source: TRAI, CRISIL Intelligence

5G connectivity offers low latency, high-speed data transfer, and increased capacity, making it a key enabler of advanced technologies such as automation, and augmented and virtual reality. These technologies are highly data-intensive and depend on real-time processing, leading to a significant surge in data traffic across networks. The increased data usage driven by the rollout of 5G is, in turn, boosting the demand for robust digital infrastructure.
To support this, edge computing plays a vital role by processing data closer to the source, thereby reducing transmission delays. As a result, edge data centres are well-suited for low-latency applications such as 5G services. With 5G adoption expected to grow rapidly soon, the demand for edge data centres is set to rise accordingly.

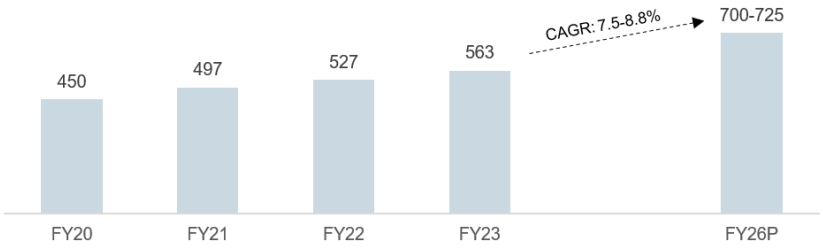
Cloud computing and OTT growth

The rapid growth of cloud computing and OTT platforms is transforming India’s digital landscape. Both have expanded significantly in recent years, driven by low-cost internet, the widespread use of smartphones, and a growing preference for online services among both consumers and businesses.
Cloud computing has become a key part of digital transformation across industries. More companies are moving their operations to cloud platforms to improve flexibility, lower IT costs, and access data and applications in real time. Sectors like e-commerce, finance, healthcare, and government are increasingly relying on cloud-based

solutions, including Software-as-a-Service (SaaS), Infrastructure-as-a-Service (IaaS), and AI/ML-driven applications.

The OTT sector in India has seen a remarkable growth. Platforms such as Netflix, Disney+ Hotstar, Amazon Prime Video, and JioCinema have gained millions of viewers. The overall online video audience is expected to reach 700-725 million in fiscal 2026, growing at a CAGR of 7.5 to 8.8%. As more people stream content in high-definition and 4K, the demand for data and internet bandwidth has risen sharply. The volume of content consumed each day, combined with the need for smooth, uninterrupted access, puts pressure on the digital infrastructure supporting these platforms.

Figure 105: Online video audience (in million)



Source: Industry, CRISIL Intelligence

To handle this surge in data, there is a growing need for scalable and well-distributed data centres. Hyperscale data centres are critical for managing large cloud-based workloads, while edge data centres are being set up closer to users to cache video content. This helps reduce delays and ensures faster, more reliable streaming experiences.

Transformation through AI, and LoT

Artificial Intelligence (AI) is growing very quickly and is now being used in many areas like education, healthcare, transport, electronics, and manufacturing. The rise of new tools like generative AI means even more people and companies are using these technologies. This has led to a sharp increase in the amount of data being created. AI needs very fast computers, low delays, and a lot of storage to work well things that only modern data centres can provide. At the same time, devices connected through the Internet of Things (IoT), such as sensors in homes, factories, and smart cities, are sending huge amounts of data that must be processed and stored efficiently.

Big data analytics is also becoming more important. Businesses now use large sets of data to make better decisions, predict trends, and improve their services. To handle this, many companies are moving to advanced data centres that can manage both large volumes of data and fast processing needs.

Together, AI, IoT, and big data are creating a strong demand for more data centres in India

Challenges slowing the growth of Data centres

While Data centre holds huge growth potential it also faces significant challenges**.** Some of these challenges are as follows:

- **Lack of uniformity in Data centre policies across states:**

several state governments have introduced or are in the process of drafting their own data centre policies. While the intent to promote the sector is positive, the resulting landscape is fragmented, with varying and at times conflicting regulations, incentives, eligibility criteria, and norms across states. This lack of uniformity creates confusion, increases compliance burden, and slows down decision-making for developers and investors. To ensure cohesive and nationwide growth of the sector, India requires a harmonised national framework. A model data centre

policy, ideally issued by TRAI, could serve as a guiding template for states. State-level deviations, if any, should be minimal and well-justified to maintain consistency and ease of doing business across the country.

- **Multiple approvals, impact ease of doing business**

Similar to other infrastructure sectors, the development of data centres involves navigating multiple layers of regulatory approvals. Developers are often required to obtain clearances from various departments at different stages of the project. In the absence of a single-window clearance mechanism, this fragmented process can lead to delays and pose significant challenges for timely and efficient data centre development. Even though certain states have implemented single window clearance

- **Regulatory and cost barriers to renewable energy adoption by Data centres**

Data centres, being energy-intensive infrastructure, are increasingly willing to adopt renewable energy sources to ensure reliable and sustainable operations. However, in many Indian states, the use of green power is rendered uncompetitive due to a host of additional charges such as transmission fees, wheeling charges, cross-subsidy surcharges, additional surcharges on third-party power purchase agreements (PPAs), and banking charges. While the central government has introduced Open Access (OA) provisions to facilitate renewable energy sourcing, state-level restrictions and inconsistencies undermine its effectiveness. Furthermore, the process for procuring Renewable Energy Certificates (RECs) remains complex, involving burdensome registration with energy exchanges and the use of advanced software systems. These challenges not only hinder the adoption of green power by data centres but also run counter to India's broader clean energy targets.

- **Lack of dedicated building classification for Data centres**

Data centres, owing to their unique technological and operational requirements, require classification as a distinct category of buildings. However, this recognition is currently lacking in India. The National Building Code (NBC 2016) does not identify data centres as a separate category, forcing them to comply with norms meant for commercial office buildings. This misalignment results in increased construction costs and regulatory hurdles, as the specific needs of data centres such as higher floor loads, advanced cooling systems, and specialised electrical infrastructure are not adequately addressed. Recognising data centres as a special building type within the code is a longstanding demand of industry stakeholders

- **Scarcity of suitable land and infrastructure for Data centre development**

Data centres face intense competition for critical resources such as land and power, often contending with other sectors for access. Unlike other real estate asset classes, data centres have highly specific location requirements driven by their dependence on reliable telecom connectivity, robust power infrastructure, access to water, and proximity to demand centres. In major data centre hubs, the availability of suitable land—free from legal, environmental, or logistical constraints—is becoming increasingly scarce and expensive. The development of a data centre involves careful consideration of multiple factors including city-level economic activity, access roads, viable cable routes, skilled workforce, and environmental risks such as seismic activity or flooding. This complex set of requirements makes it increasingly difficult to identify and secure land banks in urban areas that can support efficient and sustainable data centre development.

General recommendations to overcome these challenges.

- Establish a central Data centre policy governed by the national council to ensure uniform standards, faster approvals and coordinated growth across all sectors

- Implement a single-window clearance system to streamline and fast-track all Data centre approvals across various departments and stages
- Provide incentives to DC operators as Government subsidy to make renewable energy accessible and affordable to Data centres.
- Develop dedicated building standards tailored specifically for data centres, created in consultation with industry stakeholders, to address their unique structural, operational, and safety requirements.

Ensure availability of suitable land for data centres through dedicated zones/ Data centre parks or land banks, with clear titles, essential infrastructure and streamlined allotment processes.

Data centres booming in India

Industry to see Rs 32,000 to 34,000 crores in investments in CY 2025
India's push towards a digital economy has created a massive demand for data centres. Recognising the country's potential in this space, global players – hyperscalers, global and regional data centre players, real estate developers and private equity-backed platforms – have announced sizeable investments.

Hyperscalers

- Google and Adani Connex announced a partnership in October 2025, to develop India's largest AI data centre campus and new green energy infrastructure in Visakhapatnam, Andhra Pradesh, with a total investment of approx. Rs 1,33,000 crore for over five years from 2026 to 2030.
- Amazon Web Services (AWS) announced an investment of Rs 70,550 crore in January 2025 in cloud infrastructure in the AWS Asia-Pacific (Mumbai) region, with a memorandum of understanding (MoU) signed with the Government of Maharashtra
- Microsoft announced an investment of Rs 25,500 crore in January 2025 to be spread over the next two years on cloud and artificial intelligence (AI) infrastructure, including the expansion of Azure, at least three new data centres, and a goal to train 10 million people in AI and machine learning (ML), along with support for public sector AI adoption

Global and regional data centre players

- NTT purchased a 2.4-acre land in Mumbai for Rs 855 crore as part of its global data centre expansion plans
- NTT and Neysa Networks entered a tripartite MoU with the Government of Telangana in April 2025 to build a 400 MW data centre cluster (25,000 GPUs) in Hyderabad, outlining an investment of Rs 10,500 crore

- STT signed an MoU with the Government of Telangana in April 2025 to establish a 100 MW data centre in Hyderabad, earmarking an investment of Rs 3,500 crore. The broad goal is to achieve 1 GW capacity across India in this decade with a total investment of Rs 27,200 crore
- Digital Edge, NIIF and AGP DC have partnered to set up data centres across India, with plans to infuse Rs 17,000 crore to build 300 MW greenfield data centre in Mumbai
- CapitaLand signed an MoU with the Maharashtra government to increase its presence in the state by investing over Rs 19,200 crore by 203
- Princeton Digital Group secured a green loan of Rs 1,360 crore for its flagship MU1 data centre in Navi Mumbai, taking its total green loan portfolio to over Rs 61,800 crore. The company has also leased over 1.06 million square feet of space in Navi Mumbai, to develop its largest data centre campus in India

Real estate developers and private equity-backed platforms

- Blackstone Group and Panchshil Realty (Lumina Cloud Infra) plan to develop India's largest hyperscale data centre of 500 MW capacity in Navi Mumbai, with an investment of over Rs 20,000 crore, comprising 65% green energy, 14 buildings, and 3 million sq ft of space. Land has been acquired for Rs 900 crore in Ghansoli, Navi Mumbai
- Anant Raj plans to spend Rs 18,000 crore on setting up two data centres in Haryana, with a goal to achieve 300 MW capacity by 2032

Power and sustainability

- Nxtra has inked a 125.65 MW renewable power-wheeling deal with AmpIn in India, highlighting the growing focus on sustainable power solutions in the data centre industry

Data localisation and privacy policy

The increasing reliance on data has raised concerns regarding its misuse, underscoring the fact that growth and development come with inherent challenges.

To address the concerns and safeguard the country's sovereignty, the government has introduced several directives aimed at localising data storage and regulating data processing.

Financial data, including history of UPI payments and online money transfer data, is a sensitive and high-risk category that requires stringent protection. In response, the Reserve Bank of India (RBI) has implemented a data localisation mandate, requiring banks and financial institutions to store data within India. This directive also applies to foreign banks and companies such as Google and Amazon, which operate UPI-based payment systems in the country, necessitating the transfer of related data to domestic storage facilities.

The Securities and Exchange Board of India, on its part, has introduced a Cybersecurity and Cyber Resilience Framework, which imposes stringent requirements on regulated entities (REs). To comply with these regulations, REs needs to establish additional storage facilities or leverage cloud services in India to meet their data storage needs. This development is expected to drive demand for secure and compliant data storage solutions in the country.

Further, the Digital Personal Data Protection Act, 2023 (DPDP Act) aims to promote data privacy and minimisation. India’s first comprehensive legislation dedicated to protecting digital personal data, the DPDP Act establishes a legal framework governing how businesses and government entities can collect, process and store the personal data of individuals. It applies to the processing of personal data within India and emphasises on a consent-based framework to provide protection against misuse. The law is built on several foundational principles including lawful and transparent usage, purpose limitation and data minimisation. To operationalise the DPDP Act, the Ministry of Electronics and Information Technology released the draft DPDP Rules 2025. The key provisions are enhanced transparency, limits on cross-border data transfers and obligations to notify authorities in case of data breach. This will empower individuals to have greater control over their data.

Data centre growth drivers

- **Mandatory onshore storage to act as a demand trigger:** By requiring all payment data to reside in India, without exceptions for foreign servers, the data localisation mandate forces financial institutions and payment operators to migrate workloads to facilities in the country. Firms will either build their own facilities (high spending and difficult operations) or use cloud or colocation services in India, providing impetus to data centre capacity addition in the country
- **Compliance-driven investments:** In case of data breach, firms are required to report it within strict timelines, favouring certified data centres with audit-ready systems over in-house setups. Moreover, non-compliance with data privacy policies might incur fines of up to Rs 250 (enough to build a 4-6 MW data centre or lease one for a good few years). This indicates a favourable return on investment for local cloud storage options
- **RBI's planned cloud pilot:** To support small banks and financial institutions that are unable to afford global providers, the RBI plans to start operating its own cloud storage service, offering affordable local storage, thus enabling more institutions transition smoothly into local options, further boosting capacity demands

Competitive assessment of Data centre companies

Ctrl S Data centres limited: CtrlS, set up in 2007, offers a wide range of services such as hyperscale facilities, collocation, work area recovery, and managed services. It works with more than 20 Fortune 100 companies and serves large industries like banking, telecom, and IT/ITES. Today, CtrlS runs over 16 data centres across nine key cities with an operational capacity of 250 megawatts. CtrlS also invests in 153 MWp of solar power projects that will generate 250,000 MWh of clean energy. As of fiscal 2024, CtrlS had an operating revenue of Rs 1,390 crore and an operating and net profit margin of 47.4% and 16% respectively

Airtel Nxtra: Airtel Nxtra operates 15 hyperscale data centres across eight major markets along with 66 edge locations across India. The company has a total power capacity of over 230 MW and provides services including colocation, built-to-suit facilities, interconnect solutions, and managed support. Backed by Airtel's telecom infrastructure, Nxtra combines its data centre operations with strong network connectivity to serve enterprise customers across sectors.

Sify technologies: Sify Technologies, one of India's early data centre and ICT service providers, has built a strong footprint in the country's digital infrastructure ecosystem. The company operates 14 data centres located in key hubs such as Mumbai, Chennai, Bengaluru, Hyderabad, Noida, and Kolkata. Its service offerings include colocation, built-to-suit data centres, interconnect solutions, and green data centres, reflecting a focus on both scalability and sustainability. With a total IT capacity of 188 MW, Sify supports enterprises across diverse sectors through its pan-India network of facilities. As of fiscal 2025, the company had an operating revenue of Rs 39,886 and an operating and net profit/loss margin of 19% and -2% respectively.

Yotta Infrastructure: Backed by the Hiranandani Group, Yotta has been expanding its presence in India's data centre market through a mix of large-scale facilities and planned data centre parks. The company currently operates four data centres, Yotta NM1 and TB1&TB2 in Navi Mumbai, Yotta D1 in Greater Noida and Yotta G1 in GIFT city with a combined IT power capacity of 84 MW**.** In addition, it is developing a network of data centre parks across Mumbai, Pune, Chennai, Kolkata, and Gujarat. Yotta's service portfolio covers the full stack of data centre solutions, including colocation, connectivity, cloud services, managed security, IT managed services, and SAP solutions.

Adani Connex: Adani Enterprises Ltd. entered the data centre industry in 2020 through a 50:50 joint venture with EdgeConneX, known as AdaniConneX, a US based global data center firm, with the objective of developing a network of hyperscale data centres across India. The venture aims to deliver 1 gigawatt of environmentally and socially responsible data centres by 2030. AdaniConneX has secured over 210 MW orders from enterprise and hyperscale clients. Its operational capacity across Chennai, Hyderabad and Noida currently stands at 36.6 MW, positioning Adani as a prominent emerging player in India's data centre sector. Since its inception, it has made notable progress, with 174.4 megawatts of capacity under construction in Noida, Hyderabad and Pune, and work commenced on a 30-megawatt facility in Navi Mumbai.

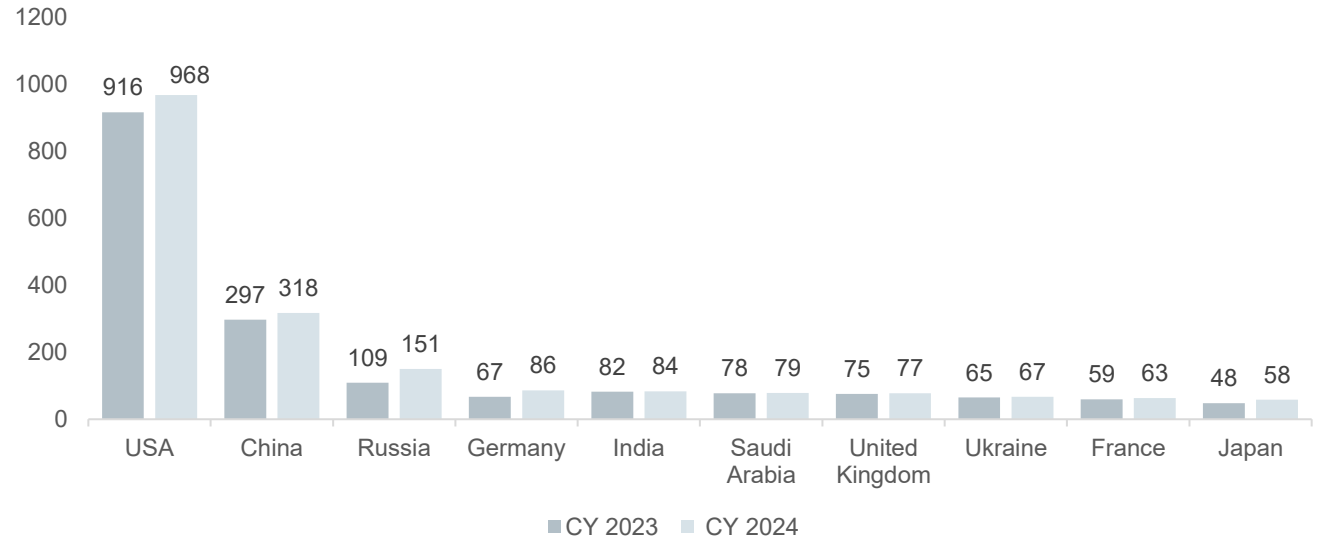
Module 9: Manufacturing – Special Manufacturing – Defence & aerospace

Overview

Aerospace and defence industry deals with the manufacturing and supply of aircraft, helicopters, missiles, radars, satellites, other defence equipment or components for these equipment. The industry can be classified into Tier 1 and 2 manufacturers. While Tier I manufacturers prepare final products such as aircraft, helicopters and missiles, Tier II manufacturers provide components for these equipment.

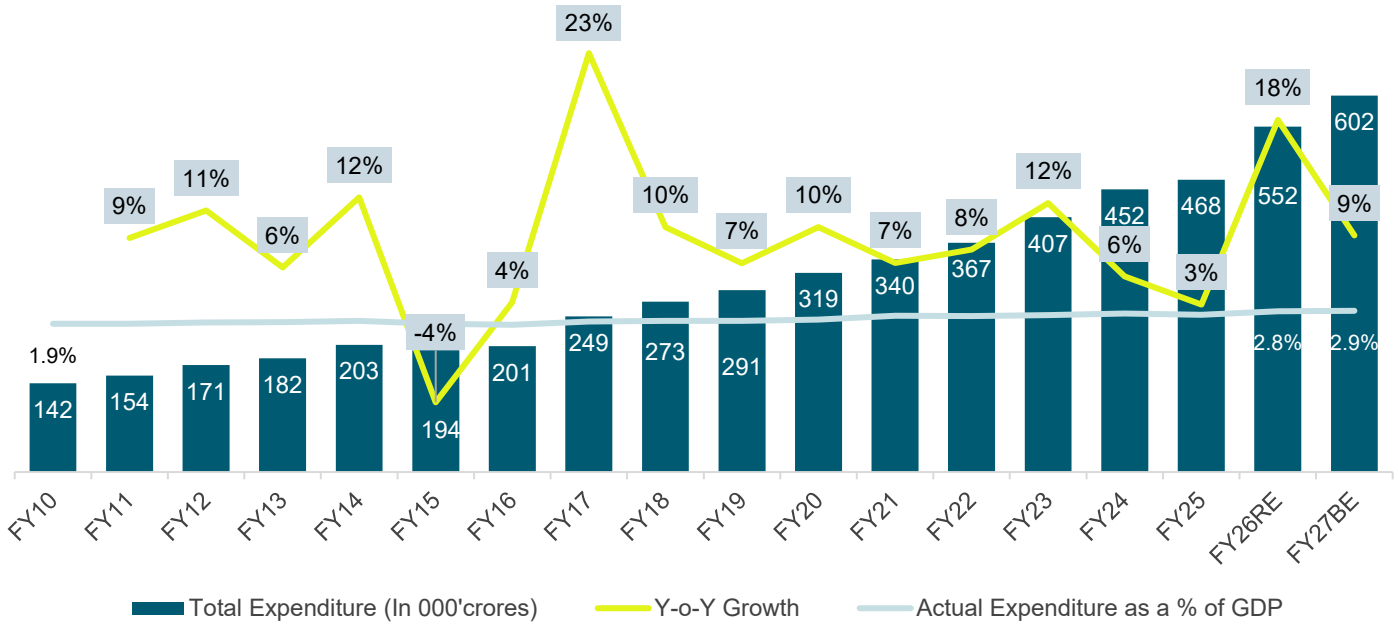
The key driving factor for growth in the industry is capital expenditure on defence procurement by the Government of India. Expenditure on defence (both revenue and capex) recorded an 9.5% CAGR over fiscals 2016 to 2026, rising from Rs 202,000 crore to Rs 552,000 crore. Outlay for fiscal 2027 is budgeted to record a 9% on-year increase to Rs 602,000 crore. India is the third largest country in the world based on defence expenditure, behind the USA and China, accounting for 3.33% of global military spending per SIPRI. The capital outlay portion of India's defence has been on a rise, but India's purchase of defence equipment has been dominated by imports. In line with Aatmanirbhar Bharat and keeping geopolitical factors in mind, the government has mandated a minimum of 75% of defence purchases reserved for Indian companies. Policies have been framed to boost the Indian defence manufacturing ecosystem in India.

Figure 106: Military expenditure by top 10 countries at current price and exchange rate ($ billion)



Source: SIPRI, Crisil Intelligence

Figure 107: Annual defence budget expenditure in value and growth rate in defence expenditure and as a percentage of GDP



Note: Budget expenditure excluding civil and pension
Source: Union budget documents, Crisil Intelligence

India's defence expenditure has steadily increased over the years, rising from Rs 2.01 lakh crore in FY16 to Rs 6.02 lakh crore in FY27 recording a CAGR of 9.5% which includes both capital and revenue expenditure. This growth in defence expenditure has outpaced India's GDP growth rate of 5% over the same period, indicating the government's continued commitment to strengthening defence capabilities. As a result the share of GDP, defence spending rose from 1.9% in FY16 to 2.8% in FY26 and move up to 2.9% in FY27.

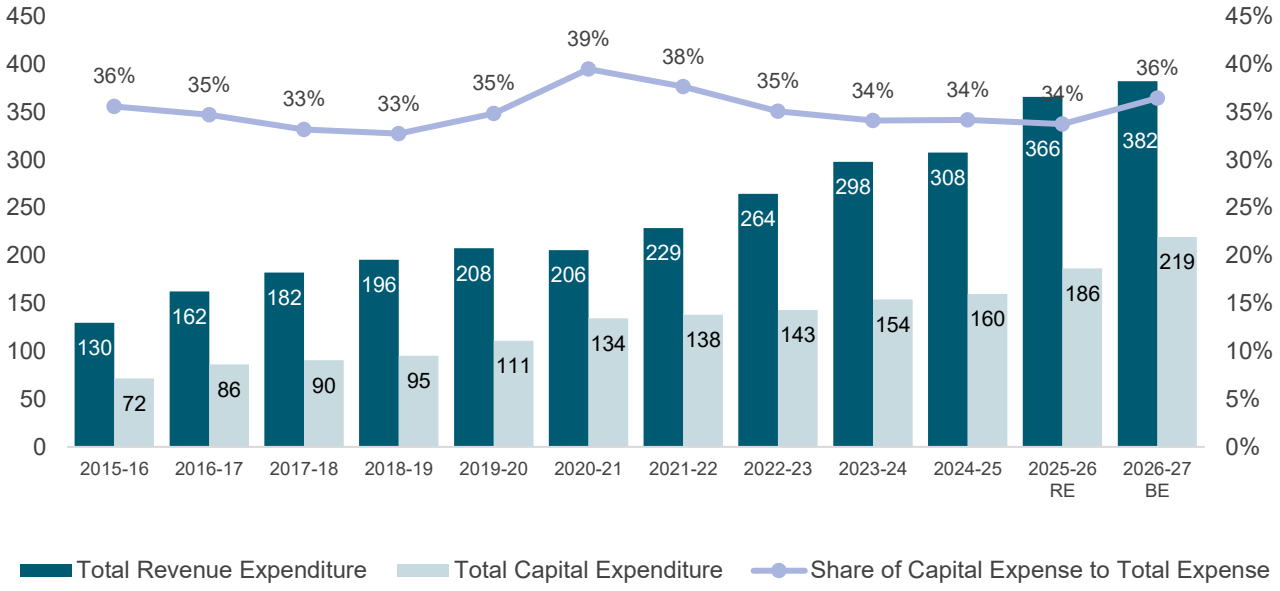
Notably, this figure excludes pension outlays for retired personnel, focusing purely on capital and revenue spending for active defence needs.

Capital outlay—which finances the acquisition of new military equipment and infrastructure—has increased from Rs 72,000 crore in FY16 to Rs 219,000 crore in FY27 (BE) recording a CAGR of 10.6%, growing in line with overall defence. Despite this growth, the capital share has remained stable at 36% between both FY16 and FY27BE.

Revenue expenditure, which covers salaries, maintenance, logistics, and operational costs, has also maintained a consistent share of 64%. It rose from Rs 1.3 lakh crore in FY16 to Rs 3.2 lakh crore in FY26BE.

This steady rebalancing indicates India's strategic shift towards strengthening long-term defence preparedness rather than focusing solely on routine expenses.

Figure 108: Segmentation and details of defence expenditure – Capital and revenue expenditure



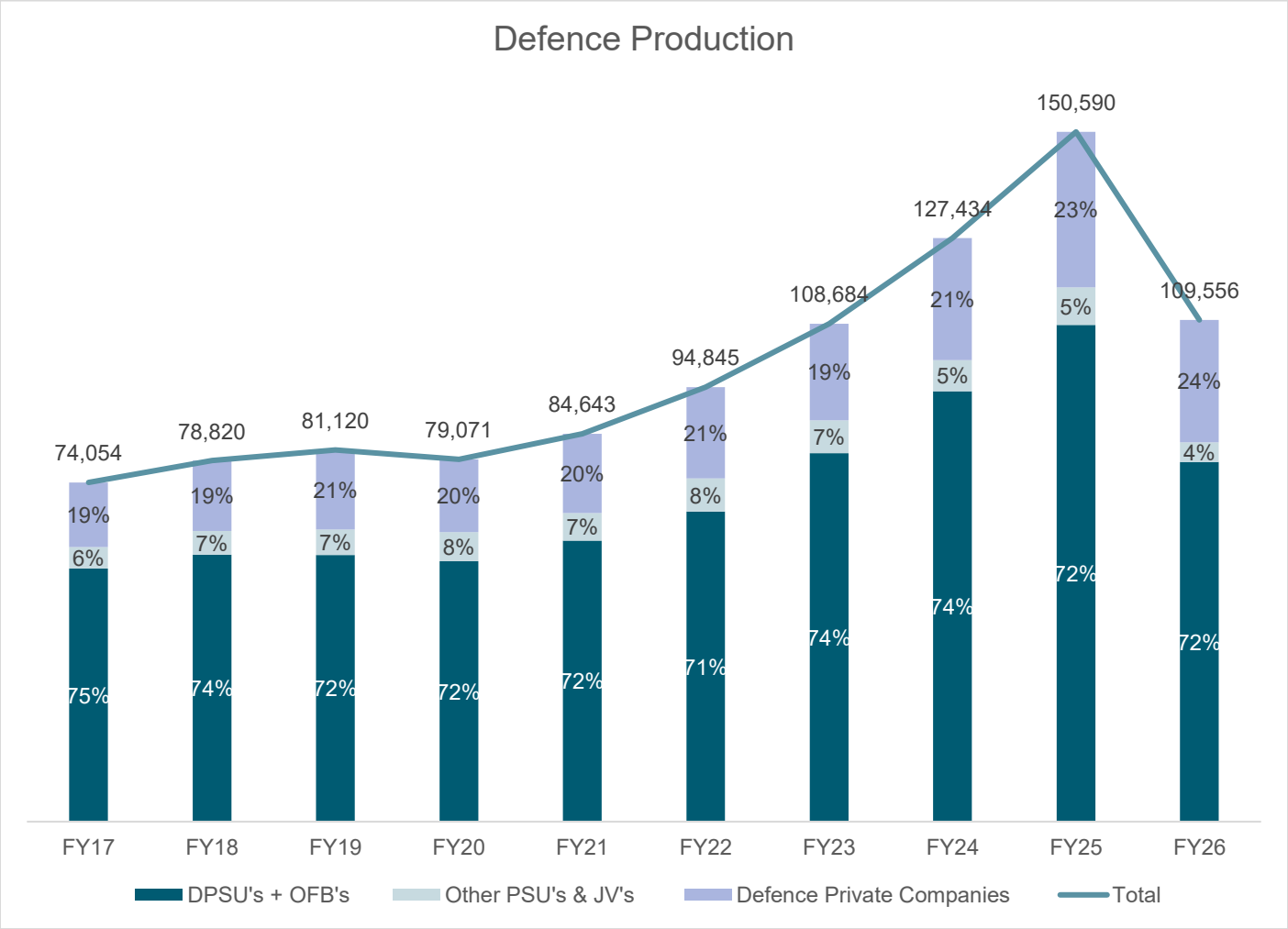
Note: Budget expenditure excluding civil and pension
Source: Union budget documents, Crisil Intelligence

Review of defence production for FY17-FY26

In May 2001, the Government of India (GoI) opened India's defence sector to 100% participation for Indian private sector. Since then, successive governments have taken efforts to increase the participation of private sector in the defence and aerospace segment. According to the Ministry of Defence data, as of July 2021, 333 private companies were issued a total of 539 industrial licences, and of these, 110 companies reported commencement of production. To aid domestic procurement, the government has earmarked 75% of the total defence budget outlay for domestic procurement. To aid improved domestic manufacturing, the government corporatised 41 Ordnance Factory Boards into seven defence public sector units effective October 1, 2022, to improve cost efficiency, improve expertise across products, and increase competitiveness, functional autonomy, growth potential and innovation in the defence sector.

India's defence manufacturing sector witnessed a CAGR of 2.1% between fiscals 2017 and 2025. Defence manufacturing consists of defence PSUs, joint ventures and private defence companies.

Figure 109: Share of public vs private sector production



Source: Ministry of Defence, Crisil Intelligence

Note: FY26 numbers are as of latest available data

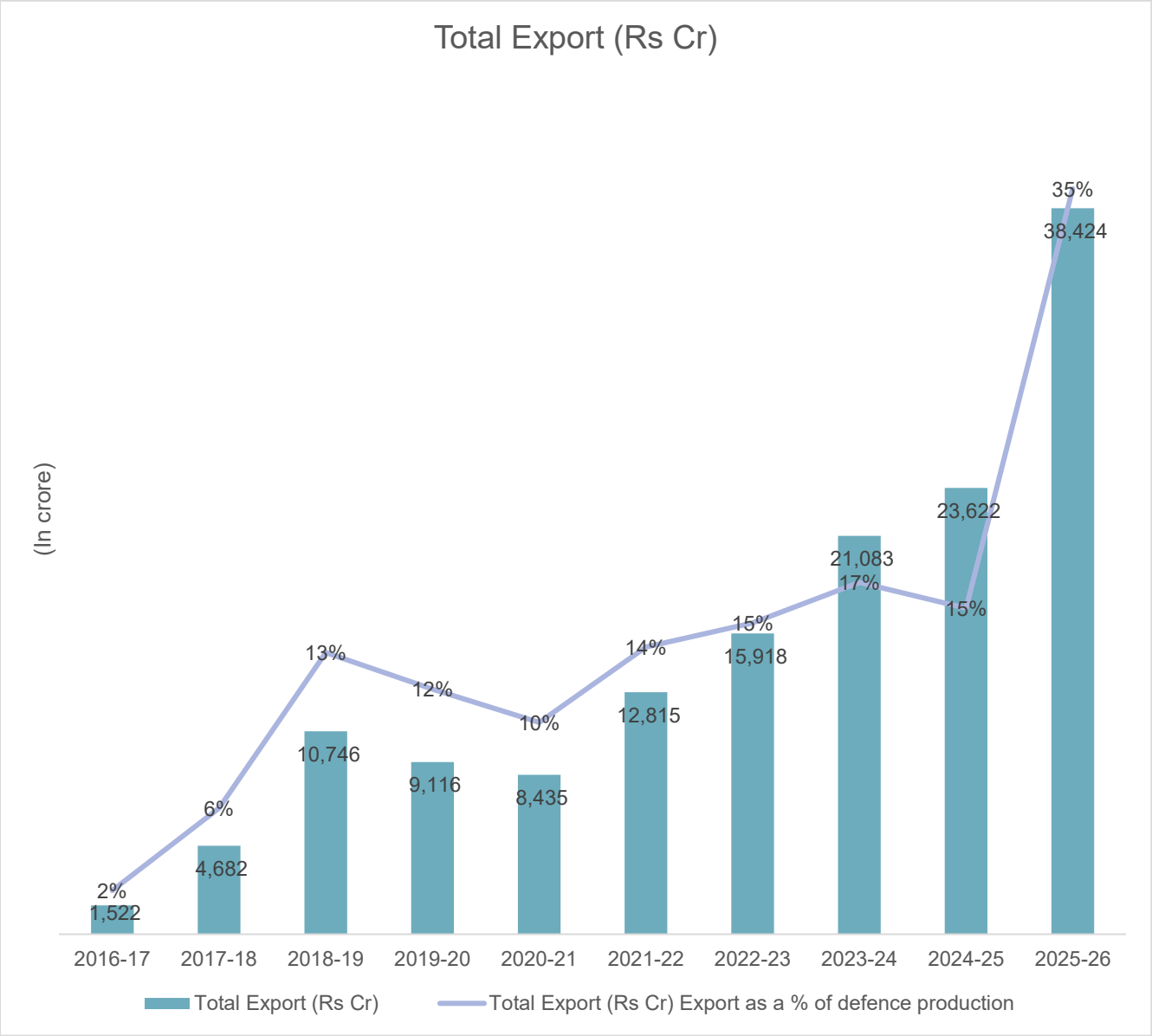
Crisil observed that year-end data is subject to revisions due to pending deliveries, private sector inputs, and late submissions. Crisil suggests relying on final year-end numbers for accurate analysis, as they incorporate these revisions and provide a more comprehensive picture.

Indian Defence production has been on a secular uptrend, doubling from FY17 to FY26 at ₹109,556 crore. DPSUs and OFBs continue to dominate, accounting for 70–75% of total production over the years. The share of private companies is on an upswing, rising from 19% in FY17 to 23% in fiscal 2025 which bodes well for the steps taken by the Government to improve private participation in defence manufacturing. Defence production for FY26 is at Rs 109,556 Crores with 72% share from DPSUs and OFBs, 24% from Defence private companies and the rest 4% from other public sector undertakings and joint ventures.

India, mainly reliant on imports of defence equipment over the years has seen an upswing in its exports aided by continuous efforts by the Indian government and the defence companies. India's defence exports have risen from ₹1,522 crore in FY17 to ₹38,424 crore in FY26. Exports grew significantly both in value and as a percentage of total defence

production, increasing from 2% to 35%, indicating strong growth momentum and improved global market presence in Indian defence products.

Figure 110: Defence exports



Source: Ministry of Defence, Crisil Intelligence

Note: Crisil observed that year-end data is subject to revisions due to pending deliveries, private sector inputs, and late submissions. Crisil suggests relying on final year-end numbers for accurate analysis, as they incorporate these revisions and provide a more comprehensive picture.

Growth drivers

1. Increased Government Spending: The Indian defence industry is primarily fueled by government spending, with the defence procurement and modernization initiatives being state-funded. The consistent allocation of funds for defence modernization, infrastructure development, and the acquisition of cutting-edge systems generates a steady stream of demand. India's defence expenditure has steadily increased over the years, rising from Rs 2.01 lakh crore in FY16 to Rs 4.65 lakh crore in FY25 recording a CAGR of 8.7% which includes both capital and revenue expenditure. This ongoing government support ensures a stable influx of capital into the sector, allowing both public and private entities to scale up their operations and invest in innovative technologies, driving growth and development.

2. Push for Localization (75% Target): To aid domestic procurement, the government has earmarked 75% of the total defence budget outlay for domestic procurement. This move emphasizes the importance of building a self-reliant ecosystem where a significant portion of equipment, components, and technologies are sourced domestically. By reducing dependency on foreign suppliers, localization not only strengthens India's industrial base but also provides long-term opportunities for local manufacturers, MSMEs, and startups engaged in the defence supply chain.

3. Indigenous Production & Import Restrictions: To further support domestic capability building, the government has published a negative import list—an inventory of defence goods that cannot be imported and must instead be manufactured locally. This policy creates a guaranteed domestic market for indigenous products and encourages the development of local expertise, R&D, and production capabilities. The Defence Acquisition Procedure (DAP) 2020 is aligned with the government's vision of making India a global manufacturing hub. It is designed to boost indigenous defence capability and reduce reliance on imports under the Make in India and Atmanirbhar Bharat initiatives. As a result, domestic players gain competitive advantage, and the industry witnesses substantial growth opportunities in both manufacturing and technology development.

Defence corridor and investments

The GoI established two defence industrial corridors in the country: Uttar Pradesh Defence Industrial Corridor with six nodes (Aligarh, Agra, Chitrakoot, Jhansi, Kanpur and Lucknow) and Tamil Nadu Defence Industrial Corridor with five nodes (Chennai, Coimbatore, Hosur, Salem and Tiruchirappalli).

The Uttar Pradesh Expressways Industrial Development Authority, the nodal agency for the Uttar Pradesh Defence Industrial Corridor has signed 62 MOUs with industries to attract potential investments of ~Rs 8,638 crore as of Feb 2022. 25 out of the 62 proposals have been finalised and land has been allotted.

Tamil Nadu Industrial Development Corporation, the nodal agency for Tamil Nadu Defence Industrial Corridor, has signed MOUs with 40 industries to attract potential investments of ~Rs 11,153 crore as of as of Feb 2022.

Government policies and regulations

Defence Acquisition Procedure (DAP) 2020

The first defence procurement policy was formulated in 2002 to institutionalise, streamline and simplify defence procurement procedure. It was revised in March 2016, to focus on indigenously design, develop and manufacture weapon systems.

In 2020, the Ministry of Defence released the new DAP to simplify the procedure for defence procurement and acquisition in order to modernise the armed forces.

The DAP is aligned with the government's vision of making India a global manufacturing hub. It is designed to boost indigenous defence capability and reduce reliance on imports under the Make in India and Aatmanirbhar Bharat initiatives.

The aim of the DAP is to ensure timely procurement of military equipment, systems and platforms as required by the armed forces in terms of performance, capabilities and quality standards, through optimum utilisation of allocated budgetary resources.

Capital acquisition schemes are broadly classified as buy, buy and make, leasing, design and development (D&D), and strategic partnership model (SPM). Under the buy scheme, procurements are categorised as buy (Indian - IDDM), buy (Indian), buy (global - manufacture in India), and buy (global). Under the buy and make scheme, procurements are categorised as buy and make (Indian) and buy and make.

In decreasing order of priority, the categories will be as follows:

(a) Buy (Indian - IDDM)

(b) Buy (Indian)

(c) Buy and make (Indian)

(d) Buy and make

(e) Buy (global - manufacture in India)

(f) Buy (global)

Buy (Indian - IDDM) – This category refers to the procurement of products from an Indian vendor, which have been indigenously designed, developed and manufactured with a minimum of 50% indigenous content (IC) on cost basis of the total contract value.

Buy (Indian) – This category refers to the procurement of products from an Indian vendor meeting one of the two conditions: products that have been indigenously designed, developed and manufactured with a minimum of 50% IC on cost basis of the total contract value; or products that may not have been designed and developed indigenously, having 60% IC on cost basis of the total contract value.

Buy and make (Indian) – This category refers to an initial procurement of equipment in fully formed (FF) state in quantities as considered necessary, from an Indian vendor engaged in a tie-up with a foreign OEM, followed by indigenous production in a phased manner involving transfer of critical technologies as per specified range, depth and scope from the foreign OEM. Under this category, a minimum of 50% IC is required on cost basis of the make portion of the contract.

Buy and make – This category refers to an initial procurement of equipment in FF state from a foreign vendor, in quantities as considered necessary, followed by indigenous production through an Indian production agency, in a phased manner, involving transfer of critical technologies as per specified range, depth and scope, to the production agency. With a view to maximise indigenous production in each procurement case, the AoN according to authority would approve an appropriate ratio of FF, completely knocked down, semi knocked down and indigenous manufacture kits; and a minimum percentage of 50% IC on cost basis for the make portion of acquisitions under the buy and make category.

Buy (global - manufacture in India) - This category refers to an outright purchase of equipment from foreign vendors as approved by the AoN according authority, in quantities as considered necessary, with a minimum of 50% IC on cost basis of the total contract value, which can be achieved in the manufacturing of either the entire equipment or spares/assemblies/sub-assemblies/maintenance.

Buy (global) - This category refers to outright purchase of equipment from foreign or Indian vendors. In case of procurement through foreign vendors, the government-to-government route or inter-government agreement may be adopted, for equipment meeting strategic/long-term requirements

Leasing - Leasing is introduced as another category for acquisition in addition to the existing buy and make category as it provides for an innovative technique for financing of equipment. Leasing provides means to possess and operate the asset without owning the asset and is useful to substitute huge initial capital outlays with periodical rental payments. Leasing has two subcategories: lease (Indian), where the lessor is an Indian entity and is the owner of the asset, and lease (global).

D&D/Innovation - Acquisitions covered under the D&D/innovation category refer to equipment/system/ subsystem/assembly/sub-assembly, major components, or upgrades thereof, to be designed, developed and manufactured by an Indian vendor/similar D&D projects by DRDO/ processed by the Services through their internal organisations such as base workshop, dockyards or base repair depots, with or without participation of the private industry, as per procedure and norms detailed in Chapter III of the DAP.

SPM. Acquisitions under the SPM refer to participation of private Indian firms and foreign OEMs in Make in India in defence and play the role of a system integrator by building an extensive eco-system comprising development partners, specialised vendors and suppliers, in particular those from the MSME sector. Strategic partnerships will seek to enhance indigenous defence manufacturing capabilities through the private sector over and above the existing production base. Detailed norms and procedures for the same are given in Chapter VII of the DAP.

Strategic partnership model in defence acquisition

To promote 'Make in India' in defence, the government introduced the strategic partnership model for acquisitions of aircraft, helicopters, submarines, and armoured fighting vehicles/ main battle tanks. The partnership model aims to incentivise the transfer of niche technology and higher indigenous content to Indian players, and to develop the country as a regional/ global manufacturing hub.

Acquisitions under the strategic partnership model refer to the participation of private Indian firms and foreign OEMs in 'Make in India' in defence and play the role of a System Integrator by building an extensive eco-system comprising development partners, specialised vendors and suppliers, particularly from the MSME sector. Strategic partnerships will seek to enhance indigenous defence manufacturing capabilities through the private sector over and above the existing production base. The benefit of this model to the indigenous industry is the development of the Indian defence manufacturing ecosystem.

The policy on strategic partnerships in the defence sector was approved by Defence Acquisition Council (DAC) in May 2017. It was promulgated on May 31, 2017, as Chapter VII of Defence Procurement Procedure (DPP) – 2016 titled 'Revitalising Defence Industrial Ecosystem through Strategic Partnerships'. The policy was placed before the Cabinet Committee on Security (CCS). The CCS considered the note on the policy in its meeting held on May 24, 2017, and noted the contents thereof. The chapter was uploaded on the Ministry of Defence website: https://www.mod.nic.in.

The policy is intended to institutionalise a transparent, objective and functional mechanism to encourage broader participation of the private sector, in addition to DPSUs / OFB, in the manufacture of defence platforms and equipment such as aircraft, submarines, helicopters and armoured vehicles. It will serve to enhance competition, increase efficiencies, facilitate faster and more significant absorption of technology, create a tiered industrial ecosystem, ensure development of a wider skill base and trigger innovation, leading to reduction in dependence on imports and greater self-reliance in meeting national security objectives. The following four segments have been identified for acquisition under strategic partnership route:

- Fighter aircraft
- Helicopters

- Submarines
- Armoured fighting vehicles (AFVs)/ main battle tanks (MBTs)

The strategic partnership model is a different category of capital acquisition in addition to the existing categories as mentioned in Chapter-I of DPP-2016, i.e. 'Buy (Indian-IDDM)'; 'Buy (Indian)'; 'Buy & Make (Indian)'; 'Buy & Make' and 'Buy (Global)'.

In a step to boost private sector participation in domestic defence manufacturing, the DAC approved the implementation of strategic partnership\ guidelines to reduce timelines so as to ensure timely delivery of equipment to the armed forces.

The DAC has also approved platform-specific guidelines for procurement of naval utility helicopters.

Offset policy

The objective of the defence offset policy is to partially compensate for the significant outflow in defence contracts. These contracts are big ticket size and government wants either a part of it to benefit local economy or transfer to technology.

Offset policy is applicable to 'Buy & Make' and 'Buy (Global)' categories of procurement.

Offset dilution: To reduce the cost of defence deals the government decided to remove offset clause for contacts between two governments or ab initio single vendor. All other international deals that are competitive, and have multiple vendors, will continue to have a 30% offset clause on contract value greater than Rs 300 crore.

Defence Testing Infrastructure Scheme (DTIS)

On May 8, 2020, the Ministry of Defence launched DTIS to domestic defence and aerospace manufacturing. This will help MSMEs and startups to get easy access to defence testing infrastructure. The scheme has an outlay of Rs 400 crore for creating state-of-the-art testing infrastructure over five years.

The government aims to set up 6-8 greenfield defence testing infrastructure facilities by providing up to 75% government funding, while the remaining 25% will be borne by a special purpose vehicle (SPV) backed by Indian private players and state governments.

Innovations for Defence Excellence (iDEX)

The iDEX (Innovations for Defence Excellence) initiative was launched in April 2018 with the goal of achieving self-reliance in defence and aerospace through innovation and technology development. It aims to collaborate with MSMEs, startups, individual innovators, R&D institutes, and academia to provide funding and support for research and development. As the executive arm of the Defence Innovation Organisation (DIO), iDEX facilitates, promotes, empowers, and funds participants, while DIO provides high-level policy guidance.

The initiative has gained significant momentum, with the Ministry of Defence allocating Rs 1,000 crore for the procurement of defence equipment developed by Indian startups in fiscal 2022. As of July 2024, iDEX has engaged with over 400 startups and MSMEs, resulting in the procurement of 37 items worth over Rs 2,000 crore. This has not only facilitated job creation but also played a crucial role in developing the defence ecosystem.

A recent development in the iDEX initiative is the signing of a Memorandum of Understanding (MoU) with the Armed Forces Medical Services (AFMS) on July 30, 2024. The MoU aims to foster innovation and research in developing novel medical technologies for the Armed Forces through the launch of Medical Innovations and Research Advancement (MIRA). This initiative will be propelled by the Defence India Start-up Challenge (DISC) edition MIRA, targeting critical medical challenges faced by the Armed Forces. By leveraging the strengths and expertise of both organisations, iDEX-DIO and AFMS aim to drive cutting-edge advancements in medical technologies.

Geopolitics

India is surrounded by countries with whom it does not share the friendliest of relations and witnessed military clashes in the past. The current geopolitical situation necessitates strengthening the country's aerospace and defence capabilities through self-reliance and modernisation.

The requirement of modern aircraft, weapons and defence equipment's for Indian armed forces coupled with Make in India and Atmanirbhar Bharat initiatives will boost the country's defence and aerospace sectors.

Adani's positioning - Defence

Adani Defence & Aerospace through Adani Defence Systems & Technology Ltd has set up an unmanned aerial vehicles (UAV) manufacturing facility along with existing missile facility in Hyderabad. The facility is touted to be the first private UAV manufacturing unit in India and the first one outside Israel to make UAVs.

On February 26, 2024, Adani Defence & Aerospace inaugurated mega facility in Kanpur, Uttar Pradesh under PLR Systems Pvt Ltd (PLR) in partnership with Israel Weapon Industries (IWI). to manufacture ammunition. Spreading over 500 acres, the facility will produce high-quality ammunition for the armed forces and create over 4,000 jobs with a 5X multiplier effect. The project involves an investment of INR 3000+ Crores and features state-of-the-art automation, including AI, for quality control. The facility started operations in less than 18 months, marking a significant milestone in India's journey towards self-reliance in the defence sector.

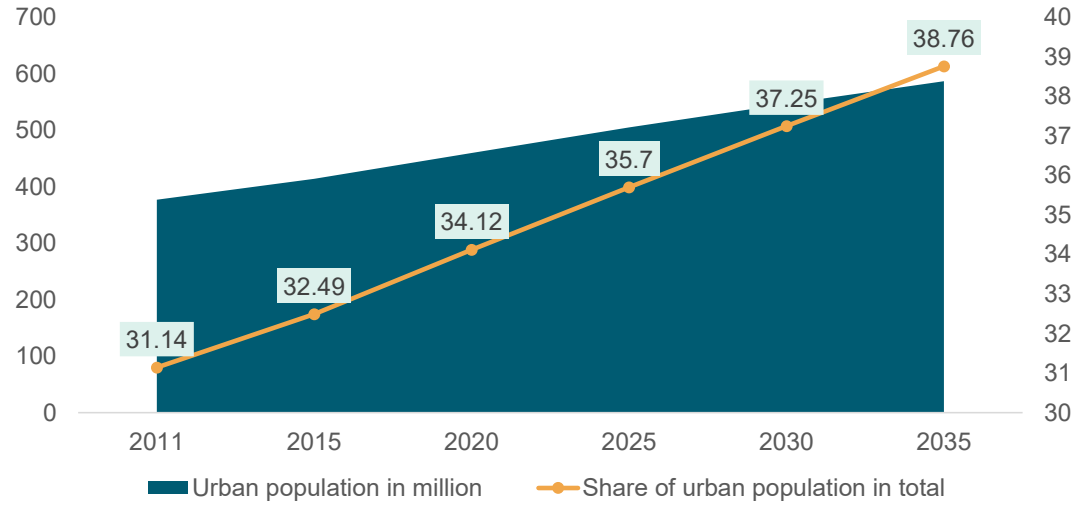
Module 10: Water Industry

Review of water supply and sanitation (WSS) industry in India

Gearing up for India's rapid urbanization

India's rapid urbanization is expected to reach a milestone by 2035, with 600 million people, or 39% of the population, residing in urban areas, up from 31% in 2011. As urban centres are projected to contribute nearly 70% to the country's GDP, effective management of this transformation is crucial to achieving India's goal of becoming a developed nation by 2047. The development of essential infrastructure is vital to creating sustainable, resilient, and inclusive cities that can drive economic growth and support the country's future prosperity.

Figure 111: Share of urban population topping at ~ 600 million by 2035



Source: World Bank, Crisil Intelligence

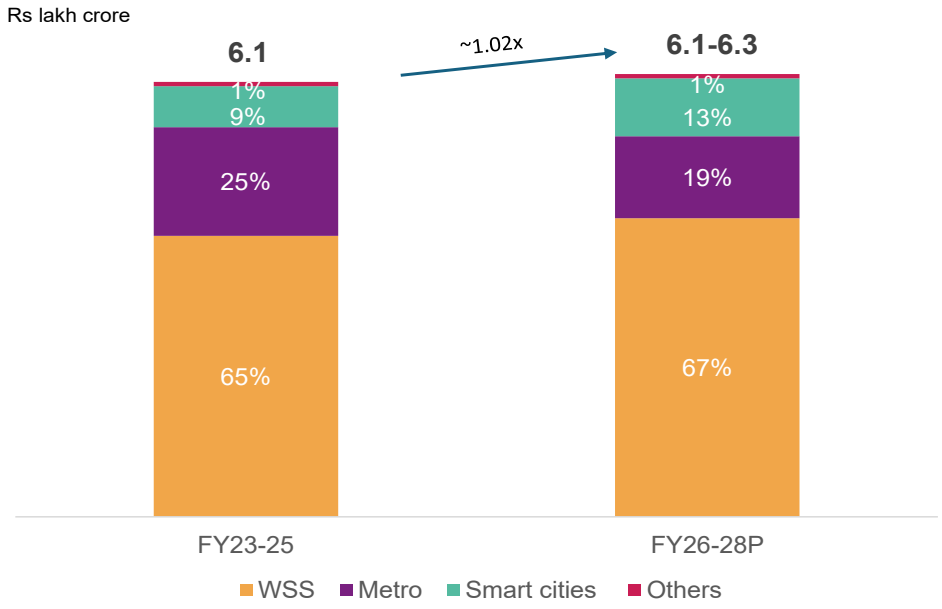
This pace of urbanization presents both a significant opportunity and a formidable challenge. As cities expand and new urban centres emerge, the demand for reliable and sustainable urban infrastructure, particularly for water supply and wastewater management is set to rise sharply.

Urban areas already face mounting pressure on existing infrastructure, with issues such as intermittent water supply, inadequate sewage networks, and untreated wastewater discharge posing risks to public health and environmental sustainability. The growing population density in cities makes it imperative to invest in resilient, technology-driven water and sanitation systems that can support both current needs and future growth.

Urban infrastructure investments are projected to rise by ~2% in the next three fiscal years: WSS investments increase share

Between fiscals 2023 and 2025, the total spending on urban infrastructure in India stood at approximately Rs 6.1 lakh crore. Over the next three fiscal years (fiscals 2026 to 2028), this investment is projected to increase by ~2%, reaching around Rs 6.1 to Rs 6.3 lakh crore. A significant portion of this expenditure is being directed towards the water supply and sanitation (WSS) segment.

Figure 112: Water supply & sanitation (WSS) investments to account for ~67% of urban infrastructure investments in the next 3 years



Source: Central budget, State budgets and Crisil Intelligence

In the past three years, WSS accounted for nearly 65% of the total urban infrastructure investment. This share is expected to grow further, reaching close to 67% of the overall outlay in the coming three years. The rising allocation towards WSS reflects a clear shift in policy and funding priorities, with both central and state governments placing greater emphasis on strengthening water and sanitation infrastructure. This increased focus aims to bridge service gaps, improve public health outcomes, and ensure sustainable urban development across both large cities and smaller towns.

WSS industry overview

The development of water supply and sanitation infrastructure in India is primarily led by the government, with active support from state agencies, urban local bodies (ULBs), and increasingly, private players through public-private partnerships. The responsibility is shared across multiple levels of government with significant roles played by both central and state institutions.

Overview of key government schemes and initiatives

- Jal Jeevan Mission (JJM)

Aims to provide functional household tap connections (FHTCs) to every rural household. It also focuses on sustainability, water quality, ground water management, and community participation.

- AMRUT (Atal Mission for Rejuvenation and Urban Transformation)

Targets improvement in urban infrastructure, including 24x7 water supply, sewage networks, and wastewater treatment facilities in selected cities.

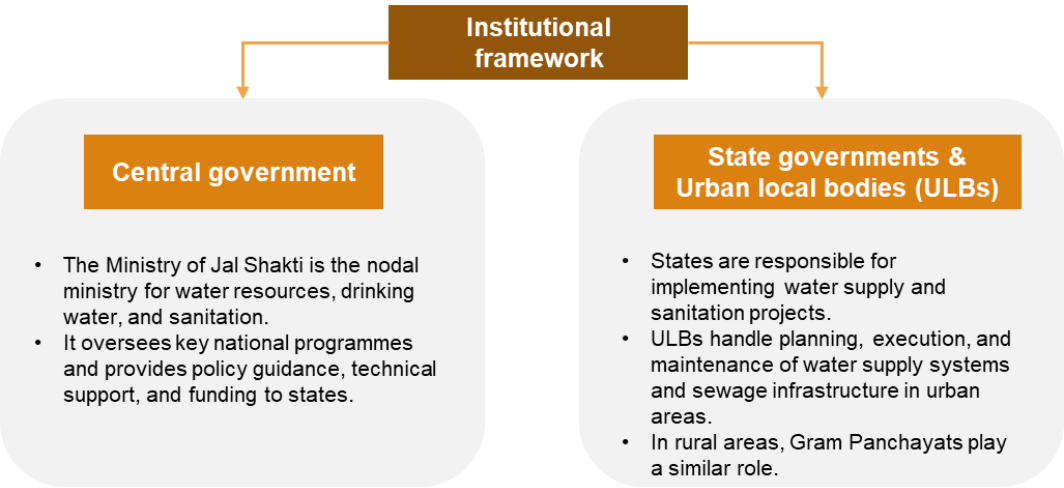
- Swachh Bharat Mission (SBM)

Focuses on eliminating open defecation and improving solid and liquid waste management across rural and urban India.

- Namami Gange Programme

Dedicated to the rejuvenation of the Ganga River, this programme includes setting up sewage treatment plants (STPs), intercepting and diverting drains, and promoting public awareness.

Institutional framework for development and maintenance of WSS infrastructure



Source: Crisil Intelligence

The development of water and sanitation infrastructure in India involves a range of components tailored to the needs of both urban and rural areas. For water supply, projects generally include critical assets such as water intake structures, treatment plants, overhead storage tanks, pumping stations, and an extensive distribution pipeline network to ensure last-mile delivery. In rural regions, the infrastructure often depends on localized sources like borewells, reservoirs, or river water, supported by simpler treatment and supply mechanisms suited to smaller populations and dispersed settlements.

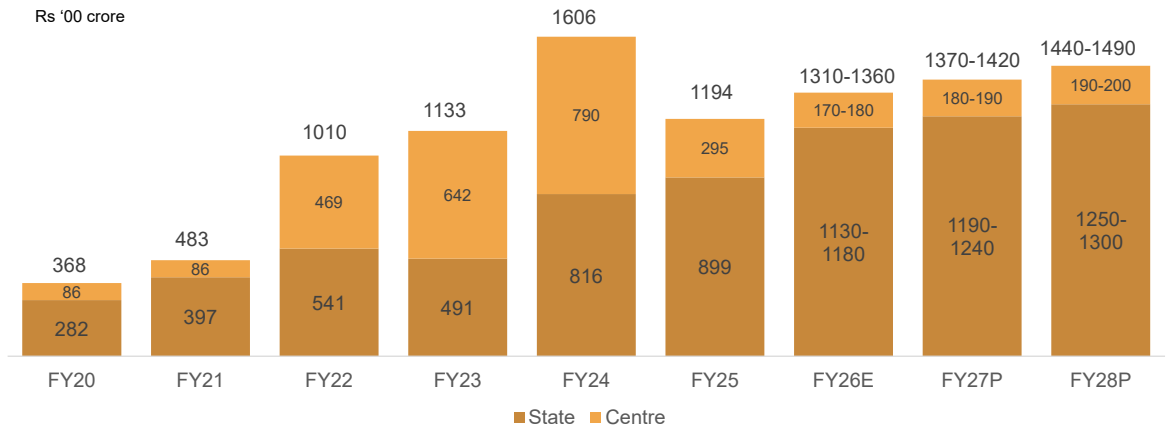
In terms of sanitation and wastewater management, the infrastructure varies based on the degree of urbanisation and geographic conditions. In urban areas, it typically includes underground sewer networks, sewage treatment plants (STPs), and effluent treatment plants (ETPs) for handling industrial discharge. In smaller towns or peri-urban regions where centralized sewer systems may be absent, sanitation solutions rely more on septic tanks, community toilets, and faecal sludge treatment units. The design and implementation of these systems are increasingly being guided by considerations of sustainability, water reuse, and environmental safety.

Financing for such infrastructure projects comes from a mix of public and private sources. The primary funding is provided through central and state government budgetary allocations under various flagship schemes. In addition, financial support is also mobilized through grants and concessional loans from international development agencies such as the World Bank, Asian Development Bank (ADB), and Japan International Cooperation Agency (JICA). Increasingly, Public-Private Partnerships (PPPs) are being leveraged to implement projects using models such as the Hybrid Annuity Model (HAM) or Engineering, Procurement, and Construction (EPC) contracts. Although user charges are also a component of revenue generation, especially for operations and maintenance, cost recovery remains a challenge—particularly in the sanitation segment—due to affordability constraints and low willingness to pay in many areas.

WSS investments review and outlook

Recognising the critical importance of water supply and sanitation (WSS) for urban development, both central and state governments have steadily increased their investments in this segment. State governments primarily fund these initiatives through capital outlays from their own budgetary resources. Meanwhile, the central government provides financial assistance to states through grants-in-aid under key centrally sponsored schemes such as the Jal Jeevan Mission (JJM), Atal Mission for Rejuvenation and Urban Transformation (AMRUT), Swachh Bharat Mission, and Namami Gange.

Figure 113: Institutional Trend in government spending on water supply and sanitation infrastructure



Source: State budgets, Central budget & Crisil Intelligence

WSS investments are expected to witness steady growth from fiscal 2026 onwards, driven by higher central government allocation and combined with state government spending. Overall WSS investments are projected to grow at a CAGR of 4-6% between fiscals 2026 and 2028. During this period, state governments are expected to contribute a dominant share ranging from 75-85% of total WSS investments, while the remaining portion will come from central government sources. This highlights the increasingly critical role of states in driving on-ground implementation of water and sanitation infrastructure.

In early 2020's, the central government's contribution to WSS investments was relatively modest, 23% in fiscal 2020 and 18% in fiscal 2021. However, as allocations under centrally sponsored schemes were scaled up, the central government share rose significantly to about 46-50% during fiscals 2022 to 2024. This upward trend saw a temporary pause in fiscal 2025, largely due to the general elections with political priorities shifting from infrastructure-related schemes, including WSS to welfare and social sector programmes. Despite this, states continued to strengthen their own investments in the sector. From fiscal 2020 to fiscal 2025, state government spending on WSS infrastructure grew at a healthy CAGR of 26%, reflecting their sustained commitment to improving basic urban infrastructure.

Increasing private sector participation in wastewater treatment

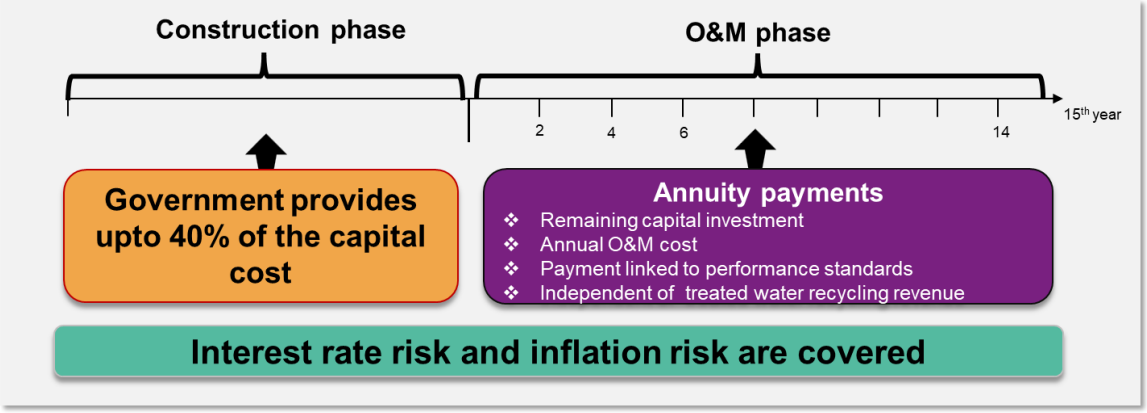
The wastewater treatment sector in India is witnessing a gradual yet important shift toward greater private sector participation, driven by the need for improved project outcomes, operational efficiency, and long-term asset sustainability. Traditional approaches to project implementation—largely reliant on government-led execution and conventional engineering, procurement and construction (EPC) contracts—have often fallen short of expectations. Many past sanitation projects have suffered from over-designed infrastructure, poor accountability, and ineffective operations and

maintenance (O&M), leading to suboptimal outcomes such as effluent discharge not meeting prescribed environmental standards.

To address these challenges and enhance the efficiency and sustainability of sewage treatment infrastructure, the government has begun to adopt innovative financing models that incentivize performance. Drawing on the successful implementation of the Hybrid Annuity Model (HAM) in the transport sector, the model has now been introduced in the sanitation space as well, particularly under the National Mission for Clean Ganga (NMCG).

Under this model, wastewater treatment projects are implemented as Public-Private Partnerships (PPPs), wherein a Special Purpose Vehicle (SPV) is formed to develop, operate, and maintain the sewage treatment plant (STP). The financial structure is designed to balance upfront support with long-term performance-based incentives. Specifically, 40% of the capital cost is paid by the government upon completion of construction, while the remaining 60% is disbursed as annuity payments over the life of the project. These annuities, along with payments for O&M, are closely linked to predefined Key Performance Indicators (KPIs), ensuring continuous accountability, asset performance, and service quality.

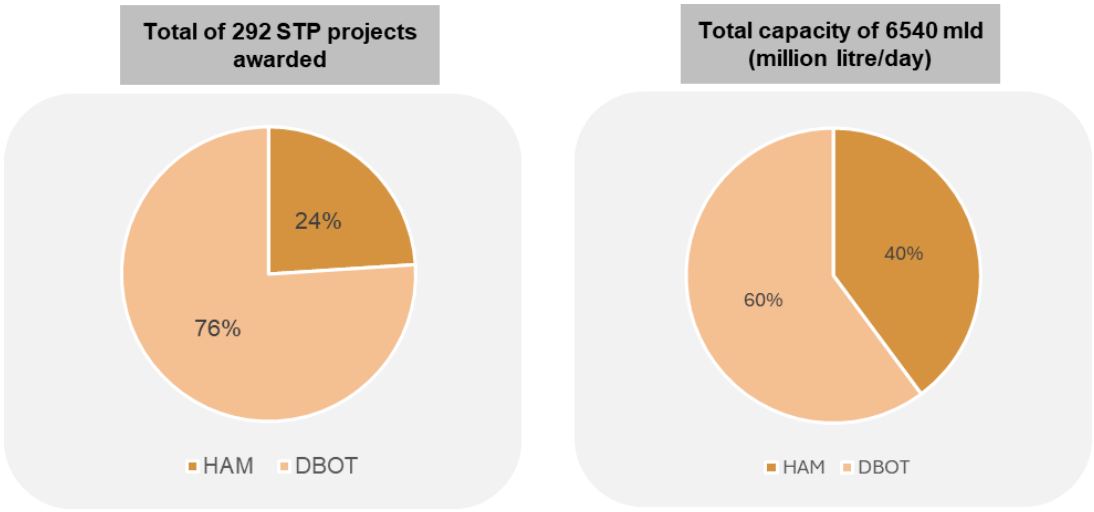
Figure 114: HAM model witnesses' successful adoption



Source: Crisil Intelligence

In addition to the Hybrid Annuity Model (HAM), the Namami Gange programme has also successfully implemented projects under the Design-Build-Operate-Transfer (DBOT) model, further reinforcing the role of the private sector in wastewater management. Under the DBOT framework, private entities are responsible for the end-to-end execution of sewage treatment projects, including the design, construction, and operation of treatment facilities for a defined concession period, after which the assets are transferred back to the public authority.

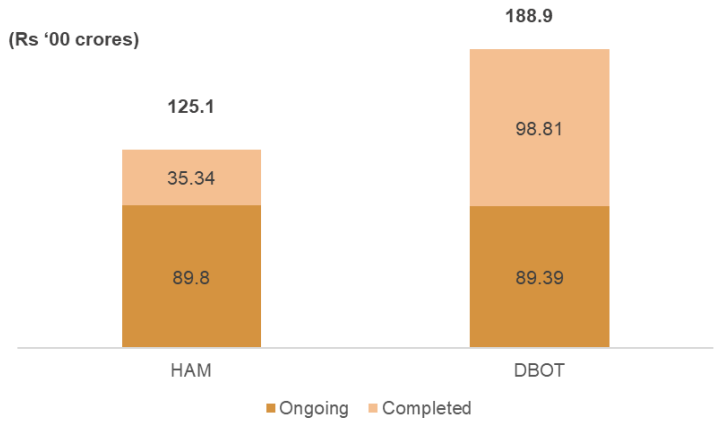
Figure 115: Sewage treatment plants (STPs) awarded under HAM & DBOT mode



Source: Namami Gange, Crisil Intelligence

The successful adoption of both HAM and DBOT models under Namami Gange highlights the government's strategic shift towards performance-linked, outcome-oriented public-private partnerships in the wastewater sector. These models are paving the way for improved asset utilisation, long-term sustainability, and greater private sector confidence in the sector. As a result, private participation in wastewater treatment is expected to expand further, contributing to India's broader water security and environmental goals

Figure 116: HAM v/s DBOT STP project costs



Source: Namami Gange, Crisil Intelligence

Overview of government schemes

Namami Gange Mission

Launched in 2014 under the Ministry of Jal Shakti, the Namami Gange Mission is the Government of India's flagship programme for the rejuvenation of the Ganga River and its tributaries. With a total outlay of approximately Rs 22,500 crore, the mission adopts a multi-sectoral approach focusing on pollution abatement, riverfront development, biodiversity conservation, and public awareness.

A core component of the mission is the development of sewage treatment infrastructure in urban centres along the river. As of October 2025,, A total of 216 sewerage infrastructure projects, valued at ₹ 34,809 crores, have been initiated to remediate polluted river areas, with a combined treatment capacity of 6,561 Million Liters per Day (MLD). Notably, 138 of these projects, with a capacity of 3,806 MLD, have been successfully completed and are now operational.
To ensure efficiency and accountability, the programme has adopted Public-Private Partnership (PPP) models such as the Hybrid Annuity Model (HAM) and Design-Build-Operate-Transfer (DBOT). These models ensure long-term operation and maintenance of assets, with payments linked to performance indicators such as treated water quality and plant up time. Namami Gange has thus set new benchmarks for outcome-oriented project implementation in the sanitation space.

Atal Mission for Rejuvenation and Urban Transformation (AMRUT)

Introduced in 2015 and extended as AMRUT 2.0 in 2021, this centrally sponsored scheme focuses on improving basic urban services, particularly water supply, sewerage, and drainage systems in cities and towns. AMRUT 1.0 covered 500 cities, while AMRUT 2.0 expands the scope to all statutory towns, targeting universal coverage of functional water tap connections and sewage systems.

As of December 2025, projects worth over Rs 77,000 crore have been grounded under AMRUT, and approximately 4,700 MLD of water treatment and distribution capacity has been created. AMRUT 2.0 aims to provide 100% tap water supply coverage to all households in 4,700+ towns, with an estimated central outlay of Rs 2.87 lakh crore, including reforms and capacity-building components. The scheme also promotes green infrastructure, water body rejuvenation, and integrated stormwater management, thus contributing to urban resilience.
Source: Press information bureau (PIB), Crisil Intelligence

Jal Jeevan Mission (JJM)

Launched in 2019, the Jal Jeevan Mission aims to provide Functional Household Tap Connections (FHTCs) to every rural household in India by 2024. It represents one of the most ambitious rural water supply programmes globally, backed by strong political will and substantial funding.

When the scheme was launched, only around 17% of rural households had access to tap water. As of date, this figure has increased to over 81.55%, covering more than 15.8 crore rural households. Eleven states and Union Territories—including Goa, Gujarat, Haryana, and Telangana—have achieved 100% rural tap water coverage. The mission also supports water quality monitoring through over 2,100 water testing laboratories, with more than 24 lakh women trained to use field test kits for quality checks in villages.

The mission is supported by significant central funding, with annual budgetary allocations rising from Rs 11,000 crore in fiscal 2021 to over Rs 70,000 crore by fiscal 2024. JJM has also promoted community involvement, source sustainability, and convergence with other schemes to strengthen outcomes.

Source: Jal jeevan mission, Crisil Intelligence

Swachh Bharat Mission (SBM)

Launched The Swachh Bharat Mission, launched in 2014 and extended as SBM 2.0 in 2021, aims to achieve sustainable sanitation and solid and liquid waste management across both urban and rural areas.

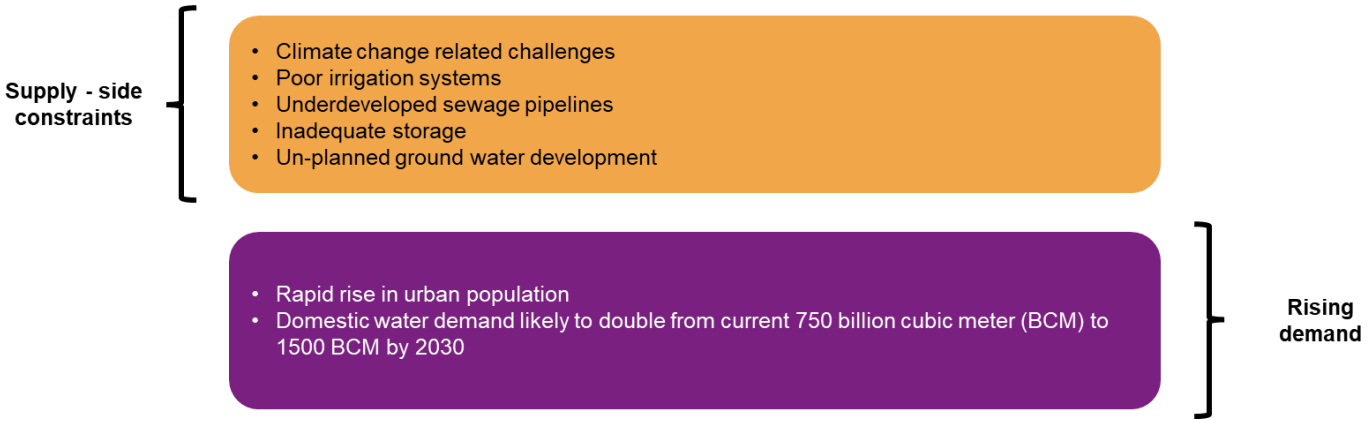
Under SBM (Gramin), over 110 million household toilets have been constructed, helping India declare itself open defecation free (ODF) in rural areas in 2019. The second phase focuses on sustaining ODF status by promoting solid and liquid waste management systems, twin-pit retrofitting, and greywater treatment through soak pits and decentralized systems. Between 2021 and 2023, more than 5 million soak pits were constructed under the Sujlam campaign.

SBM (Urban) focuses on scientific waste management, construction of public toilets, and treatment of faecal sludge and septage (FSM). Despite challenges in operation and upkeep in certain cities, SBM has significantly improved urban hygiene standards and fostered behavioural change through public awareness campaigns. SBM 2.0 aims to make all cities ODF+ (with safely managed sanitation systems) and ODF++ (with complete treatment of faecal sludge and wastewater) in a phased manner.

Key risks and challenges for water supply and sanitation sector

India is home to nearly 18% of the world's population, yet it possesses only about 4% of the global freshwater resources. This stark imbalance highlights the immense pressure on the country's limited water reserves. With the population continuing to grow, particularly in urban areas, the demand for freshwater is rising at an accelerated pace, while supply remains constrained due to infrastructural limitations.

Figure 117: Widening supply demand gap



Source: Central Pollution Control Board (CPCB), Ca, Crisil Intelligence

Despite growing policy support and rising investment, the water and wastewater treatment sector in India continues to face several structural and operational challenges that could impact the pace and effectiveness of infrastructure development. Addressing these issues is critical to ensuring long-term sustainability, service reliability, and environmental compliance.

- Inadequate cost recovery

One of the most pressing challenges in the sector is the limited ability of utilities and urban local bodies (ULBs) to recover operating costs through user charges. Water and sewerage tariffs remain heavily subsidised, often politically sensitive, and in many cases, not even sufficient to cover basic operations and maintenance (O&M) expenses. This leads to poor financial viability and limits reinvestment in system upgrades.

- Weak institutional capacity

Many ULBs and state-level agencies lack the technical, managerial, and financial capacity to plan, implement, and monitor complex water and wastewater projects. This often results in delays, suboptimal project design, and ineffective execution, especially in smaller towns and rural areas.

- Poor operations and maintenance (O&M)

Inadequate focus on long-term O&M frequently leads to asset deterioration and non-compliance with discharge norms. STPs often operate below capacity or remain non-functional due to lack of skilled personnel, irregular maintenance, and inadequate monitoring systems.

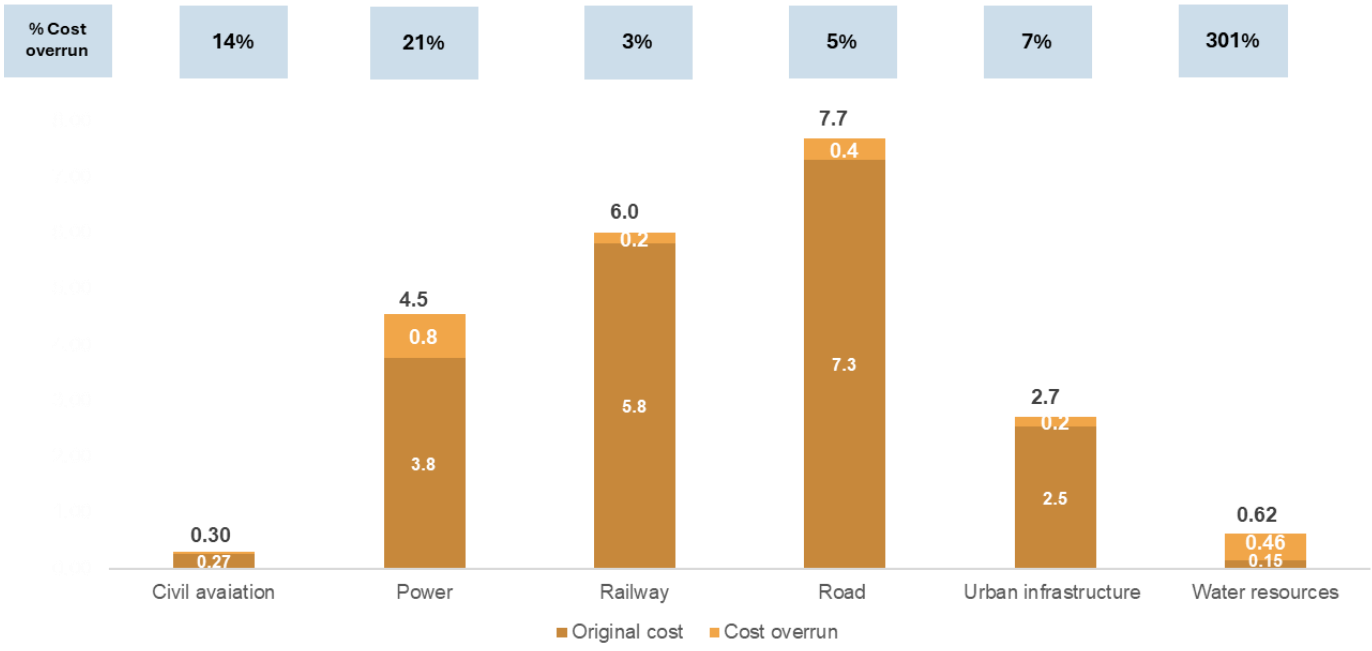
- Fragmented governance and overlapping jurisdictions

The sector suffers from institutional fragmentation, with overlapping roles among central ministries, state departments, ULBs, and parastatal agencies. This often leads to coordination challenges, delays in decision-making, and lack of accountability in service delivery.

- Land Acquisition and project delays

Large-scale water and sewerage projects often require land for treatment plants and network infrastructure, which can lead to delays due to resistance from local stakeholders, regulatory bottlenecks, and challenges in securing environmental clearances.

Figure 118: Water resources observe highest cost overrun (%) among infrastructure sectors



Source: MoSPI, Crisil Intelligence

Note: Projects include central government infra projects costing Rs 150 Cr or more. Data as of Jun 25'.

Adani Enterprises Ltd. is strategically expanding into the water infrastructure sector, recognising the surgent need for capacity augmentation in India. The company has made its foray by securing wastewater treatment, recycling, and reuse project at Prayagraj under the National Mission for Clean Ganga scheme. Building on this milestone, Adani Enterprises aims to pursue opportunities in sewage treatment plant (STP) construction and rehabilitation, irrigation infrastructure, large-scale water supply and distribution, and desalination to provide potable water for domestic and industrial use. With water conservation at the core of its sustainable development agenda, the company is well-positioned to contribute meaningfully to India's long-term water security.

Table 24: Water project portfolio of Adani Enterprises Ltd.

Project	Location	Capacity	Project model	Concession period (In years) (Const + O&M)	Project status
Prayagraj Water Pvt Ltd (PWPL)	Uttar Pradesh	326 MLD	HAM	2 + 15	COD achieved - Operational
Bhagalpur Wastewater Ltd (BWWL)	Bihar	45 MLD	HAM	2 + 15	Completion > ~96%; Applied for Pre-COD with available 11 MLD flow
Morsagar Bisalpur Water Ltd (MBWL)	Rajasthan	200 MCM	HAM	2.75 + 20	Pre-engineering works are in process
Brahmani Barrage Water Ltd (BBWL)	Rajasthan	55 MCM	HAM	2.75 + 20	Pre-engineering works are in process
Shakhar Pench Micro Lift Irrigation Project	Madhya Pradesh	95000 Ha	EPC	6 + 5	Dam & Pipelaying execution agencies finalized. Pipe supply execution is initiated.
Mithi River Development and Pollution Control Project (Package III)	Maharashtra	18 Nos Gate Pump area.	EPC	6 + 10	LOA issued on 09th Dec 25.

Note: LoA: Letter of Award I COD – Commercial Operation Date I MLD – Million Liters Per Day I Ha – Hectare I MCM – Million Cubic Meter

Source: Company filings, Crisil Intelligence

Peers of Adani Enterprises Ltd in the water Industry

L&T Limited has its presence in the water industry through its Water & Effluent Treatment (WET) business segment that provides complete solutions through its concept to commissioning capability involving design, detailed engineering, procurement, project management and execution. During the year fiscal 2025, L&T commissioned 10 WET projects and some of these projects include Narmada Kshipra Lift Irrigation In Madhya Pradesh, Water Transmission Project in Oman, HPCL Rajasthan Refinery Ltd. (HRRL) Water Block Package, Gujarat and Athi Kadavu – Avinashi LIS, Tamil Nadu. Going forward, L&T aims to focus on expanding opportunities in irrigation, wastewater treatment, desalination and urban water management while strengthening its international footprint.

Welspun Enterprises has its presence Indian transportation and water infrastructure sectors and has an investment in the oil and gas sector through a JV with Adani Enterprises – Adani Welspun Exploration Limited. Welspun's presence in water industry is across key focus areas such as Water transmission and distribution, water treatment, wastewater treatment, and niche technologies. The company has number of large projects under its portfolio such as The Dharavi wastewater treatment facility in Mumbai, Rural water supply project under Jal Jeevan Mission in Uttar Pradesh, Bhandup water treatment plant, Tertiary treated water conveyance tunnel project and the Mithi river water quality improvement project.

Module 11: Green Hydrogen

Introduction

According to IEA, India's energy demand is expected to grow faster than any other region by 2050 driven by robust economic growth, rapid urbanization, expanding construction, and rising needs for electricity, cement, and steel. This surge could strain its energy system, heavily dependent on imported fossil fuels like crude oil and natural gas. Consequently, increased fossil fuel use in transportation, power generation, and industry may significantly elevate India's carbon emissions.

To tackle these challenges, India is actively pursuing decarbonization and energy diversification. The country has set an ambitious goal of achieving net-zero emissions by 2070, with significant investments in solar and wind energy and policies to strengthen domestic clean energy supply chains.

Building on the decarbonization potential of green hydrogen, India has strategically integrated it into its ambitious climate framework, known as the Panchamrit announced at the COP26 summit in 2021. The Panchamrit, or "five nectar elements," outlines India's commitment to achieving net-zero emissions by 2070 through five key targets:

- reaching 500 gigawatts (GW) of non-fossil energy capacity by 2030,
- sourcing 50% of its energy requirements from renewable energy by 2030,
- reducing total projected carbon emissions by one billion tonnes by 2030
- reducing the carbon intensity of its economy by 45% by 2030 compared to 2005 levels
- achieving net-zero emissions by 2070.

Figure 119: Steel sector to lead carbon cuts under efficient emissions scenario with green hydrogen

Source: Niti Ayog document, Crisil Intelligence

These goals align with India's broader vision of energy independence by 2047 and position green hydrogen as a linchpin for decarbonizing high-emission sectors like industry and transport, which are critical to meeting these targets. The National Green Hydrogen Mission (NGHM), launched in January 2023 with an outlay of Rs 19,744 crore, aims to produce 5 million metric tonnes per annum (MTPA) of green hydrogen by 2030, supported by 125 GW of additional renewable energy capacity, to abate approximately 50 MMT of CO_2 emissions annually. This mission complements the Panchamrit by fostering a green hydrogen ecosystem that enhances industrial competitiveness, reduces fossil fuel imports, and supports India's climate commitments.

Further, in COP 27, India submitted its long-Term Low Emission Development Strategy to the United Nations Framework Convention on Climate Change (UNFCCC), in which importance of hydrogen along with electric vehicles and ethanol to achieving decarbonization has been emphasized

The role of green hydrogen in decarbonization is pivotal, particularly for hard-to-abate sectors where direct electrification is impractical. For instance, in heavy industries like steel and cement production, green hydrogen can replace fossil fuels as a reducing agent or heat source, significantly reducing carbon dioxide (CO_2) emissions. In transportation, it powers fuel cell electric vehicles (FCEVs), offering a zero-emission alternative for heavy-duty trucks, shipping, and aviation. The International Renewable Energy Agency (IRENA) projects that green hydrogen could abate up to ~920 million tonnes of CO_2 annually if scaled globally, replacing fossil fuel-derived hydrogen. Moreover, green hydrogen fosters energy independence by reducing reliance on imported fossil fuels, while its storage capabilities support renewable energy integration into power grids. However, challenges such as high production costs, water intensity, and infrastructure requirements necessitate technological advancements.

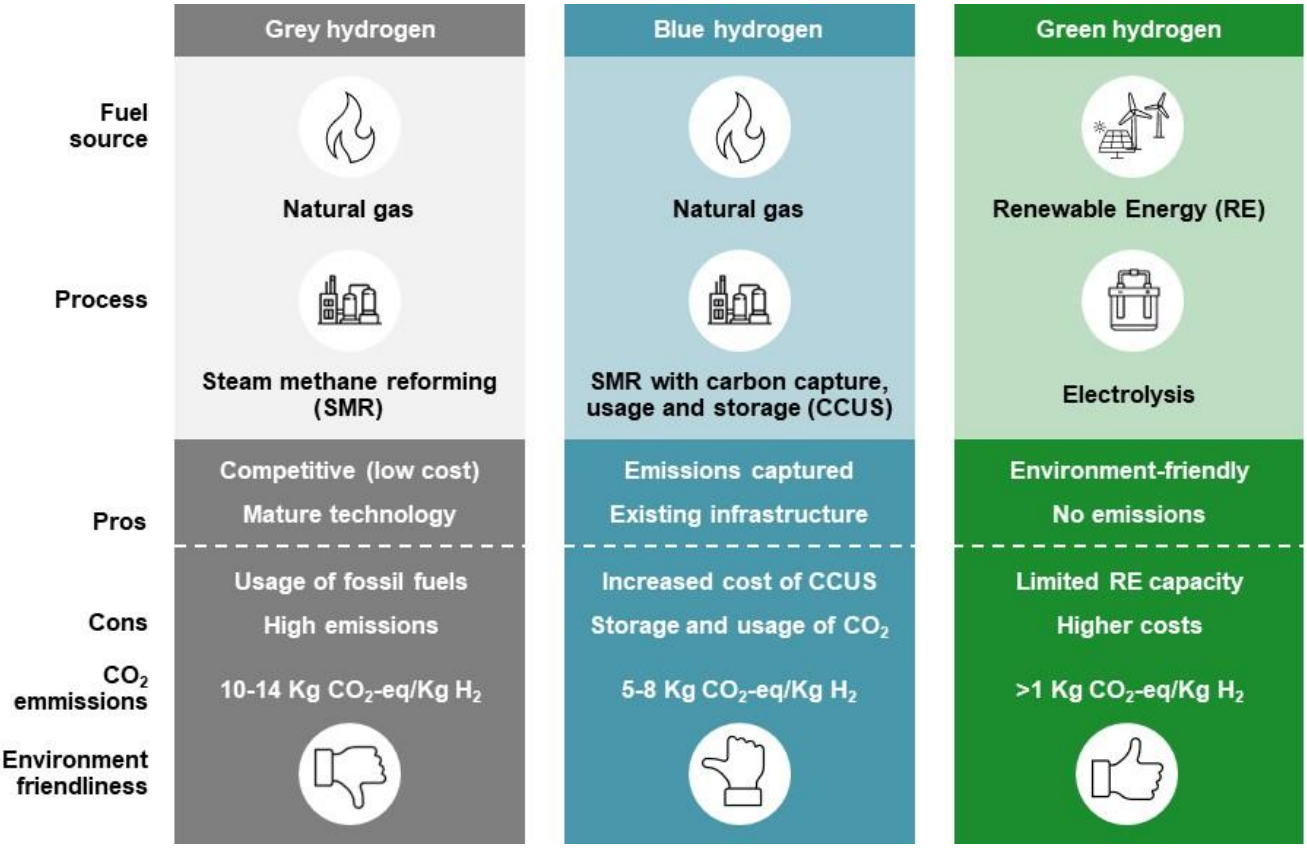
Production and colours of hydrogen

Hydrogen is categorized into different "colours" based on its production method and environmental impact, each with distinct implications for India's energy transition. The primary types include:

- **Grey Hydrogen**: Produced via steam methane reforming (SMR) of natural gas or coal/lignite gasification, grey hydrogen is carbon-intensive, contributing to significant CO2 emissions. It dominates global hydrogen production (96%) due to its low cost but is unsuitable for decarbonization goals.

- **Blue Hydrogen**: Generated from natural gas or coal with carbon capture and storage (CCS) or utilization (CCU), blue hydrogen reduces emissions compared to grey hydrogen. However, its reliance on fossil fuels and the high cost of CCS infrastructure limits its long-term viability in a net-zero framework.
- **Green Hydrogen**: Produced through electrolysis powered by renewable energy or biomass gasification, green hydrogen is emission-free and aligns with decarbonization objectives. Its sustainability makes it the most suitable for India's climate goals, though high production costs and water requirements pose challenges.
- **Other Colors**: Less common variants include yellow hydrogen (produced using nuclear energy), pink hydrogen (nuclear-powered electrolysis), and turquoise hydrogen (methane pyrolysis with solid carbon capture). These are less relevant for India due to limited nuclear infrastructure and technological maturity

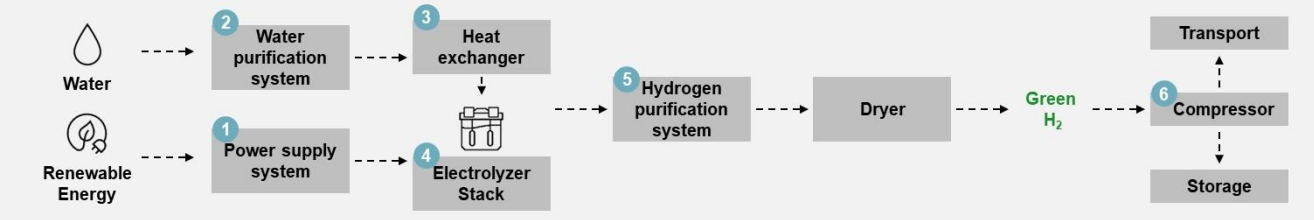
Figure 120: Grey hydrogen is the most commonly produced type of hydrogen



Source: Crisil Intelligence

Green hydrogen, produced through the electrolysis of water using electricity derived from renewable sources such as solar, wind, or hydropower, represents a cornerstone of clean energy innovation due to its zero-emission profile. Unlike conventional hydrogen production methods that rely on fossil fuels, green hydrogen generates no greenhouse gas emissions during production, making it a critical tool for decarbonizing sectors that are challenging to electrify directly. The process involves splitting water into hydrogen and oxygen using renewable energy, resulting in a versatile energy carrier that can be used as a fuel or feedstock in industries such as steel, chemicals, refining, and transportation. Additionally, green hydrogen can be produced from biomass gasification, further expanding its sustainable production pathways. Its ability to store and transport energy over long periods and distances addresses the intermittency of renewable energy sources, enhancing grid stability and energy security.

Figure 121: Green hydrogen production uses renewable energy to split water into hydrogen and oxygen



Advantages	Disadvantages
Minimising GHG emissions and helps move closer to net-zero	Need large amount of electricity
Employs renewable energy sources	High cost of renewable energy
Promoting technology development and creation of new jobs	Technology needs to mature. Needs large amount of investments

1 **Power supply system** converts the input AC power to DC at required voltage to send it to the electrolyser stack. System includes AC/ DC rectifier, DC transducer etc

2 **Water purification system** is used to treat water using either reverse osmosis or demineralisation to avoid membrane blockage or degradation

3 **Heat exchanger is used** to maintain the temperature at inlet and outlet of Electrolyzer stack

4 **Electrolyser stack** is assembled using seals gaskets etc. with all the components termed as balance of stack (BoS)

5 The Hydrogen obtained from Electrolyser would contain moisture which needs to be removed used to obtain the desired purity levels using **purification system**

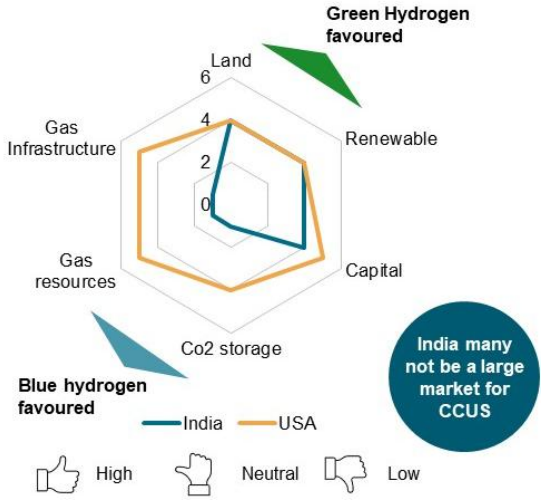
6 **Compressor** is used to store H2 at above 30 bar.

Source: Crisil Intelligence

The choice of blue or green hydrogen largely depends on varied factors. Countries like the United States, the Gulf, and some regions in Europe, etc., which have abundant gas resources, infrastructure, and CO2 storage facilities, are likely to initially pursue the blue hydrogen route along with the green.

Green hydrogen is the most suitable for India due to its abundant renewable energy potential, particularly in solar and wind, which can drive down production costs over time. India's geographical advantages, including high solar irradiation and wind potential in states like Gujarat, Rajasthan, and Karnataka, position it to become a global hub for green hydrogen production, with a target cost of $1.5 per kg by 2030. The NGHM supports this by incentivizing electrolyser manufacturing, pilot projects, and infrastructure development, addressing the current ~7.5 MTPA grey hydrogen demand in refineries and fertilizers. While grey hydrogen is cheaper, its environmental impact conflicts with India's Panchamrit goals, and blue hydrogen's reliance on fossil fuels and costly CCS makes it less feasible. Green hydrogen's alignment with renewable energy expansion and its potential to decarbonize hard-to-abate sectors like steel, fertilizers, and heavy transport make it the optimal choice for India's net-zero trajectory, provided cost reductions and water management challenges are addressed through policy and innovation

Figure 122: Green Hydrogen remains a favourable option for India to reach its net zero goals



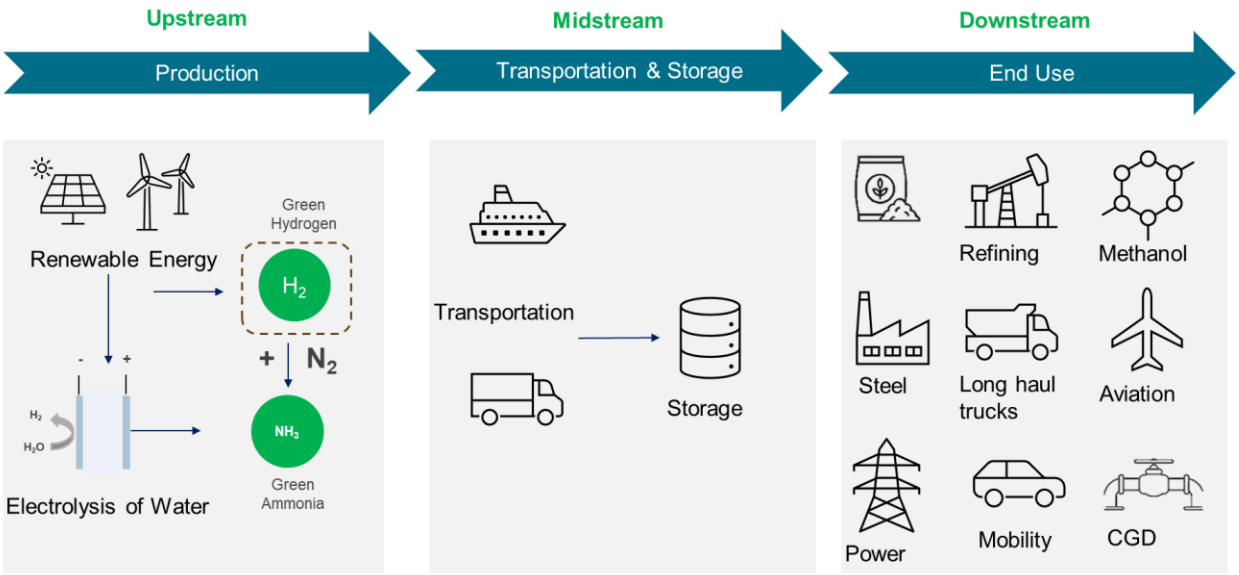
Source: Crisil Intelligence

Green hydrogen value chain

The hydrogen value chain can be broadly categorised into three parts:

- Upstream
- Midstream
- Downstream

Figure 123: Green hydrogen value chain



Source: Crisil Intelligence

Upstream - production of hydrogen

Most of the hydrogen produced today comes from fossil fuels, which, without mitigation measures such as carbon capture, will not meet the carbon neutrality requirements set out in the EU and UK strategies. The International Energy Agency (IEA) estimates that only 0.1% of total hydrogen production today derives from water electrolysis, which is the most common method for green hydrogen production using renewable power sources.

Water electrolysis is an old technique but has found few commercial takers due to its higher cost and cheaper alternatives to produce hydrogen using coal and natural gas. However, in the current decarbonization trend, electrolysis has made a comeback due to its zero-emission merit if powered through renewable energy.

There are four types of electrolysers: Alkaline and polymer electrolyte membranes (PEM) are already commercial, while anion exchange membranes (AEM) and solid oxide, now at the R&D stage, promise a major step forward.

- **Alkaline**: Alkaline electrolysers are the most used hydrogen generators in the industry. In alkaline technology, the water is split into its constituents in the presence of a caustic electrolyte solution. This leads to a reaction between two electrodes. And when sufficient voltage is applied, water molecules take electrons to make OH ions and a hydrogen molecule. The OH ions travel through the solution toward the anode, where they combine and give up their extra electrons to make water, hydrogen, and oxygen. Recombination of hydrogen and oxygen at this stage is

prevented by means of an ion-exchange membrane, which was historically made of porous white asbestos. However, membranes have advanced significantly in recent years.

- **PEM:** Polymer Electrolyte Membrane (PEM) technology is the electrolysis of water in a cell equipped with a solid polymer electrolyte (SPE) to separate hydrogen and oxygen. PEM electrolysis creates a reaction using an ionically conductive solid polymer rather than a liquid. When voltage is applied between two electrodes, negatively charged oxygen in the water molecules produces protons, electrons, and oxygen at the anode. The H+ ions travel through a polymer membrane towards the cathode, where they take an electron and combine to make hydrogen. The electrolyte and two electrodes are sandwiched between two bipolar plates, which transport water to them or gases away from them, conduct electricity, and circulate a coolant fluid to cool down the process.
- **Solid oxide electrolysis**: These operate at high (700–850 °C) temperatures, which enables the favourable kinetics that allow the use of relatively cheap nickel electrodes, a lower electricity demand, and the potential for reversibility (for operating as a solid oxide fuel cell). On the downside, thermo-chemical cycling, especially during shutdown or ramping periods, leads to faster degradation and shorter lifetimes. Other issues related to stack degradation include challenges related to sealing at higher differential pressures, electrode contamination by silica used as sealants, and other additional contaminant sources from piping only deployed at the kW-scale, although some current demonstration projects have already reached 1 MW.
- **Anion Exchange Membranes (AEM):** This is the latest technology, with only a few companies commercialising it and limited deployment. It's a combination of a less harsh environment from alkaline electrolysers with the simplicity and efficiency of a PEM electrolyser. Also, it allows the use of non-noble catalysts and titanium-free components and, as with PEM, operation under differential pressure. However, AEM membrane has chemical and mechanical stability problems, leading to unstable lifetime profiles and lower-than-expected performance, mostly due to low AEM conductivity, poor electrode architectures, and slow catalyst kinetics. Performance enhancement is typically achieved by tuning the membrane conductivity properties or by adding a supporting electrolyte. Such tuning could lead to decreased durability.

Figure 124: Characterisation of different types of electrolysis

	Alkaline	PEM	AEM	Solid oxide
Operating temperature	70-90 °C	50-80 °C	40-60 °C	700-850 °C
Operating pressure	1-30 bar	< 70 bar	< 35 bar	1 bar
Electrolyte	Potassium hydroxide (KOH)	PFSA membranes	DVB polymer support with KOH or NaHCO3	Yttria-stabilized Zirconia (YSZ)
Separator	5-7 molL-1	Solid electrolyte	Solid electrolyte	Solid electrolyte
Electrode / catalyst (Oxygen side)	ZrO2 stabilized with PPS mesh	Iridium oxide	High surface area Nickel or NiFeCo alloys	Perovskite-type (e.g. LSCF, LSM)
Electrode / catalyst (hydrogen side)	Nickel coated perforated stainless	Platinum nanoparticles on carbon black	High surface area nickel	Ni/YSZ
Porous transport layer anode	Nickel mesh	Platinum coated sintered porous titanium	Nickel foam	Coarse Nickel-mesh or foam
Porous transport layer cathode	Nickel mesh	Sintered porous titanium or carbon cloth	Nickel foam or carbon Cloth	None
Bipolar plate anode	Nickel-coated stainless steel	Platinum-coated titanium	Nickel-coated stainless steel	
Bipolar plate cathode	Nickel-coated stainless steel	Gold-coated titanium	Nickel-coated Stainless steel	Cobalt-coated stainless steel
Frames and sealing	PSU, PTFE, EPDM	PTFE, PSU, ETFE	PTFE, Silicon	Ceramic glass

Source: International Renewable Energy Agency (IRENA), Crisil Intelligence

Table 24: Non-exhaustive list of electrolyser manufacturers across the world

Name of the company	Country	Alkaline	PEM	AEM	SOEC
Asahi Kasei	Japan	✓			
Bloom Energy Corporation	USA				✓
Cavendish Renewable Technology (CRT)	Australia			✓	
CETH2	France		✓		
Cummins, Inc	Germany, Belgium, USA, Spain, Canada etc.	✓	✓		
Electric Hydrogen Co	USA		✓		
Elogen	France		✓		
Enapter	Germany			✓	
EvolOH, Inc	USA	✓			
Giner ELX Inc	USA		✓		
Green Hydrogen Systems	Denmark	✓			
h2e Power Systems Pvt. Ltd	India		✓	✓	✓
Haldor Topsoe	Denmark				✓
Hitachi Zosen Corporation	Japan	✓	✓		
Hoeller Electrolyser Gmbh	Germany				
H-Tec Systems	Germany		✓		
HydrogenPro ASA	Norway	✓			
HyGear	Netherlands	✓	✓		
Hygreen Energy	China	✓	✓		
Hystar	Norway		✓		
IPS-FEST Gmbh	Germany		✓		
ITM Power Plc	UK		✓		
John Cockerill S.A	Belgium	✓			
LONGi Hydrogen Technology Co., Ltd	China	✓			
McPhy Energy S.A	France	✓			
Nel Hydrogen	Norway	✓	✓		
Next Hydrogen	Canada	✓			
Ohmium International, Inc	USA/India		✓		
OxEon Energy, LLC	USA				✓
PERIC Hydrogen Technologies Co., Ltd.	China	✓	✓		
Plug Power Inc	USA		✓		
Shandong Saikesaisi Hydrogen Energy	China		✓		
Siemens Energy	Germany		✓		
Steisdal	Denmark	✓			
Sunfire GmbH	Germany	✓			✓
Suzhou Jingli Hydrogen	China	✓			
Teledyne Energy Systems	USA	✓			
Thyssenkrupp Nucera AG & Co. KGaA		✓			✓
Topsoe	Denmark				✓

Toshiba Energy Systems	Japan				✓
Verdagy	USA	✓			

Source: Company websites, Crisil Intelligence

Table 25: Non-exhaustive list of electrolyser manufacturers in India

Name of the company	Electrolyser Technology	Key Projects
Ohmium Operations Private Limited	PEM	Ohmium International has launched a new gigafactory in India near Bengaluru, covering 14,000 sq meters, to manufacture and ship 2GW of electrolyser systems expandable to 4 GW for green hydrogen production.
Advait Infratech Limited	Alkaline	Company aims to increase its electrolyser manufacturing capacity to 200 MW per year by 2025, expanding its presence in the green energy sector. The company currently has a 120 MW/year capacity at its Gujarat plant, producing electrolysis cell stacks and modules for hydrogen production and sustainable services.
L&T Electrolysers Ltd	Alkaline (based on McPhy Energy)	Larsen & Toubro has successfully commissioned first domestically produced electrolyser at the Green Hydrogen Plant located in Hazira, Gujarat, within the A M Naik Heavy Engineering Complex with a 1 MW capacity expandable to 2 MW.
Reliance New Energy Limited (RNEL	Alkaline (based on Nel ASA)	Reliance has signed a technology licensing agreement with Nel ASA granting exclusive rights to manufacture alkaline electrolysers based on Nel's technology in India. Reliance has won 300 MW of capacity in SECI's tender to set up 1.5 GW of electrolyser manufacturing capacity in India
Hild Electric Private Limited	Alkaline and AEM	Hild Electric has signed a contract with NTPC Renewable Energy Limited (NTPC-REL) to provide alkaline Electrolysers with an initial capacity of 600 MW for various industrial applications, including the production of green hydrogen and ammonia
Waaree Energies	Alkaline	Waaree Group has initiated 300 MW electrolyser manufacturing facility in Valsad, Gujarat. It aims to supply electrolysers to major industries including steel, refining, transportation, fertilizers, chemicals, food, and power generation
Matrix Gas and Renewables	Not Mentioned	Matrix Gas and Renewables is investing ₹500 crore to establish an electrolyser manufacturing facility in Sanand GIDC, spanning 25 acres. The project's first phase, supported by a Rs 440 crore Production Linked Incentive (PLI) scheme, will have a manufacturing capacity of 350 MW, with commercial production expected to commence by July 2026. The company aims to significantly scale up its capacity to 3 GW by 2030, with plans for additional investments to drive this expansion.
Adani New Industries	Alkaline	Adani New Industries has secured a deal to establish a 300 MW electrolyser manufacturing facility in India. The company has been awarded 198.5 MW under the first tranche and 101.5 MW under the second tranche of the PLI scheme. The projects are expected to be completed within 30 months and will receive incentives of approximately $352 million and $235 million, respectively, over a period of five years. The incentives will support the development of an alkaline electrolyser facility under 1st tranche and an indigenous stack technology under 2nd tranche

Source: Company websites, SECI, Crisil Intelligence

Midstream - transport and storage

After hydrogen is produced using any of the technologies, it can either be transported directly (which is a risky and costly affair) or converted to ammonia, which would be referred to as “green ammonia”. Conversion to ammonia has two main advantages: A) It can be used as a feedstock to manufacture urea and complex fertilisers. B) Or it can be exported to other countries, where it can be directly used or reconverted to Hydrogen. The production of green ammonia will need the following two additional steps after Hydrogen is produced:

- Air separation: It is the most common process used to extract one or all of the main constituents of atmospheric air. The three main components are Nitrogen (78.1%), Oxygen (20.9%) and Argon (.9%). Nitrogen is created in a cryogenic air separation unit, which utilizes the differing condensing/boiling points of the components of air to enable separation by distillation at cryogenic temperatures.
- Habers-bosch process: It is is basically one of the most efficient and successful industrial procedures to be adopted to produce ammonia. The Haber Bosch process converts nitrogen to ammonia by a reaction with hydrogen using a metal catalyst. A tonne of ammonia requires nearly 176kg of hydrogen and 824kg of nitrogen.

After the production of ammonia, which is usually in anhydrous form, it is converted to liquid to be stored in tanks or transported in anhydrous form

There are two broad categories of hydrogen distribution: Central plant and storage, and transportation.

Central plant and storage: Hydrogen storage poses a significant challenge owing to its low density, making it more challenging to store compared to fossil fuels. Hydrogen can be stored in two main modes: physical or material-based and as a gas or liquid. However, storing hydrogen as a gas requires high pressure, typically between 350-700 bar, while storing it as a liquid demands cryogenic temperatures.

The most widely used option is compressed hydrogen. The low density of hydrogen means that 3-4x more storage infrastructure is needed, which is estimated to cost ~$637 billion by 2050 to match current energy security levels[1]. Furthermore, large-scale, low-cost storage options such as salt caverns are limited owing to geography, and alternative methods can be more expensive than producing the hydrogen itself, thereby making storage a major hurdle for a future hydrogen-based economy

The low density of hydrogen not only makes it difficult to store but also increases the cost of transporting it by road or ship. However, it has an advantage when it comes to pipeline transportation, as it can flow nearly 3x faster than methane, making it a cost-effective option for large-scale transportation.

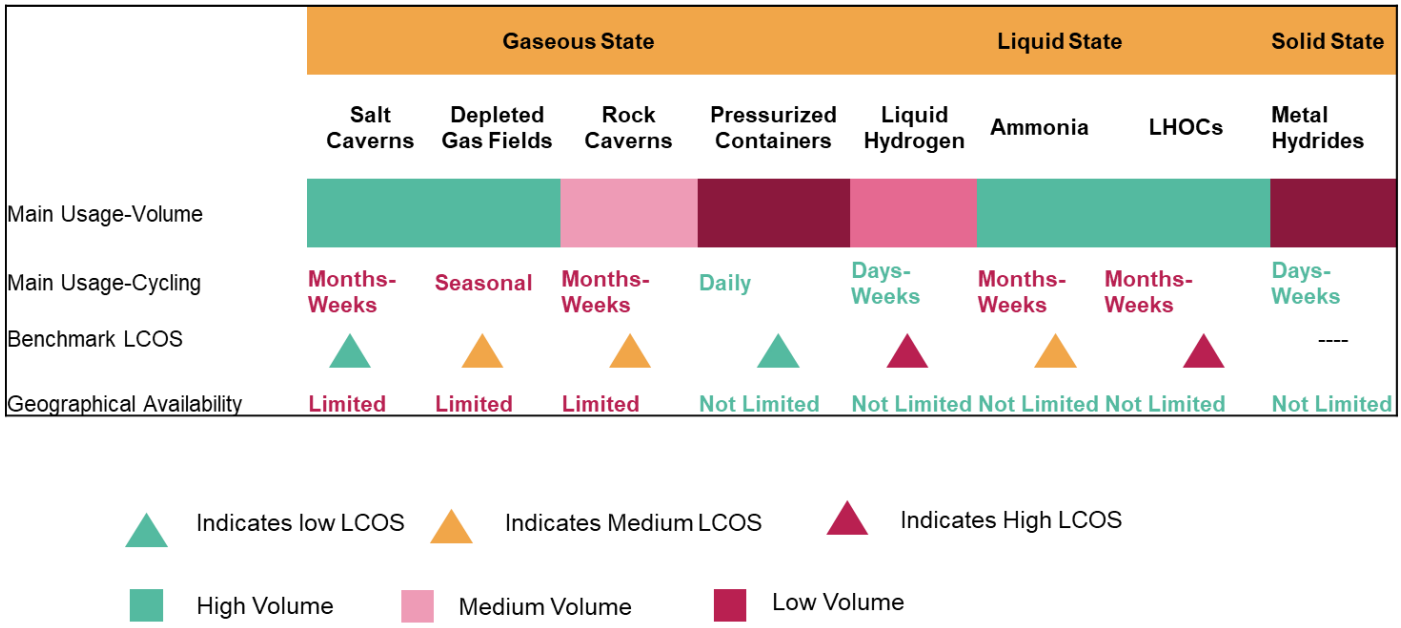
Nevertheless, for widespread adoption as in the case to natural gas, a large-scale coordinated effort will be required to upgrade and build new infrastructure, as hydrogen is often incompatible with existing pipelines and systems, thereby requiring significant modifications.

Transportation: Hydrogen is currently transported from production sites to consumption points through various methods, including pipelines, cryogenic liquid tanker trucks and gaseous tube trailers. Pipelines are typically used in areas with high and stable demand, while liquefaction plants, liquid tankers and tube trailers are used in regions with emerging or smaller-scale demand. At the point of use, additional infrastructure such as compression is often implemented. Gaseous hydrogen is commonly transported by trucks or pipelines, requiring compression to higher pressures before transport. Meanwhile, liquid hydrogen transportation is preferred for high-volume transport without pipelines, involving a liquefaction process that cools the hydrogen to cryogenic temperatures. Overall, the choice of transportation method depends on the demand and infrastructure available, with trucks and pipelines being the most common approaches for gaseous hydrogen and liquid hydrogen being used for larger-scale transport.

[1] *https://data.bloomberglp.com/professional/sites/24/BNEF-Hydrogen-Economy-Outlook-Key-Messages-30-Mar-2020.pdf*

To be sure, the hydrogen landscape in India is evolving, with no dedicated interconnected hydrogen pipeline across the country developed. There are three ways to transport hydrogen through pipelines. The first uses specialised pipelines designed specifically for hydrogen, as it can damage regular pipelines. The second involves modifying existing natural gas pipelines to carry a mix of natural gas and hydrogen. The third blends a small amount (5-10%) of green hydrogen with natural gas and uses the existing natural gas pipeline infrastructure.

Figure 125: Low cost, large storage options a major challenge for green hydrogen uptake



LHOC – liquid organic hydrogen carrier
Source: Bloomberg, Industry, Crisil Intelligence

While the development of Infrastructure will require capital, in the medium term, existing natural gas pipelines can be utilised either for blending or for distribution of hydrogen.

In India, demand for hydrogen is divided into two categories: captive demand and merchant demand. Currently, the majority of hydrogen consumption (about 90%) falls under captive demand, where industries such as refining, fertilisers and chemicals produce and use hydrogen for their own needs, due to the underdeveloped hydrogen infrastructure. However, as the infrastructure improves and the focus on clean energy grows, there is potential for an increase in merchant demand, driven by industries such as optic fibre, float glass and sorbitol, which could lead to a shift towards a more open market for hydrogen supply.[2]

In addition to manufacturing, investment in Hydrogen infrastructure is a key enabler to decarbonisation and bolstering trade activity.

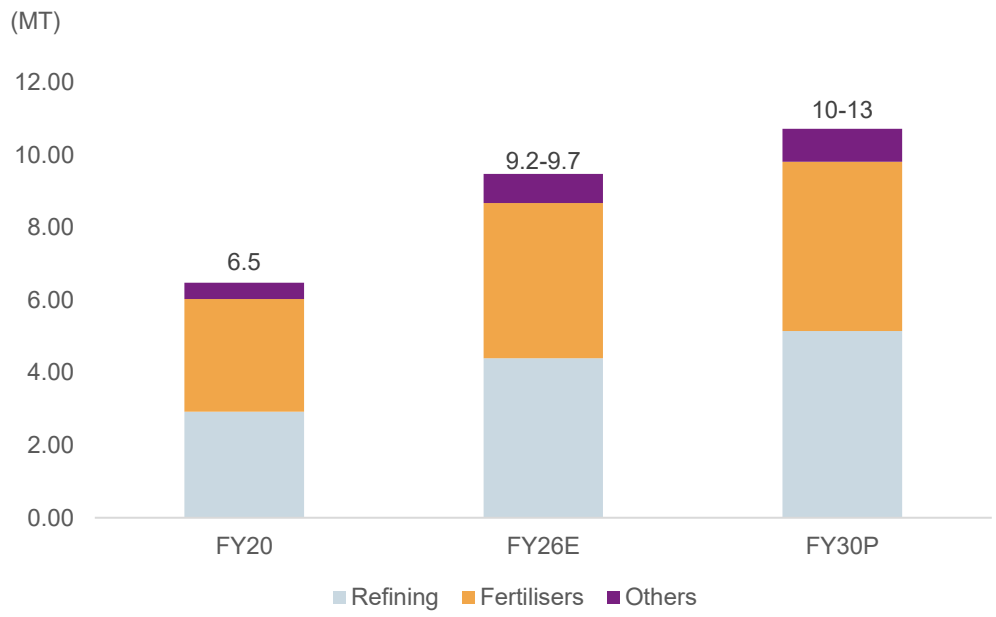
[2] *https://wwfin.awsassets.panda.org/downloads/green-hydrogen-demand-assessment.pdf*

Downstream - end-users

India's current hydrogen consumption stands at approximately 9.2-9.7 MT, driven primarily by the refining and fertiliser sectors. The refining sector accounts for 45-50% share, utilising ~4.2-4.6 MT of hydrogen for processes, such as hydrocracking and desulphurisation, which enable the production of high-quality fuels that meet stringent standards. The fertiliser industry consumes over ~4.0-4.4 MT (45-50% of the total) of hydrogen for the synthesis of nitrogen-based fertilisers, with share slightly less than the refining sector.

Currently, India relies predominantly on grey hydrogen, produced through the SMR process of natural gas. However, the country is actively transitioning to green hydrogen as part of its decarbonisation agenda. The adoption of green hydrogen in India will be crucial in reducing carbon emissions across various industries, with sectors such as refining, fertiliser and steel being at the forefront of this transition. Although green hydrogen is currently more expensive, ongoing policy initiatives, including subsidies, tax incentives and long-term offtake agreements, are expected to drive demand growth in the coming years.

Figure 126: Grey hydrogen leads usage, gradual shift towards green hydrogen expected by FY30



Source: MoPNG, IEA, Crisil Intelligence, Industry
Note: FY26 figures represent initial estimates

Refining

Hydrogen plays a vital role in various oil refinery processes, enabling the production of high-quality products. Refining of heavier, sour crude oils requires more extensive processing due to their high sulphur and contaminant contents. The refining process typically commences with distillation, followed by hydrotreating, which involves addition of hydrogen to remove impurities such as sulphur, nitrogen and unsaturated hydrocarbons. This process utilises a catalyst to convert sulphur compounds into hydrogen sulphide and nitrogen compounds into ammonia, resulting in a cleaner product.

Another crucial process, hydrocracking, employs hydrogen to break down heavy oil molecules into lighter, more valuable products such as diesel, aviation fuel and gasoline. This process involves high temperatures and pressures, and

hydrogen is essential for converting heavy feedstocks into lighter distillates. The resulting products are not only lighter but also free of sulphur and other contaminants.

In addition to hydrotreating and hydrocracking, hydrogen is also used in other refinery processes, such as isomerisation, alkylation and tail-gas treatment, albeit in smaller quantities. Overall, hydrogen is a critical component in the production of high-quality petroleum products for removal of impurities and creation of lighter, more valuable molecules.

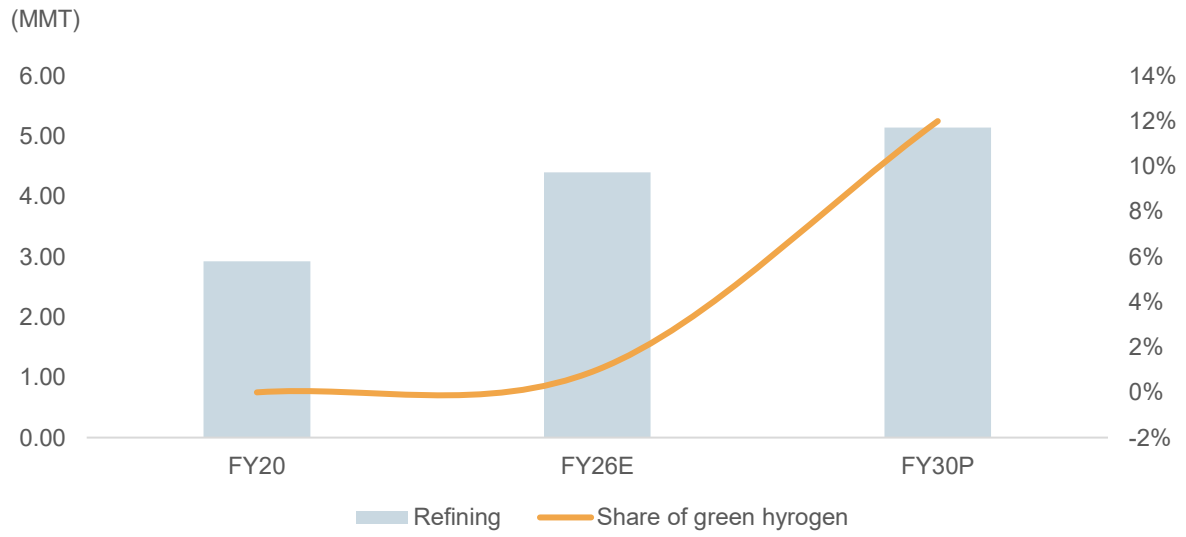
The production and recovery of hydrogen are essential to refining operations that convert crude oil into light, high-quality products. The product slate of a refinery is closely correlated with the availability and consumption of hydrogen. In recent years, there has been a surge in demand for hydrogen from oil refineries due to declining crude quality and stricter emission norms. As a result, the refining sector is expected to continue to drive demand for hydrogen, underscoring the need for reliable and efficient hydrogen production and supply chains.

In refineries, hydrogen is often produced as a by-product of the refining process but is typically insufficient to meet the overall consumption needs of the process. To bridge this gap, additional on-site hydrogen production is usually required, which is currently generated through natural gas or naphtha reforming. Refineries commonly build natural gas reforming units on site to produce hydrogen. As a significant consumer of hydrogen, the refining industry accounts for a substantial share of the country's total hydrogen usage, making it a crucial sector for the adoption of green hydrogen to achieve government targets.

Fortunately, the refining sector is relatively insensitive to production costs, with hydrogen accounting for only 2-4% of overall production costs. This makes it more feasible for refiners to absorb the additional cost of switching to green hydrogen. In contrast to sectors such as fertiliser, where hydrogen costs are a major expense, the relatively low hydrogen cost in refining make it a more viable sector for green hydrogen adoption.

India's current refining capacity stands at 256 million tonne per annum (MTPA), with an estimated hydrogen consumption of ~4.2-4.6 MTPA. By 2030, the refining capacity is expected to increase to 330-350 MTPA, driving hydrogen consumption to around ~4.5-5.5 MTPA, with a projected CAGR of 3-5% driven by increased use of lower-quality crude oil and stricter emission norms. As newer refining capacities come online with integrated captive green hydrogen production, the proportion of green hydrogen in overall hydrogen consumption of refineries is expected to reach 10-15% by fiscal 2030. However, with a policy push from the government, this proportion could potentially increase to around 60%, accelerating the transition to a more sustainable and low-carbon refining sector.

Figure 127: Share of green hydrogen in refining to be around 10-15% by FY30



Source: Crisil Intelligence, IEA, Industry

The increase in the share of green hydrogen in over hydrogen usage by refiners will be driven by the narrowing cost gap between green and grey hydrogen, as well as increasing regulatory support. The decline in production cost of green hydrogen is anticipated to be driven by two key factors: lower capital expenditure (capex) for electrolysers and further reduction in renewable energy tariffs. As the cost of green hydrogen continues to decrease, it is likely to become an increasingly viable option for refiners, supporting the transition to a more sustainable and low-carbon future.

Fertilisers

India's fertiliser industry is heavily reliant on imports of natural gas, ammonia and fertilisers, making it vulnerable to geopolitical tensions and supply-chain disruptions that drive up costs and increase the financial burden on the government. The industry's dependence on imported raw materials also poses a significant threat to the country's food security.

However, the production of green hydrogen and ammonia domestically can help mitigate these risks, reduce reliance on imports and lower emissions from fertiliser production. By leveraging green hydrogen, the country can decrease its dependence on natural gas imports, enhance food security and promote a more sustainable fertiliser industry.

The fertiliser sector is a significant consumer of hydrogen, with ammonia production being critical to urea manufacturing. Currently, the production of urea in integrated fertiliser plants utilises carbon dioxide (CO_2) that is already available as a by-product of ammonia production from fossil fuels. However, as the industry transitions to green ammonia, urea manufacturers will need to source CO_2 from external sources, such as the cement industry or through carbon capture and utilisation (CCU) technologies. This will require significant investments in new infrastructure and technologies. In contrast, the production of non-urea fertilisers, which relies largely on imported ammonia, may find it easier to switch to green ammonia, as these products are not dependent on the same CO_2 supply chain.

The fertiliser sector in India is contending with imbalanced fertiliser consumption with over reliance on nitrogen compared with phosphorous and potassium, leading to soil degradation and lower crop yields. Also, the government significantly regulates the fertiliser market, particularly with regard to urea. The price of urea is controlled, and fertiliser companies receive subsidies to offset the difference between production cost and market price, ensuring that farmers have access to the nutrient at an affordable price.

The government’s rising subsidy burden is making it the case for more sustainable and efficient fertiliser production and consumption practices. In fact, a push for organic and alternative fertilisers to improve nutrient efficiency is expected to shape the future of the domestic fertiliser sector, offering opportunities for innovation and development of more environment-friendly fertiliser products. Also, growing awareness with regard to soil health will see demand largely driven by non-urea fertilisers.

India's push for self-sufficiency in fertilisers by end-2025 is expected to drive the demand for hydrogen, owing to capacity expansions in the urea, diammonium phosphate (DAP), and nitrogen, phosphorus and potassium (NPK) segments.

Hydrogen is a critical feedstock to produce ammonia, which is used to manufacture urea, DAP and NPK. In fiscal 2026, domestic ammonia demand from the fertiliser industry is estimated to have reached 22 million tonnes, with ammonia required for urea accounting for ~84% share.

And with the government initiating the process of commissioning several new urea plants by 2025, an additional ~8 million metric tonne of new capacities will be added, of which six urea plants were commissioned between 2019 and 2022.

This expansion will not only reduce India's reliance on fertiliser imports but also create new opportunities for the adoption of green hydrogen in the fertiliser sector.

Figure 128: Cost of hydrogen production contributes significantly to fertiliser production costs

Sectors	Refining	Fertilisers	Natural gas blending	Steel
Current hydrogen demand	★★★	★★★	★☆☆	★☆☆
Demand potential for green hydrogen by 2030	★★★	★☆☆	★★☆	★☆☆
Share in overall production cost	2-4%	60-70%	NA	30-50%
Offtakers	Refiners	Green ammonia producers	City gas distribution entities	Steel manufacturers

Source: International Renewable Energy Agency, Niti Aayog, International Energy Agency (IEA), Ministry of New and Renewable Energy (MNRE), Crisil Intelligence

Hydrogen is typically produced in-house through conventional methods such as SMR or coal gasification. Further, the CO_2, released during the conventional process is recovered and combined with ammonia to form urea (CH_4N_2O). Thus, in switching to green hydrogen, an external source of CO_2 is required as an additional process, which will push up the cost of production. As a result, the adoption of green hydrogen in the urea manufacturing process is expected to be gradual.

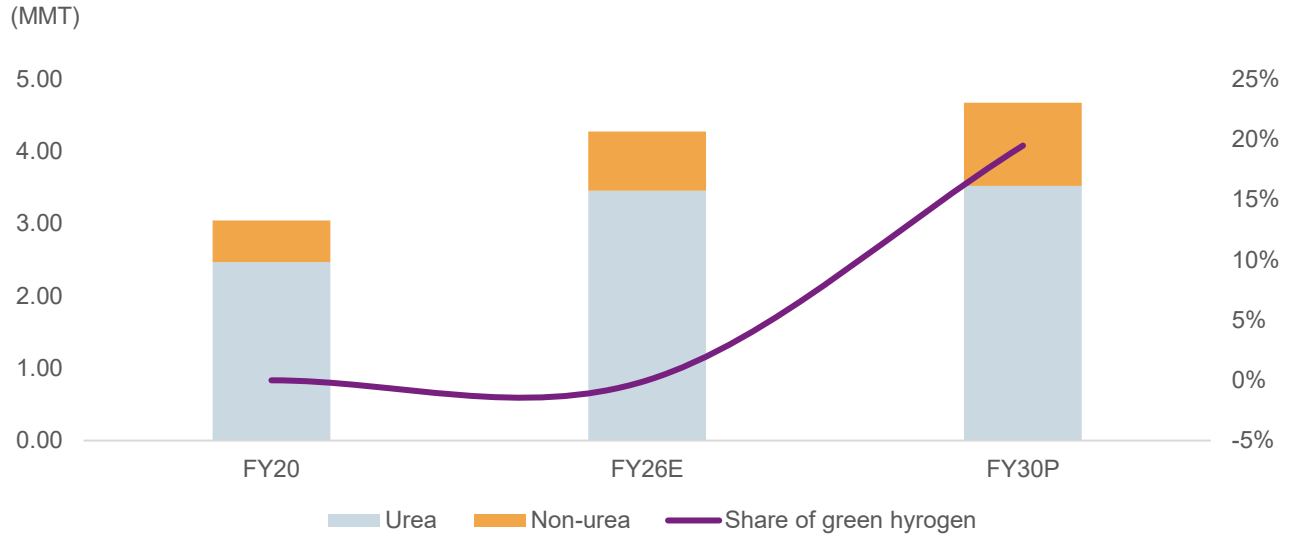
In contrast, hydrogen demand from the non-urea segment is expected to increase to 0.5-1.5 million tonne in fiscal 2030 from 0.7-0.9 million tonne in fiscal 2026, with at least 90% of the demand expected to be met by local green hydrogen production. The non-urea segment is likely to drive the adoption of green hydrogen, given its lower dependence on conventional hydrogen production methods. At this point, non-urea fertilisers are expected to drive demand due to their lower premium compared with urea fertilisers and the relatively easier transition from traditional to green ammonia production, with lower technical challenges.

Non-urea-based fertilisers ideal segment for green hydrogen adoption

India's ammonia imports are currently dominated by countries with abundant and cheap natural gas resources, such as Saudi Arabia, Qatar, Oman and the UAE. However, the volatility of natural gas prices has a direct impact on ammonia prices, making it highly unpredictable.

By transitioning to green ammonia (derived from green hydrogen) from grey ammonia (derived from grey hydrogen), the sector can reduce its dependence on natural gas and mitigate risks associated with price fluctuations. Moreover, investing in green ammonia infrastructure can alleviate the financial burden of annual subsidies, which are currently linked to fluctuating natural gas prices, and provide a more stable and sustainable solution for the fertiliser industry.

Figure 129: Trend in green hydrogen demand based on fertiliser segment



E – estimated; P – projected

Source: Crisil Intelligence, IEA, Industry

Other sectors

Still, sectors could potentially adopt green hydrogen:

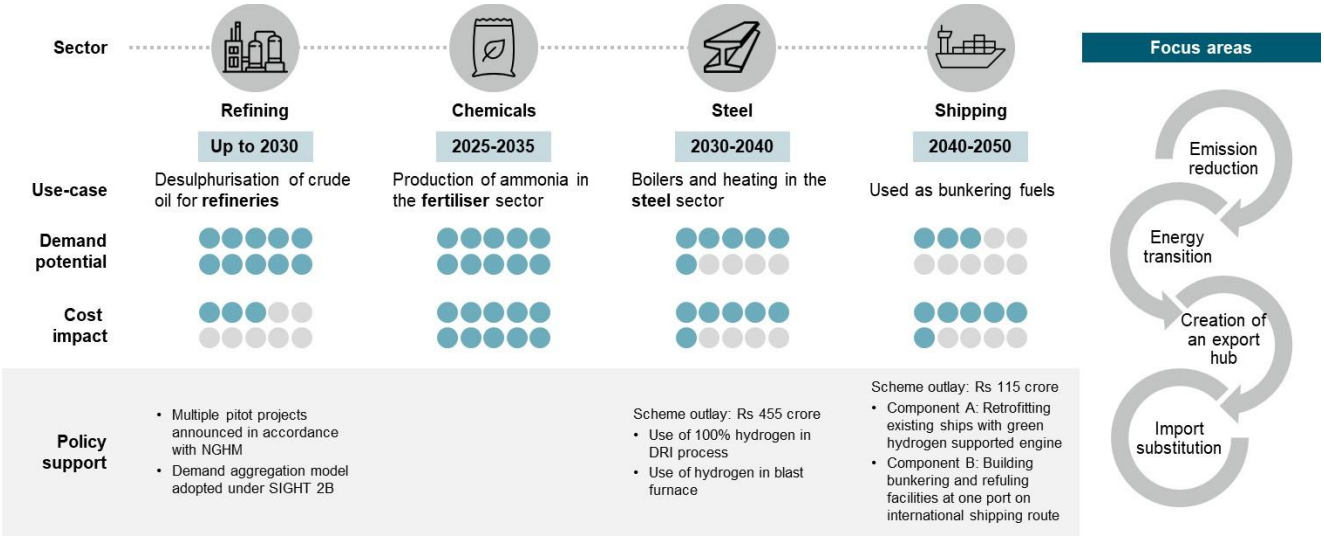
- **Methanol**: Apart from fertilisers and refining, a small amount of hydrogen is also required in methanol production. This segment in India is relatively small, with a demand of 1.5–2 MMT[3], of which nearly 80% is imported.[4] This is the result of a large portion of methanol production coming from natural gas, which is abundantly available in the Middle East at very low prices. However, the Indian government is rapidly pushing coal-based methanol production not only to reduce imports but also to displace other crude oil products across major end-use sectors, such as transport and residential. Green hydrogen-based methanol production can also be explored as a low-carbon-intensive option. However, as with urea production, this process requires an external CO_2 source. Thus, green hydrogen adoption in the methanol segment is some time away
- **Steel production**: Steel is one of the most carbon-intensive sectors, contributing 12% to India's total industrial emission.[5] Hydrogen is being explored as a viable solution for decarbonising steel production through direct reduced iron technology, which uses hydrogen as a reducing agent instead of coke/natural gas. India's position as the world's second-largest steel producer further underscores the importance of this sector in green hydrogen adoption. The Indian government has approved three pilot hydrogen projects in the steel industry with ~$41 million allocated as part of the National Green Hydrogen Mission.[6]
- **Heavy-duty transportation**: Hydrogen is increasingly being seen as a solution for decarbonising the heavy commercial vehicle segment, including buses, trucks and trains. In India, hydrogen fuel cell electric vehicles (FCEVs) are being tested in several cities, with early successes in buses and trucks. The challenge, however, remains the

[3] *https://wwfin.awsassets.panda.org/downloads/green-hydrogen-demand-assessment.pdf*
[4] *https://www.niti.gov.in/sites/default/files/2022-06/Harnessing_Green_Hydrogen_V21_DIGITAL_29062022.pdf*
[5] *https://www.climatepolicyinitiative.org/decarbonizing-indias-steel-industry-how-transition-finance-can-help/#:~:text=The%20iron%20and%20steel%20(I&S,(DRI%2DIF)%20route.*
[6] *https://gmk.center/en/news/india-will-fund-three-pilot-hydrogen-projects-for-steel-production/*

cost of hydrogen refuelling infrastructure and competition from BEVs. Still, green is expected to play a significant role in the long-term decarbonisation of transport, especially in sectors where electrification is less feasible

- **Shipping and aviation**: In the maritime and aviation sectors, hydrogen-derived fuels such as ammonia and synthetic jet fuel are being explored as a means to reduce emissions. India has a significant maritime sector, and as international focus shifts towards decarbonisation, hydrogen and hydrogen-derived fuels are expected to be pivotal. Similarly, hydrogen-powered aircraft are still in the experimental stage; but future commercial adoption could contribute to significant emission reduction in aviation
- **Energy storage and grid integration**: Hydrogen is poised to be a vital element in India's energy storage landscape, facilitating the seamless integration of renewable energy sources into the grid. By storing hydrogen and converting it back into electricity via fuel cells or gas turbines, India can overcome the limitations of traditional battery technologies and ensure stable energy supply. As a result, hydrogen is expected to play a pivotal role in the country's long-term renewable energy plans. Additionally, hydrogen fuel cell generators offer a reliable alternative for backup power, particularly in critical infrastructure such as hospitals, and in remote areas where traditional renewable energy sources are not feasible due to unfavourable conditions

Figure 130: Cost is a key parameter to assess demand for green hydrogen in new sectors



Source: Niti Aayog, Crisil Intelligence

Cost of green hydrogen

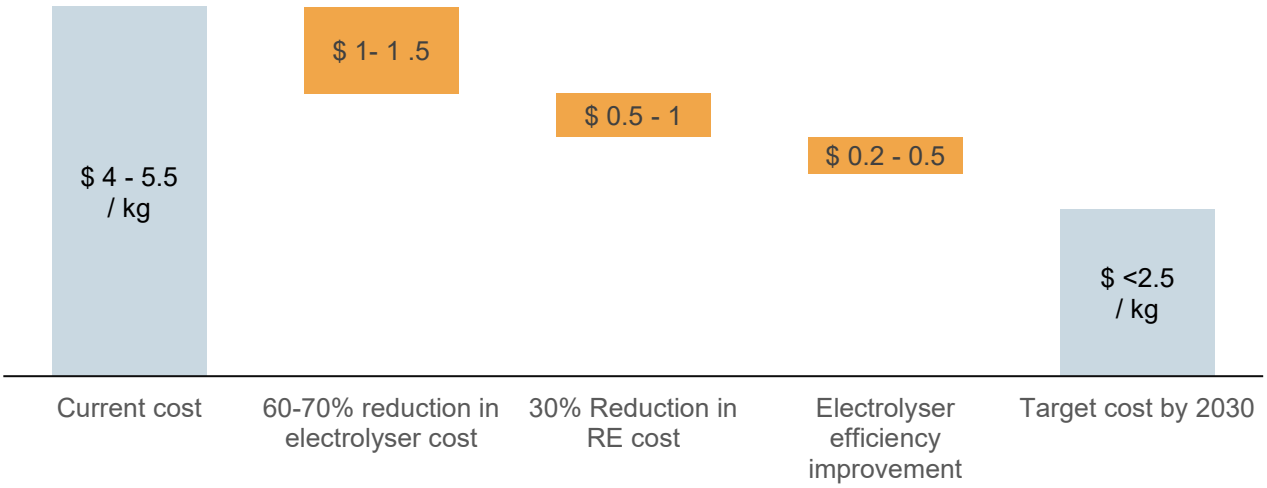
A major hindrance for the uptake of green hydrogen is the cost of production, which is estimated at $3-6 per kg, nearly twice that of grey hydrogen. Major cost drivers in the manufacturing process are electrolysers and renewable energy.

While electrolysis as a technology is not a new phenomenon, deployments of the same have been relatively scarce due to more cost-effective alternatives using coal and natural gas. However, in the current decarbonization trend, electrolysis has made a comeback due to its zero-emission merit if powered through renewable energy. The cost of electrolyser deployment is expected to fall over the next few years, driven by technological development and economies of scale. Furthermore,

Green hydrogen costs need to come down to grey hydrogen costs to ensure its wider adoption. According to industry estimates, the cost of producing green hydrogen in India, which depends on several factors such as the type and mix of renewable energy sources, capacity utilisation, plant load factor, power efficiency and price of electrolysers, ranged $4.0-5.5 per kg in 2024. To reduce the cost of green hydrogen, the NGHM has allocated funds for green hydrogen production and domestic electrolyser manufacturing.

Additional policy incentives, such as exemptions from power banking and open-access charges, reduced GST on renewable energy components, lower GST on electrolyser components will help in reducing the cost of green hydrogen. The cost could be further reduced by ~$0.41 per kg through incentives, such as access to green debt and the SIGHT programme, and market-driven innovations in improving electrolyser efficiency. Furthermore, improvement in renewable energy technologies will lead to lower renewable energy costs and lead to an estimated reduction of $0.62 per kg. If these incentives and innovations are implemented, the cost of green hydrogen could potentially decrease by $1.6-3.2 per kg.

Figure 131: Cost reduction crucial for green hydrogen adoption; central policies to play a major role



Source: Niti Aayog, Industry, Crisil Intelligence

Green hydrogen policies

Developed countries and regions are increasingly viewing hydrogen energy as a vital strategy for their energy transition, with focus on building a green hydrogen industry that leverages renewable energy sources such as photovoltaic and wind power. As a result, several countries have developed national strategies to promote the rapid development of green hydrogen, which is expected to have a considerable impact on the global geopolitical landscape and the structure of the global energy market

Table 26: Over 40 countries have announced hydrogen strategies, with aim for commercial use by 2030

	Policy target	Associated renewable energy capacity additions	Electrolyser target	Capital outlay	R&D and investment focus	Policy objective
India	5 MMT/yr by 2030	~125 GW	60-100 GW by 2030	$2.37 bn	Electrolysers Storage and distribution Fuel cells Alternate technologies for low carbon H_2 production	To become a global hub for production, usage and export of GH_2 and its derivatives
Japan	3 MMT/yr by 2030 12 MMT/yr by 2040 (with ammonia) 20 MMT/yr by 2050	No target declared	15 GW by 2030	$52 mn	Electrolysers Fuel cells Transportation Power and heating Efficient GH_2 production	To develop, demonstrate and industrialise technologies for hydrogen and its derivatives' manufacturing, and to achieve carbon neutrality and overseas market penetration
EU	10 MMT/yr by 2030 10 MMT/yr by 2030	80-120 GW	40 GW by 2030	$609 bn	Electrolysers Storage and distribution End-use applications Safety	To move towards the EU's commitment to reach carbon neutrality by 2050
South Korea	3.9 MMT/yr by 2030 5.3 MMT/yr by 2040 27 MMT/yr by 2050	No target declared	1.4 GW	$653 mn/yr	Fuel cells	To become a hydrogen-based economy with focus on transportation, decarbonising industry and buildings, and managing the production and distribution of hydrogen
USA	10 MMT/yr by 2030 20 MMT/yr by 2040 50 MMT/yr by 2050	Broad dedicated capacity not announced	3+ GW by 2028	$9.5 bn	Electrolysers Alternate technologies for low carbon H_2 production New use cases	Develop clean hydrogen value chain to achieve de-carbonisation in all sectors
	1 MMT/yr by 2030	No target declared	25 GW by 2030	$50 mn	Challenges for accelerated local deployment	To become a major global exporter of

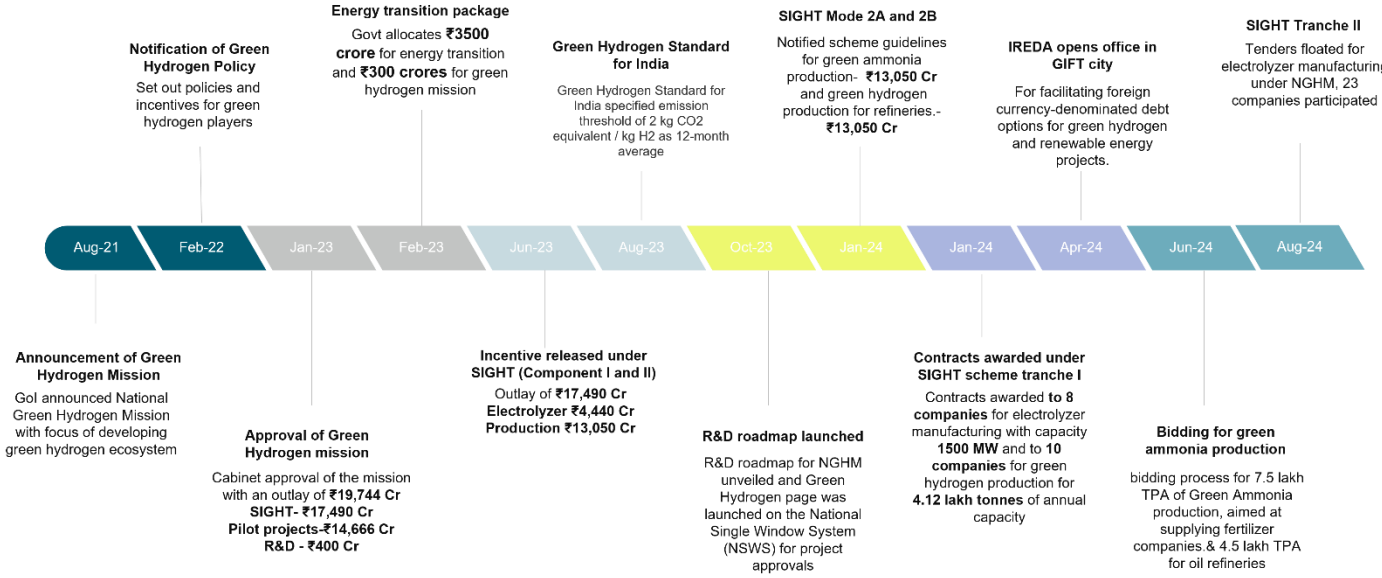
Chile						green hydrogen, leveraging the potential for abundant access to low-cost renewable energy
Australia	0.5 MMT/yr by 2030	Not identified	1 GW	~ $1.5 bn	Production	To set up hydrogen industry for local as well as international use, with focus on top 3 exporters of hydrogen

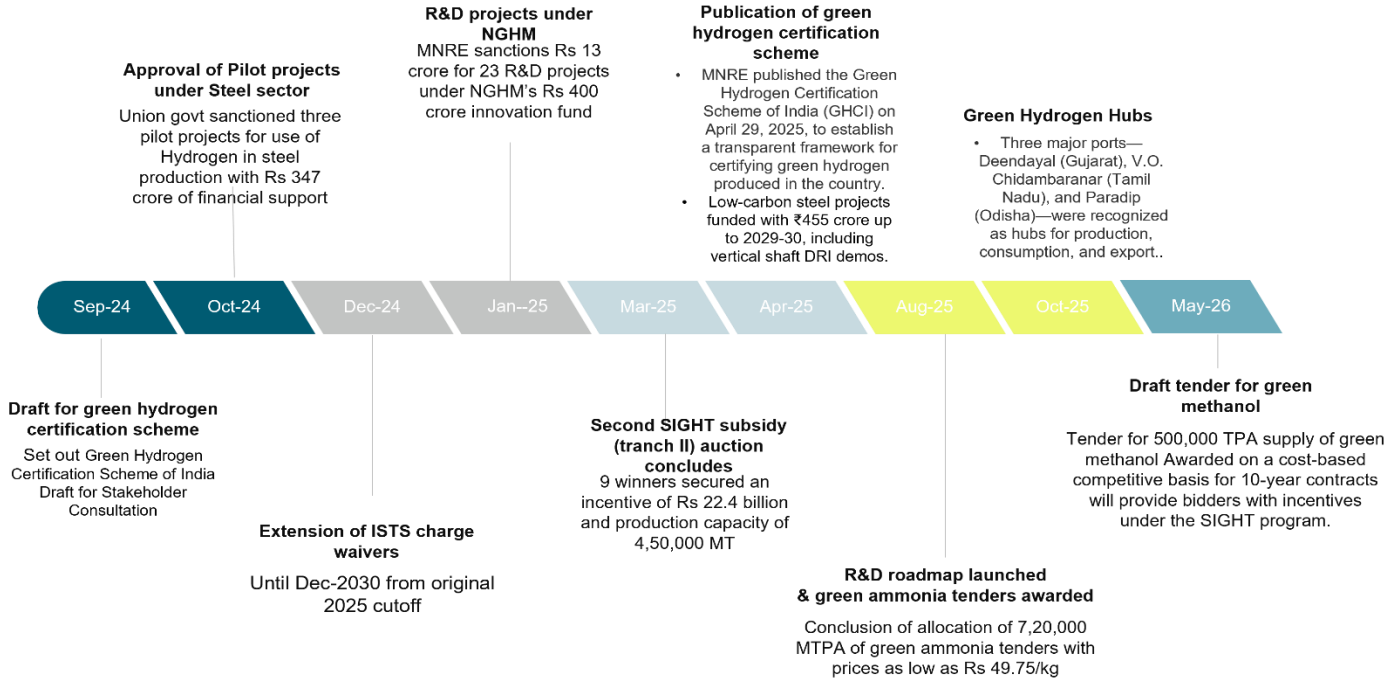
Production capacity | Demand

Green hydrogen policy in India

The Government of India, in collaboration with its agencies, is actively promoting the adoption of hydrogen, with various initiatives underway to drive its development, as outlined in this section.

Figure 132: Green Hydrogen Policy in India

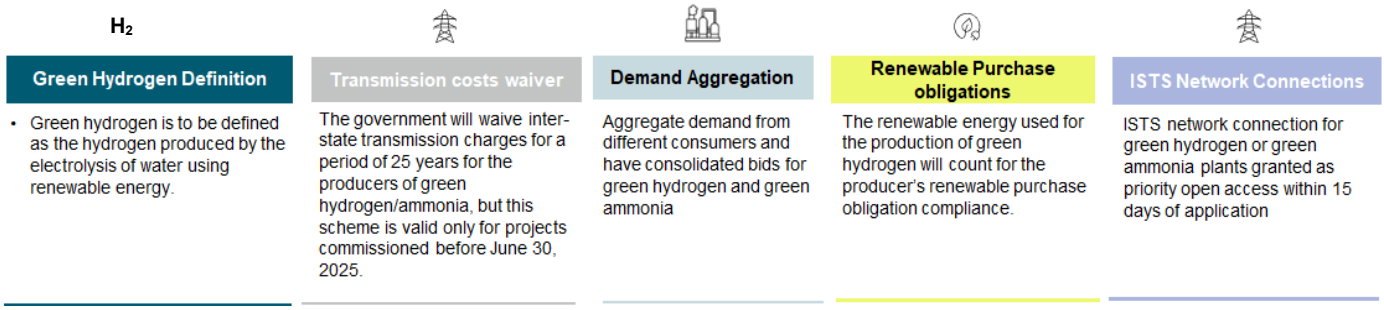




Source: Official documents, Industry

In 2022, the Green Hydrogen Policy established targets to increase domestic production of green hydrogen and its derivatives, such as green ammonia, to 5 MMT per year by 2030 (Government of India 2022). The policy aims to bolster renewable energy generation and boost green hydrogen production in the country.

Figure 133: Key highlights of the policy

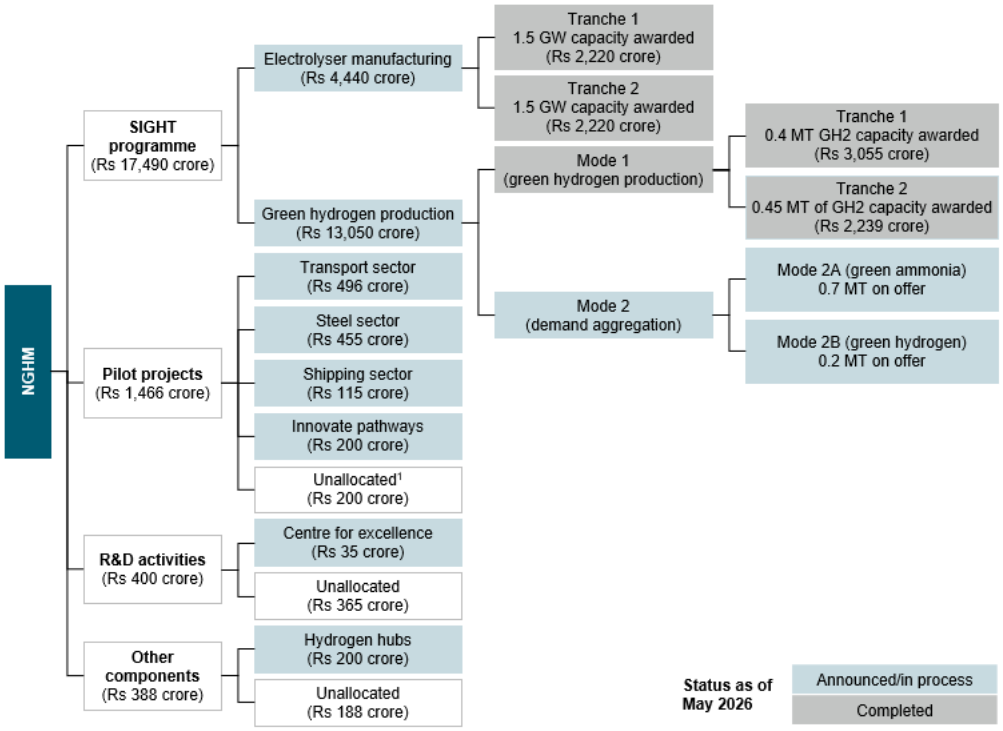


Source: Official documents, Industry

National Green Hydrogen Mission (NGHM)

India's policy framework is a key enabler for the green hydrogen sector. The launch of the NGHM in January 2023 was a significant milestone, outlining the government's commitment to creating a green hydrogen economy. The mission, supported by Rs 197.4 billion in financial aid from the government, aims to produce at least 5 mtpa of green hydrogen, add 125 GW to the country's renewable energy capacity, attract investments worth Rs 8 trillion and create 600,000 jobs by CY 2030.

Figure 134: Hydrogen Mission lays the foundation for green hydrogen ecosystem in India



SIGHT scheme – Strategic Interventions for Green Hydrogen Transition
Note: Other target areas include decentralised energy applications, hydrogen production from biomass, hydrogen storage technologies, etc
Source: MNRE, industry

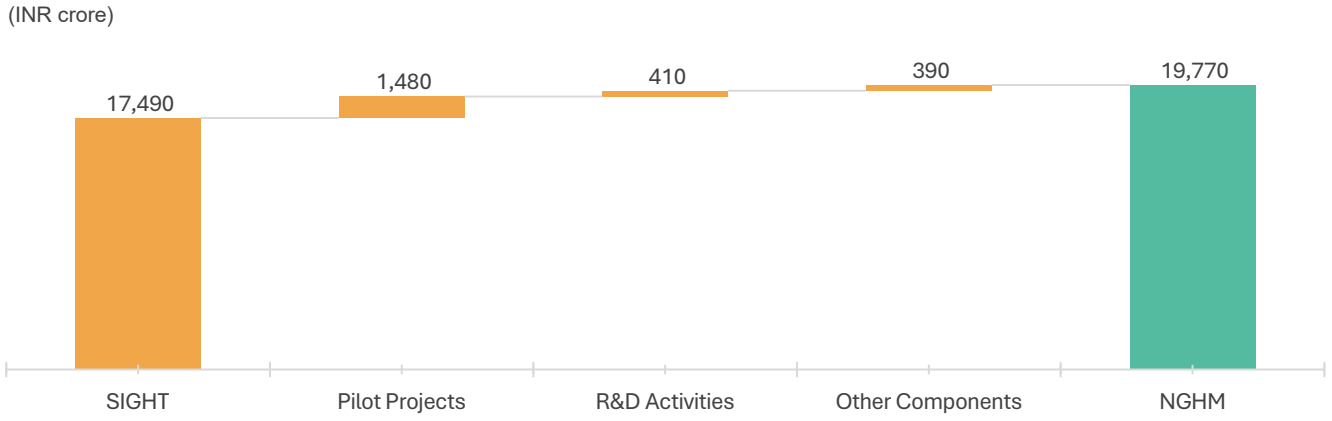
Manufacturing and production roadmap

NGHM outlines a comprehensive plan for the sector, offering incentives for the production of electrolysers, integration of renewable energy and the development of a robust hydrogen infrastructure. The mission will be implemented in two phases.

The first phase focuses on generating demand and ensuring a stable supply by increasing domestic electrolyser manufacturing, promoting the use of green hydrogen in industries such as refineries and fertilisers, and launching pilot projects for steel production, heavy duty mobility and shipping.

The second phase aims to make green hydrogen competitive with fossil fuels, enabling large-scale production and supporting commercial projects in sectors such as steel, mobility and shipping.

Figure 135: Hydrogen mission focuses on incentivising green hydrogen production



Note: Other target areas include decentralised energy applications, hydrogen production from biomass, hydrogen storage technologies, etc
Source: MNRE, industry

Additionally, pilot projects are planned for emerging sectors such as railways and aviation. Several Indian states have already introduced their own green hydrogen policies, aiming to attract investments, promote local manufacturing and set targets for green hydrogen adoption in key industries.

Key incentives

The government's Strategic Interventions for Green Hydrogen Transition (SIGHT) programme aims to accelerate the production of green hydrogen by incentivising the setting up of electrolyser manufacturing facilities, ramping up technology and developing infrastructure and skills. As much as Rs 44.4 billion is being allotted under the programme to encourage electrolyser manufacturing capacity.

The central government has initiated aggregation schemes, such as Mode2B, to stimulate demand for green hydrogen, particularly in the refining and fertiliser sectors. In refining, green hydrogen has the potential to transform processes such as hydrocracking and desulphurisation. Mode2B encourages oil and gas companies to aggregate demand and invite bids for the lowest-cost production of green hydrogen, thus incentivising the industry to adopt cleaner alternatives.

India's green hydrogen strategy extends to sectors that contribute significantly to emissions, such as shipping, steel and transport. Specific schemes have been launched to promote the use of hydrogen in these sectors. For instance, a pilot scheme for green hydrogen in ship propulsion has an allocated budget of Rs 1.2 billion until fiscal 2026, while Rs 4.6 billion has been earmarked for promoting the use of green hydrogen in steelmaking until fiscal 2030. These initiatives are designed to facilitate the adoption of green hydrogen in hard-to-abate sectors.

Research and development activities

R&D in green hydrogen technologies has received considerable attention with an allocation of Rs 4 billion. This funding will support the development of technologies to enhance the efficiency of hydrogen production, storage and distribution as well as reduce costs. Additionally, India is focusing on establishing hydrogen hubs with two hubs identified for fostering innovation and collaboration within the sector with an allocation of Rs 2 billion. Safety standards for hydrogen use are also being developed to ensure safe handling, storage and transport of hydrogen, which is critical to building industry confidence.

Tenders bid out

In January 2024, the Indian government awarded contracts to 8 companies, including Reliance and Greenko, to set up electrolyser manufacturing capacities of 1,500 MW per annum under the SIGHT scheme, with a total incentive allocation of Rs 2220 crore. The tender was divided into two buckets: Bucket 1 (1,200 MW) for electrolyser manufacturing capacity using any stack technology, and Bucket 2 for biomass-based pathways.

Separately, 10 companies, including Reliance and Acme Clean Tech, were awarded contracts to establish green hydrogen production facilities with a total capacity of 4,12,000 metric tonnes per annum (mtpa), with a maximum average incentive of Rs 34.7/kg.

In March 2024, SECI issued a tender for 1,500 MW of electrolyser manufacturing capacity under SIGHT scheme Electrolyser manufacturing tranche II which attracted bids from 23 companies

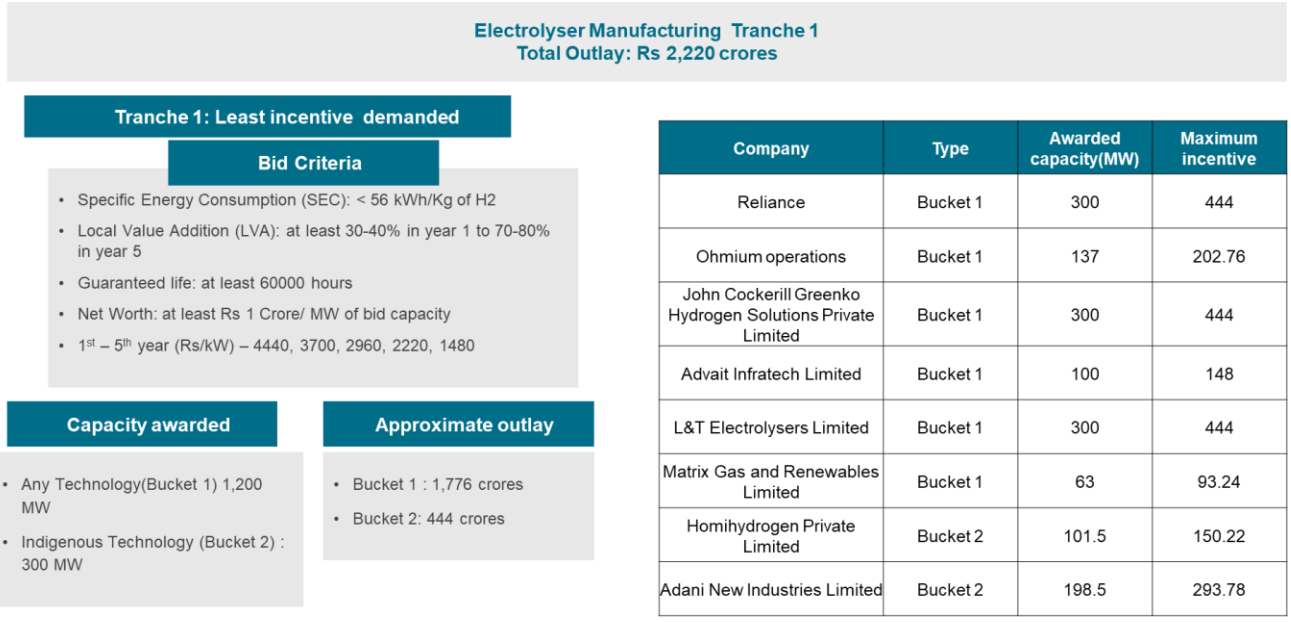
In July 2024, the Solar Energy Corporation of India (SECI) launched a tender for 450,000 mtpa of green hydrogen production capacity, which was awarded to 9 companies, including Reliance and L&T Energy GreenTech, with a total allocated incentive of Rs 22.3 billion.

In August 2025, SECI awarded 7,24,000 mtpa of green ammonia production capacity as part of SIGHT scheme across 13 fertilizer plants in India. The lowest price discovered under the auctions was Rs 49.75/kg and highest price was Rs 64.74/kg both won by ACME. The prices discovered are nearly half the prices discovered at H2Global's green ammonia auction. India has established itself as a leader in the green ammonia market by offering highly competitive pricing, setting a new global standard and solidifying its position as a pioneer in the industry.

In May 2026, SECI has issues a draft tender for 500,000 tonne-per-year (TPA) supply of green methanol supply the National Green Hydrogen Mission. Awarded on a cost-based competitive basis, the 10-year contracts will provide bidders with incentives under the SIGHT program.

These initiatives aim to support India's goal of scaling up green hydrogen and ammonia production, reducing reliance on fossil fuel-based hydrogen, and establishing a low-carbon economy.

Figure 136: Tenders awarded under SIGHT scheme Mode 1 and 2



Company	Type	Awarded capacity(MW)	Maximum incentive
Reliance	Bucket 1	300	444
Ohmium operations	Bucket 1	137	202.76
John Cockerill Greenko Hydrogen Solutions Private Limited	Bucket 1	300	444
Advait Infratech Limited	Bucket 1	100	148
L&T Electrolysers Limited	Bucket 1	300	444
Matrix Gas and Renewables Limited	Bucket 1	63	93.24
Homihydrogen Private Limited	Bucket 2	101.5	150.22
Adani New Industries Limited	Bucket 2	198.5	293.78

Green Hydrogen Manufacturing
Total Outlay: 3,055 crores

Mode 1 Tranche I: Least incentive demanded

Bid Criteria

- Single bid for Green Hydrogen (GH_2) production facilities
- Capacity quoted in multiples of 500 MT per annum
- Bucket-I (Technology Agnostic): 10,000 MT - 90,000 MT
  Bucket-II (Biomass Based): 500 MT - 4,000 MT
- Incentive : Rs 50/Kg, Rs 40/Kg and Rs 30/Kg in 1st to 3rd year of production

Capacity awarded

- Technology Agnostic: 410,000 MTPA
- Biomass Bases: 2,000 MTPA

Approximate outlay

- Technology Agnostic: 3,037.4 crores
- Biomass Bases: 18 crores

Company	Type	Average incentive (Rs/kg)	Annual capacity	Maximum incentive (Rs crore)
CESE projects	Bucket 1	0	10500	0
UPL Limited	Bucket 1	0	10000	0
RIL	Bucket 1	18.9	90000	510
Welspun	Bucket 1	20	20000	120
HHP Two pvt ltd	Bucket 1	25.04	75000	563
Torrent power ltd	Bucket 1	28.89	18000	156
ACME	Bucket 1	30	90000	810
Greenko	Bucket 1	30	90000	810
JSW	Bucket 1	34.66	6500	67.6
BPCL	Bucket 2	30	2000	18

Electrolyser Manufacturing Tranche II
Total Outlay: Rs 2,220 crores

Tranche 2: Least incentive demanded

Bid Criteria

- Specific Energy Consumption (SEC): < 56 kWh/Kg of H2
- Local Value Addition (LVA): at least 30-40% in year 1 to 70-80% in year 5
- Guaranteed life: at least 60000 hours
- Net Worth: at least Rs 1 Crore/ MW of bid capacity for bucket 1 and 2A, at least Rs 30 lakh/ MW of bid capacity for bucket 2B
- 1st – 5th year (Rs/kW) – 4440, 3700, 2960, 2220, 1480

Capacity awarded

- Any Technology(Bucket 1) 1,100 MW
- Indigenous Technology (Bucket 2A) : 300 MW
- Indigenous Technology, smaller units (Bucket 2B) : 100 MW

Approximate outlay

- Bucket 1 : 1,628 crores
- Bucket 2A: 444 crores
- Bucket 2B: 148 crores

Company	Type	Awarded capacity(MW)	Maximum incentive
Advait Infratech Limited	Bucket-1	200	296
Matrix Gas and Renewables Limited	Bucket-1	237	351
Newage Green Electro Private Limited	Bucket-1	71.5	106
Ohmium Operations Private Limited	Bucket-1	137	203
Waaree Energies Ltd	Bucket-1	300	444
GH2 Solar Private Limited	Bucket-1	105	155
Avaada Electrolyser Private Limited	Bucket-1	49	73
Adani Enterprises Limited	Bucket-2A	71	106
Newage Green Electro Private Limited	Bucket-2A	228	338
Adani Enterprises Limited	Bucket-2B	30	44
Eastern Electrolyser Limited	Bucket-2B	30	44
Newtrace Private Limited	Bucket-2B	30	44
Suryaashish KA1 Solar Park Private Limited	Bucket-2B	10	15

Green Hydrogen Manufacturing
Total Outlay: 2,239 crores

Mode 1 Tranche II: Least average incentive demanded

Bid Criteria

- Bidding based on least average incentive quoted
- Minimum and Maximum bid capacities:
  Bucket-I: 10,000 TPA - 90,000 TPA ; Bucket-II: 500 TPA - 4,000 TPA. A bidder can bid in either or both buckets
- Maximum capacity that can be allotted to a single bidder: 90,000 TPA
- Incentive : Rs 50/Kg, Rs 40/Kg and Rs 30/Kg in 1st to 3rd year of production

Capacity awarded

- Technology Agnostic: 448,500 MTPA
- Biomass Bases: 15,00 MTPA

Approximate outlay

- Technology Agnostic: 2,220 crores
- Biomass Bases: 18 crores

Company	Type	Average incentive (Rs/kg)	Annual capacity	Maximum incentive (Rs crore)
Oriana Power	Bucket 1	0.01	10000	0.03
Suryadeep KA1	Bucket 1	8	19000	45.60
L&T Energy Green Tech	Bucket 1	11.11	90000	299.97
GH2 Solar	Bucket 1	14.97	10500	47.15
Green Infra Renewable Energy Farms	Bucket 1	16.2	90000	437.40
Waaree Clean Energy Solutions	Bucket 1	18.9	90000	510.30
AM Green Ammonia (India)	Bucket 1	19	90000	513.00
Reliance Green Hydrogen and Green Chemicals	Bucket 1	24.99	49000	367.30
Matrix Gas and Renewables	Bucket 2	39.67	1500	17.85

Source: SECI, Industry, Crisil Intelligence

Figure 141: Tenders awarded under SIGHT Mode 2A-Tranche I (green ammonia production)

SECI Green Ammonia tender Mode-2A-Tranche I
Total Outlay: Rs 1533.4 crores

Tranche 2: Least incentive demanded

Bid Criteria

- Based on e-reverse auction on Rs/kg
- Long term Supply (10 years) of green ammonia production
- Bidder net worth must be at least Rs 5 crore/1000 MT of annual green ammonia capacity
- Incentives : Rs 8.82/kg (1st year), Rs 7.06/kg (2nd year), Rs 5.30/kg (3rd year)

Capacity awarded

- Awarded capacity of 724000 mtpa

Approximate outlay

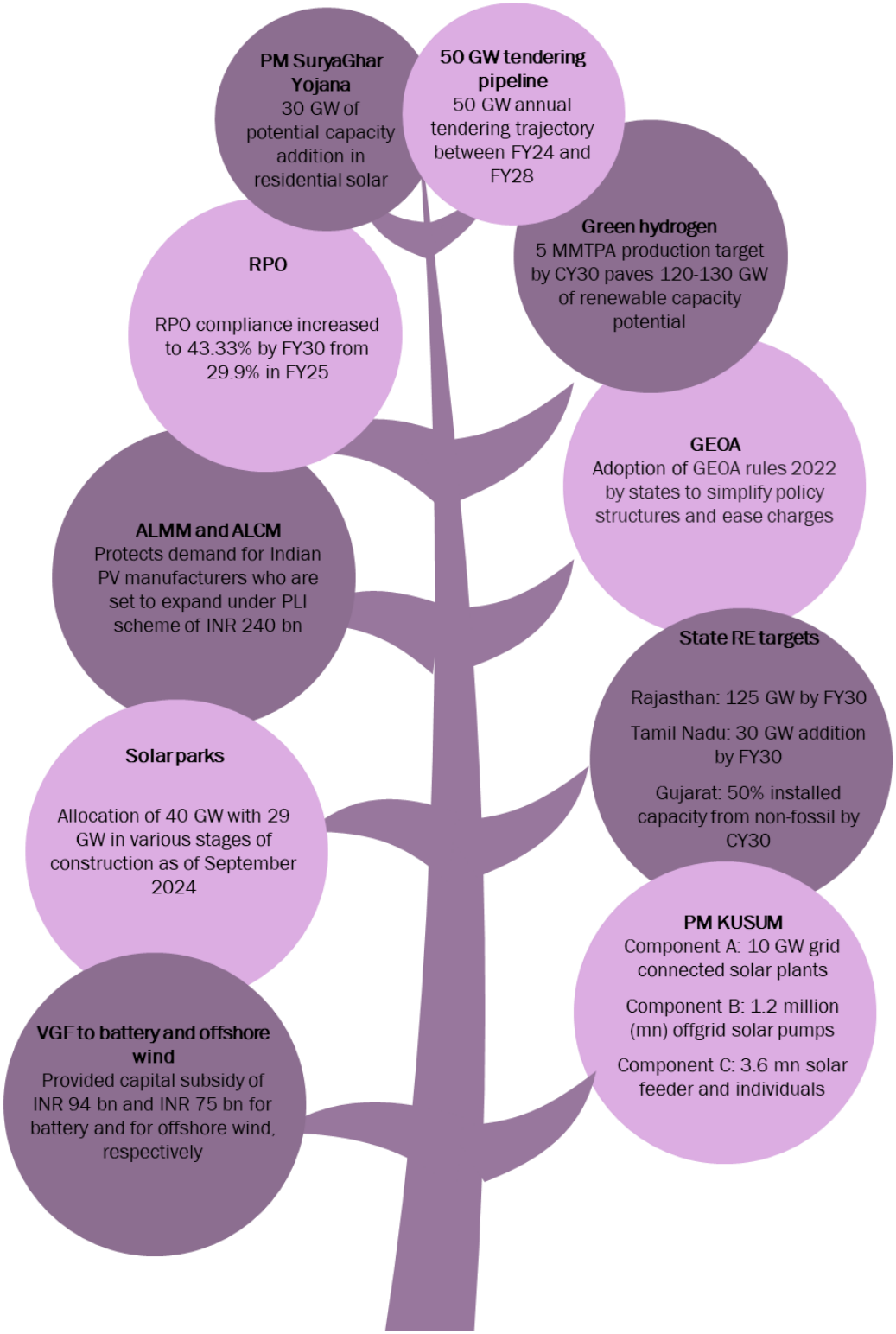
- Outlay of Rs.1533.4 crores

Company	Buyer	Capacity(MTPA)	Cost(Rs/kg)
ACME, Odisha	Paradeep Phosphate Ltd	75000	55.75
NTPC, MP	Krishna Phoschem Ltd	70000	51.80
Oriana, MP	Madhya Bharat Agro Products Lts	60000	52.25
SCC, Maharastra	MBAPL	70000	53.05
Onix, Gujrat	Gujarat Narmada Valley fertilizers & chemicals Ltd	50000	52.50
Jakson, Andhra pradesh	Coromandel International Ltd	85000	50.75
ACME, Andhra Pradesh	Coromandel International Ltd	50000	51.89
ACME, Gujrat	Indian Farmers Fertilizer Cooperative Ltd	100000	54.73
ACME, Odisha	Indian Farmers Fertilizer Cooperative Ltd	100000	49.75
ACME, Goa	Paradeep Phosphate Ltd	25000	62.84
ACME, West Bengal	Indorama India Pvt Ltd	20000	64.74
SCC, Karnataka	Mangalore Chemicals and Fertilizers	15000	57.65
Suryam, Chennai	Madras Fertilizers	4000	50.00

Source: SECI, Industry, Crisil Intelligence

While there is a scheme for incentivising green hydrogen production and demand aggregation in India, focus on wide renewable energy adoption is a key enabler in establishing a green hydrogen ecosystem. The Government of India targets 500 GW of installed capacity from non-fossil fuels by 2030, for which, various efforts have been made, which are stated as under:

Figure 137: Various policy drivers for enabling renewable capacity



RPO – Renewable purchase obligations; VGF – Viability gap funding; GEOA – Green Energy Open Access; ALMM – Approved List of Models and Manufacturers; ALCM – Approved List of Cells Manufacturers
Source: SECI, MNRE, MoP and Crisil Intelligence

Renewable energy demand

As of fiscal 2026, renewable energy sources had a combined installed capacity of ~275 GW in India.

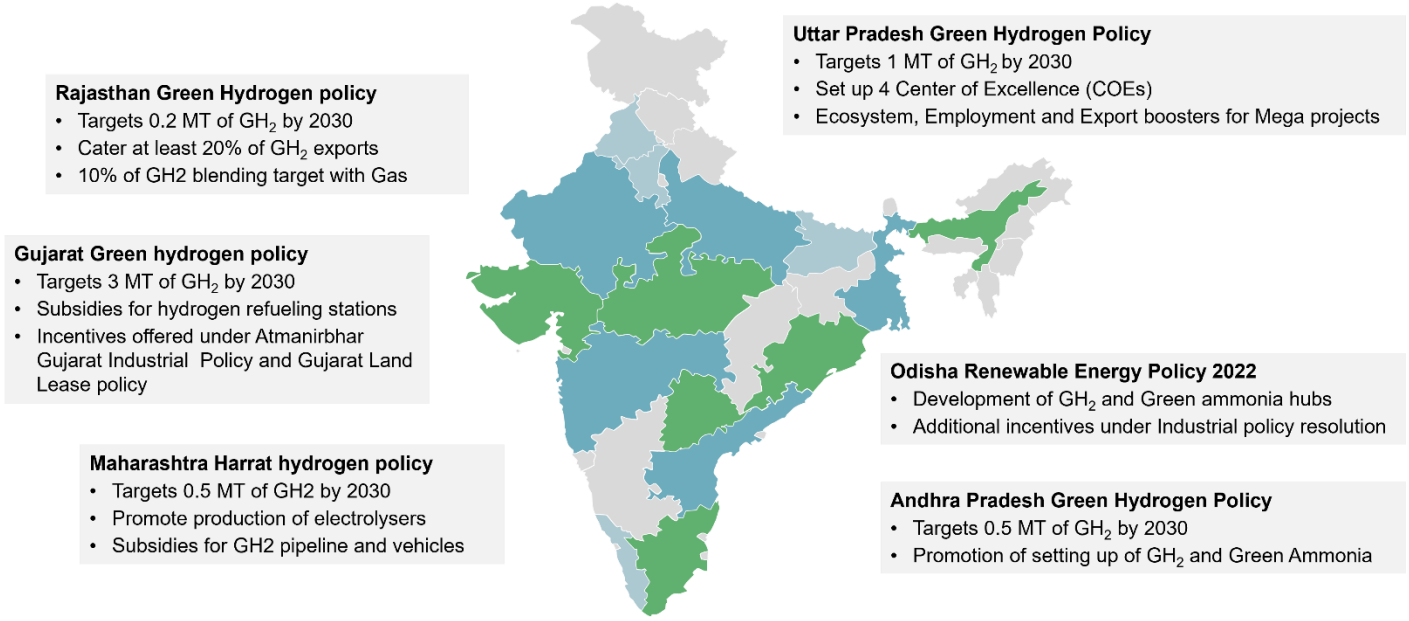
For green hydrogen, the Government of India has set a production target of 5 MTPA by 2030. This will require an electrolyser installation capacity of 27–30 GW and nearly 110–130 GW of renewable capacity.

However, given the favourable regulatory policy as well as aggressive announcements by the players, hydrogen production by 2030 may exceed the target, in which case there are significant upside risks to renewable capacity requirements.

State government schemes

India's national hydrogen policies set a clear direction for the industry, providing a solid base for state governments to develop their own initiatives. As of March 2025, several states, including Andhra Pradesh, Maharashtra, Uttar Pradesh, Rajasthan and West Bengal, have launched green hydrogen policies, while others, such as Madhya Pradesh, Odisha, Tamil Nadu and Kerala, have incorporated green hydrogen into their renewable energy plans. Many more states, including Gujarat, Punjab and Haryana are in the process of developing their own policies. These state-level policies outline specific targets, offer incentives for key applications, and provide benefits for electricity supply, aiming to lure investors and foster the growth of green hydrogen production facilities across the country.

Figure 138: Map highlighting major Indian state governments announcing schemes supporting green hydrogen



Source: Crisil Intelligence, policy documents

Table 27: State incentives to give additional boost to green hydrogen demand

State	Target	Capital subsidy	T&W charges concession	Other power-related subsidies	Land concessions	Land stamp duty
Maharashtra	0.5 MTPA	30% capital subsidy 1% interest subsidy for hydrogen pipelines	50-60%	CSS, ASC exempted		100% exemption on stamp duty charges for land conversion

State	Target	Capital subsidy	T&W charges concession	Other power-related subsidies	Land concessions	Land stamp duty
Uttar Pradesh	1 MTPA	Up to Rs 25 lakh/year for 5 years for start-ups Capital subsidy up to Rs 210 crore or 100% SGST reimbursement or 30%+ PLI incentives	100%	Waiver on CSS, ASC, ED, intra-state wheeling and transmission charges for up to 10 years after commercial date of operation	Rent at Rs 15,000 per hectare, government PSU to receive land at Rs 1 per hectare	Waived for PSU
Andhra Pradesh	0.5 MTPA		25% up to Rs 10 lakh	Cross subsidies exempt for five years	Rent at Rs 31,000 per hectare	
Odisha		30% capital subsidy on plant and machinery	100%	Rs 3 per unit reimbursement and electricity duty exempt 100% exemption from ED STU, CSS and ASC to be exempted or reimbursed 25% exemption on wheeling charges	Land provided at 50% concessional rate	No stamp duty will be required to be paid in respect of transfer of land or shed by the government, IDCO and private industrial estate developers to new industrial units.
Gujarat	3 MTPA	20% capital subsidy on electrolyser (1-10 MW), BESS and oxygen bottling (capped) 20% capex subsidy up to INR 35 crore per green hydrogen hub 20% capex subsidy for biomass based green hydrogen projects (up to 5 KTPA & max 5 projects) 20% subsidy for the first 5 desalination plant	50% reimbursement for 5 years	Exemption from electricity duty CSS and ASC not applicable to captive RE projects		100% reimbursement of stamp duty and registration charges to, capped at INR 5 lakh per project.
Rajasthan	0.2 MTPA		50%	Cross subsidy exempt	Priority allotment	
West Bengal			100% waiver on ISTS and wheeling charges	100% ED exemption	100% waiver on land conversion fees	Exemption on stamp duty
Madhya Pradesh		Capital subsidy up to Rs 200 crore Up to Rs 5 crore for infrastructure development Up to Rs 10 crore for establishing ETP	50% waiver on wheeling charges for RE projects for 5 years	Exemption from electricity duty Rs 1/unit rebate on tariff for 10 years for RE projects		Mega Industrial units with investment of more than ~500 crores shall be eligible for customised

State	Target	Capital subsidy	T&W charges concession	Other power-related subsidies	Land concessions	Land stamp duty
						package under CCIP
Tamil Nadu		20-33% subsidy for 10-15 years		CSS and ASC exempt for RE projects		
Kerala (draft)	~0.16 MTPA		~50% exemption on wheeling and ISTS	100% ED and CSS exemption		
Bihar (Draft)	0.25 MTPA					100% reimbursement of stamp duty, registration fees and land conversion charges for the first time lease/sale/transfer of land for green hydrogen project
Assam	0.002 MTPA	30% subsidy on electrolyzer plant and equipment costs for projects 25% capital subsidy for 2G lignocellulosic biomass-based green hydrogen plants	100% waiver up to 20 years	100% electricity duty exemption, Cross-Subsidy & Additional Surcharge exempted, 50% waiver on monthly banking charges, banking allowed up to 30 days	Priority allocation of government land at rates as per policy. Permission to set up storage bunkers near ports.	100% reimbursement of charges for land reclassification and stamp duty.

Source: Crisil Intelligence, State policy documents

Projects for green hydrogen and electrolyser production in India

Table 28: Key project announcements by public sector players

Sr. No.	Entity	Key insights
1	IOCL	• GH4India Pvt Ltd was established as a joint venture between ReNew Power, Larsen & Toubro, and Indian Oil Corporation to produce green hydrogen • The company aims to meet at least 50% of its hydrogen needs with green hydrogen by 2030, replacing grey hydrogen • It also plans to adopt green hydrogen usage across all its refineries in the near future • The overall target is to produce 350 KTPA • L&T recently won tender to supply ~10 KTPA of green hydrogen to IOCL's Panipat refinery at Rs 397/kg plus 18% GST • IOCL plans to set up green hydrogen units at all of its refineries as part of a Rs 2.4 lakh crores green transition plan to achieve net zero carbon emission status by 2046
2	HPCL	• Installed a 0.37 KTPA electrolyser-based green hydrogen facility at its Visakh refinery in Andhra Pradesh • Ordered large-scale industrial electrolysers • Submitted proposals for green hydrogen and green ammonia projects in Germany and Oman through a partnership with HPCL and ACME • Aims to achieve a total production of 29 KTPA by 2030 • Ocior Energy, a company based in Abu Dhabi, has won a tender to supply 5,000 tonnes of green hydrogen annually to HPCL Visakhapatnam refinery.
3	BPCL	• Invited bids to set up a 5 MW electrolyser and associated system to blend green hydrogen with natural gas in the city gas network • Intends to set up a 1 MW electrolyser manufacturing facility in India by 2025 through support from Bhabha Atomic Research Center for green hydrogen. • Planning a 20 MW electrolyser installation at its Bina refinery in Madhya Pradesh for green hydrogen production • Targeting a total green hydrogen production capacity of 30 KTPA by 2030 • Ocior Energy won BPCL's Bina refinery green hydrogen tender at Rs 328/Kg
4	MRPL	• Plans to establish green hydrogen production units in Karnataka by 2030 • Aims for a total production of 0.5 KTPA by 2026
5	CPCL	• Intends to commission a 1 KTPA-green hydrogen plant in Tamil Nadu by 2027
6	GAIL	• Plans to develop a green hydrogen plant with 10 MW capacity in Madhya Pradesh • Awarded a contract to set up one of India's largest PEM electrolyser plants at its Vijaipur complex in Guna, Madhya Pradesh.
7	NRL	• Floated a tender for a 20 MW electrolyser to be completed by end of 2024, using AEL, AEM, or PEM technology • Developing a green hydrogen facility at Numaligarh, Assam • Plans to reach total production of 20 KTPA by 2038
8	ONGC	• Signed an MoU with Greenko ZeroC (Greenko) to explore projects in renewables, green hydrogen, green ammonia, and other derivatives of green hydrogen • Targets a cumulative green ammonia production of 2 MTPA

Sr. No.	Entity	Key insights
9	NTPC	• Planning a green hydrogen facility (5 MW capacity) as part of its upcoming 4,750 MW renewable energy project in the Rann of Kutch • Taken up the initiative of blending green hydrogen in the piped natural gas network of GGL (Gujarat Gas Limited) at NTPC Kawas. Green hydrogen will be produced by using electricity from the existing 1 MW floating solar project of NTPC Kawas • Set up a hydrogen fueling station and solar plant and provided five fuel cell buses for operation on intracity routes of Leh • Aiming to produce 1500 TPD Green Hydrogen and 7500 TPD Green Hydrogen derivatives • Signed a MoU with the government of Uttar Pradesh to develop renewable energy lined green hydrogen projects in the state. The agreement focuses on deploying renewable power infrastructure to support green hydrogen production
10	SECI	• Set up production facilities for green hydrogen in India under the SIGHT programme • Targets producing 450 KTPA in total

Source: Hydrogen strategy documents, Company Report, Crisil Intelligence
Note: List is non exhaustive

Several private companies, including Adani, ACME and Avaada, have set ambitious targets for producing green hydrogen and green ammonia in the coming years. These goals differ in scope, with some companies setting organisation-wide targets and others focusing on specific locations or facilities, which may involve expanding existing operations or introducing new ones.

Adani New Industries Limited (ANIL) has launched a green hydrogen pilot plant in Kutch, Gujarat, which is powered by solar energy and supported by a battery storage system. The 5 MW facility demonstrates the feasibility of decentralized green hydrogen production and has the potential to reduce carbon emissions in sectors such as fertilizers, refining, and heavy transport.

The Mundra Green Hydrogen Hub developed by ANIL is a project that aims to create an integrated green hydrogen ecosystem. The hub will feature an expansion of renewable energy generation, with a target of 30 GW of solar and wind power by 2030. The project also includes the development of manufacturing facilities for wind turbines, solar modules, and hydrogen derivatives. The goal is to produce 1 million tonnes of green hydrogen per annum by 2030, which could help reduce India's dependence on imports and decarbonize certain sectors.

Adani Energy Solutions has secured a transmission project worth Rs 2,800 crore to support green hydrogen and ammonia production in Mundra, Gujarat. The project involves upgrading the existing electrical substation and constructing a new transmission line to ensure a reliable supply of renewable energy for large-scale hydrogen production. This initiative is expected to contribute to India's green energy infrastructure.

Adani Total Gas Ltd has launched a green hydrogen blending project in Ahmedabad, which aims to reduce emissions by blending green hydrogen into piped natural gas for domestic and commercial consumers. The project has the potential to be scaled up to achieve a higher blend of green hydrogen.

As part of its long-term infrastructure development plan for clean energy, the Government of India is developing an integrated hydrogen ecosystem under the National Green Hydrogen Mission (NGHM). The Ministry of New and Renewable Energy (MNRE) has identified Deendayal, Paradip, and V.O. Chidambaranar Ports as the country's first green hydrogen hubs, positioning them as gateways for production, storage, and export. In parallel, the Ministry of Road Transport and Highways (MoRTH) has unveiled plans to establish national hydrogen highways, connecting major industrial and logistics corridors through a network of refueling stations.

These initiatives are part of India's efforts to transition to a more sustainable energy mix and reduce carbon emissions. They demonstrate the country's interest in exploring alternative energy sources and reducing its reliance on fossil fuels.

A summary of the planned green hydrogen and green ammonia production facilities, along with their capacities, is provided in the table below, highlighting the green hydrogen/ electrolyser production commitments of these Indian private sector entities:

Table 29: Key project announcements by private sector players

Sr no	Entity	Key insights
1	Adani New Industries	• Aims to produce 1 MTPA of green hydrogen by 2030 with expansion plans to produce additional 2 MTPA within 10 years. Plans to establish approximately 30 GW of renewable energy capacity by 2030 • Received a subsidy under the SIGHT programme for electrolyser manufacturing • ANIL commissioned India's first off-grid 5 MW green hydrogen facility in Kutch, Gujarat. An off-grid green hydrogen plant is a facility that produces hydrogen using electrolysis powered by renewable energy sources, such as solar or wind, and is not connected to the main electrical grid. This means the plant relies entirely on its own renewable energy generation for the hydrogen production process. • Adani Total Gas Ltd (ATGL) has launched a project to blend green hydrogen with natural gas in Ahmedabad, Gujarat, starting with a 2.2-2.3% blend and aiming for 5-8%.
2	ACME Solar	• Unveiled plans for integrated green hydrogen/green ammonia plants in Tamil Nadu (1.32 MTPA (0.22 MPTA of green hydrogen and 1.1 MTPA of green ammonia), Karnataka (1.2 MTPA of both green hydrogen and green ammonia), and Odisha (1.1 MTPA of green hydrogen and green ammonia) • Commissioned the country's first pilot project for green hydrogen and green ammonia (1.7 KTPA) at Bikaner, Rajasthan • Granted subsidy under the SIGHT scheme for electrolyser manufacturing
3	Hygenco India	• Intends to invest $2.5 billion in green hydrogen projects across India over the next three years • Awarded subsidy under SIGHT for electrolyser manufacturing and green hydrogen production
4	Avaada Group	• Plans to establish a 0.5 MTPA green hydrogen production facility • Will make an initial investment of Rs 80,000 million (equivalent to $964 million) • Secured subsidy under SIGHT for electrolyser manufacturing and green hydrogen production. The group has partnered with Casale to develop India's largest green ammonia plant in Odisha with capacity of 1500 tonnes per day
5	AM Green Ammonia BV (backed by Greenko Group)	• Committed to an initial investment of Rs 125,000 million (equivalent to $1.5 billion) • Proposed 1 MTPA green ammonia plant in Kakinada, Andhra Pradesh • Plans to invest $6 billion into pumped storage hydropower facilities to support green ammonia production • Signed a long-term offtake agreement with Uniper for up to 500,000 TPA of green ammonia from its Kakinada project. The supply is intended to be EU RFNBO-compliant, with first export targeted from 2028
6	ReNew Power	• Plans to develop a green hydrogen unit (0.22 MTPA) and a green ammonia unit (1.1 MTPA) in Kerala • Plans to invest Rs 264,000 million (equivalent to $3.2 billion) in all facilities, including associated facilities such as renewable energy plants

Sr no	Entity	Key insights
7	Ocior Energy	• Signed a Memorandum of Understanding (MoU) with the Gujarat government for setting up a 1 MTPA green hydrogen/green ammonia production facility in the Kutch district with an investment of $4.8 billion
8	ABC Cleantech	• Proposed to build a green hydrogen facility (0.2 MTPA) and a green ammonia plant (1.0 MTPA) • Signed an MoU with the government of Karnataka to establish a green hydrogen facility supported by 5 GW renewable energy capacity within the state • Plans to invest Rs 500 billion (equivalent to $6 billion) in overall infrastructure, including supporting units such as renewable energy installation
9	Yamna Co	• Signed an MoU with Government of Andhra Pradesh which aim to produce 5 MMTPA of green hydrogen and 1 MMTPA of green ammonia and plan to invest $2 billion
10	Torrent Group	• Green hydrogen plant in Uttar Pradesh to produce 72 tonnes green hydrogen per year which will be blended upto 2% into city gas distribution/CNG.
11	Advait greenergy	• Signed an MoU with the government of Gujarat to invest INR 1400 crore across a diverse green energy and infrastructure projects in Gujarat
12	JSW Energy ltd	• India's first green steel production project with 25 MW capacity which includes a 7-year agreement with JSW steel to supply 3800 tons of green hydrogen annually.
13	Ohmium	• Gigafactory factory to manufacture Indian made PEM electrolysers with initial manufacturing capacity of approx. 500 MW/year and future plan to scale up to 2000 MW/year
14	Essar	• Plan to develop 1 GW of hydrogen capacity along with its derivatives (1 million tonne/annum) in Jamnagar with an investment around INR 30000
15	CESC Ltd	• CESC Ltd, owned by RSPG group will construct a 10500 tonnes green hydrogen facility on the east coast with an investment range of INR 450-500 crore
16	KPI Green Energy	• KPI green received a INR 128.5 crore green hydrogen contract from NTPC for deployment of plasma gasification-based hydrogen generation of capacity 1 TPD (tonne per day) from refuse and agriculture waste
17	Oswal Greenzo Energy	• Oswal Greenzo Energies secured a contract for a 5 MW green hydrogen plant at Deendayal Port, Kandla (Gujarat). The project is expected to produce 800 TPA of green hydrogen and includes provision for expansion up to 10 MW
18	GH2 Solar	• GH2 Solar is planning to build an investment pipeline of about ₹1,000 crore by the end of 2026. The firm plans to launch an IPO to raise ₹250 crore to ₹300 crore and invest ₹600 crore in a 10,500 TPA GH2 production plant

Source: Hydrogen strategy documents, Company Reports, Crisil Intelligence
Note: List is non exhaustive

Despite large-scale announcements in this evolving sector, India's electrolyser ecosystem remains at a nascent stage, with significant investments in R&D needed to improve electrolyser technology and make it more efficient and economical. A few PSUs in India possess the manufacturing capability for producing balance of plant (BoP) components, but domestic production of electrochemical stacks remains insignificant. In addition to R&D, companies have been actively entering into strategic tie-ups with global players to bridge technology gaps.

Table 30: Major strategic tie-ups announced

Tie-ups	Electrolyser production/ supply	H_2 production	H_2 transport	End-use	Comments
L&T-HydrogenPro	✓				Gigawatt-scale manufacturing of alkaline water electrolysers based on HydrogenPro technology
Greenko-John Cockerill		✓		✓	John Cockerill to supply 2 GW electrolysers to Greenko for its green ammonia plant with production capacity of 1 MTPA
IOCL-L&T-Renew	✓	✓	✓	✓	Develop the green hydrogen sector in India in addition to manufacturing and selling electrolysers
Reliance Industries-Steisdal	✓				Agreement for technology development, and manufacture Steisdal's HydroGen Electrolysers
Adani-TotalEnergies	✓	✓	✓	✓	Invest ~$5 billion in a 2 GW electrolyser fed by renewable power from a 4 GW solar and wind farm to manufacture 1.3 MTPA of urea derived from green hydrogen. ANIL targets to produce 1 MTPA of green hydrogen by 2030
NTPC-Bloom Energy	✓				NTPC has awarded a contract to Bloom Energy to supply 240 kW solid oxide electrolyser (SOE) for its micro-grid project
JSW-Fortescue					Conduct scoping work for green hydrogen production-related projects for use in green steelmaking, hydrogen mobility, green ammonia, etc.
GAIL-Cummins		✓			Cummins will provide its proton exchange membrane electrolysis technology
HMEL-NTPC Green Energy		✓			Agreement to collaborate for opportunities in green hydrogen and derivatives
L&T and IOCL		✓			L&T energy GreenTech a subsidiary of L&T will build India's largest green hydrogen plant at IOC's Panipat refinery supplying 10 KTPA for 25 years at $4.67/kg with 18% GST
FACT (Fertiliser and chemical Travancore Ltd & OIL		✓			Signed a MoU to explore the potential of green hydrogen production in Kochi

Tie-ups	Electrolyser production/ supply	H_2 production	H_2 transport	End-use	Comments
Sembcorp & BPCL		✓		✓	Sembcorp green hydrogen India a subsidiary of Sembcorp industries will focused on green ammonia and bunkering projects aims to decarbonize ports and heavy industry using integrated RE and H_2 supply
Juno Joule green energy & Select energy GmbH		✓	✓		$1.3 billion private investment to build 180 KTPA H_2 capacity with export terminal one the India largest private H_2 export projects
Tata steel & Hygenco		✓			Invest $2.5 billion over the next three years to expand its green hydrogen projects across India. Aim to produce 1 MTPA of green ammonia in various phases
Sterlite Technologies & Hygenco		✓		✓	Invest $2.5 billion over next 3 years to commission 10 GW of green hydrogen and ammonia production by 2030
Desco Infratech & KPI green hydrogen & ammonia Pvt Ltd & Naveriya gas Pvt Ltd		✓		✓	MoU signed to explore green hydrogen and natural gas blending projects in the city gas distribution
NTPC and ENEOS		✓			Signed an MoU with ENEOS to explore supply of green methanol/hydrogen derivatives and its further support NGEL target of achieving 60 GW renewable energy portfolio by 2032
GH2 India & IHFCA (International Fuel Cell Association)			✓		The partnership aims to strengthen global collaboration in hydrogen technologies, promote knowledge exchange, and enhance India's participation in the international hydrogen and fuel cell ecosystem
IIT Madras and Hyundai Motor India	✓				Hyundai motor, IIT madars and Tamil nadu government have launched the HTWO innovation center a INR 100cr R&D facilities for pilot stage hydrogen system in India
ACME & IHI		✓			A joint venture to develop India largest green ammonia project in Odisha, targeting 0.4 tons of annual hydrogen

Tie-ups	Electrolyser production/ supply	H_2 production	H_2 transport	End-use	Comments
					production and reducing 0.8million tonnes of CO_2 per year
Oswal Energies ltd & Deendayal Port		✓			Signed an MoU for the development of green hydrogen, ammonia, methanol and 100 MLD desalination plant under the National green energy initiatives
ACME & IPICOL		✓		✓	ACME and IPICOL partnered to establish a 200 KTPA green methanol plant in Kendrapada, Odisha with renewable integration
KP group & Jeonbuk Province (South Korea)		✓		✓	Signed an MoU with Jeonbuk special self-governing province to collaborate on green hydrogen and ammonia project development
TKIL & SoHHytec		✓			TKIL partnered with SoHHytec SA to manufacture and deploy photo electrolysis green hydrogen technology in India, positioning TKIL as an EPC provider for industrial green hydrogen projects
Indian Oil and IIT(ISM) Dhanbad		✓			Mou signed with IIT (ISM) Dhanbad for a INR 76.42 lakh CSR funding project to develop indigenous solar hydrogen based clean cooking and micro-power system for rural households
NISE & TOYOTA Kirloskar Motor				✓	Signed an Mou to advance green hydrogen mobility in India, focusing on real world testing and validation of hydrogen fuel cell vehicle (Mirai) across Indian climate, road, and traffic conditions over 2 years
Avaada Group, GRIDCO & IIT Bhubaneswar				✓	Signed an MoU to establish a green hydrogen centre of excellence (CoE) in Odisha, focused on R&D and technology development across key green hydrogen application
NGEL & Paradip Port Authority			✓	✓	The partnership was formed to develop and implement green hydrogen-based mobility and related projects at Paradip port which aims to decarbonise port operations and integrating hydrogen into logistics and industrial activities

Tie-ups	Electrolyser production/ supply	H_2 production	H_2 transport	End-use	Comments
Desco Infratech & KPI Green hydrogen				✓	Signed an MoU to implement hydrogen-natural gas blending in the CGD sector, with KPI producing green hydrogen, Desco enabling blending engineering, and Naveriya Gas integrating the blending fuel cutting carbon emissions by up to 30% while leveraging existing gas infrastructure
PEDA & IISc Bengaluru		✓			The PEDA-IISc Bengaluru partnership was formed to develop a pilot green hydrogen production project using biomass (primarily paddy straw), aimed at curbing stubble burning
Thermax & HPCL	✓				Signed an Mou to collaborate on green hydrogen and biofuels, focusing on advanced electrolyser technology (AEM), carbon capture, and bio-pyrolysis solution
NTPC & Assago				✓	Signed an MoU to develop India first indigenous green fertilizer plant at Pudimadaka Green hydrogen hub, with planned 2.5 MMTPA of green chemicals
Reliance Industries & Samsung C&T Corporation				✓	Reliance Industries (RIL) has entered into a binding long-term Supply and Purchase Agreement (SPA) with Samsung C&T Corporation, South Korea, for the supply of Green Ammonia over a 15-year period commencing in the second half of FY2029. The SPA is valued at more than US$3 billion

Source: Hydrogen strategy documents, NITI Aayog, Crisil Intelligence
Note: List is non exhaustive

India is actively pursuing both multilateral and bilateral agreements to boost green hydrogen production and trade, including the National Green Hydrogen Mission. Bilateral agreements focus on strategic partnerships for production, export and research, while multilateral efforts aim to coordinate international initiatives for green hydrogen

Table 31: Multilateral and bilateral agreements

Sr no	Partnership	Key insights
1	India-EU green hydrogen partnership	Aims to harness India's strength in renewable energy and the EU's strength in technology The India-EU partnership was strengthened at the 10th Energy Panel meeting in Brussels, where they agreed on a roadmap for promoting green hydrogen, including building infrastructure, coordinating regulations and improving supply chains. The next phase of their Clean Energy and Climate Partnership (2025-2028) will prioritise green hydrogen, offshore wind, integrated electricity markets, energy efficiency and climate cooperation, aiming to create a sustainable and interconnected energy system
2	Indo-German green hydrogen roadmap	This roadmap focuses on promoting green hydrogen trade, facilitating bilateral offtake agreements, and establishing trading platforms, auction mechanisms and other initiatives
3	Project offtake agreement between India and Japan	The Heads of Terms (HoT) agreement was signed between Sembcorp Industries, Sojitz Corporation, Kyushu Electric Power Co. and NYK Line, solidifying a cross-border green ammonia supply partnership from India to Japan Singapore-headquartered Sembcorp Industries will lead the production of green ammonia in India, utilising renewable energy sources. Kyushu Electric Power Co. has committed to integrating this green ammonia into its energy mix, partially replacing coal consumption at its thermal power plants in Japan. Sojitz Corporation will act as the business intermediary, facilitating the connection between the ammonia producer and the offtaker. NYK Line will oversee the maritime transportation of the green ammonia from India to Japan

Note: The list of projects is not exhaustive
Source: Crisil Intelligence, industry, media reports

Several green hydrogen projects have been commissioned in India with the list as under:

Table 32: List of commissioned projects

Date/Quarter	Project Name/Company	Location	Capacity	Key Remarks
March 2024	Larsen & Toubro (L&T)	Hazira, Gujarat	1 MW (45 kg/day, ~16.4 TPA)	First domestically built 1 MW electrolyser at AM Naik Heavy Engineering Complex for captive use. Demonstrates India's progress in local electrolyser manufacturing.
March 2024	Jindal Stainless Steel (JSL)	Hisar, Haryana	NA	India's first stainless steel company to commission a commercial-scale green hydrogen plant, aimed at decarbonizing steel production.
May 2024	GAIL (India) Ltd	Vijaipur, Madhya Pradesh	4.3 tonnes/day (1,569 TPA)	India's largest green hydrogen plant as of May 2024, using a 10 MW PEM electrolyser. Supplies hydrogen for blending with natural gas in city gas distribution networks.
May 2024	Hindustan Petroleum Corporation Ltd (HPCL)	Bengaluru, Karnataka	NA	India's first Solid Oxide Electrolyser (SOE) at HP Green R&D Centre, aimed at R&D

				for high-efficiency green hydrogen production.
June 2024	Airox Nigen Equipments (for SJVN)	Jhakri, Himachal Pradesh	NA	Commissioned an indigenously built alkaline electrolyser and fuel cell for SJVN's multi-purpose green hydrogen pilot project. Supports renewable energy integration.
March 2025	INOX Air Products	Chittorgarh, Rajasthan	190 TPA	First green hydrogen plant by INOX Air Products at Asahi India's Soniyana facility, supplying green hydrogen for glass manufacturing.
March 2025	Hero Future Energies	Andhra Pradesh	300 KW (25 TPA)	India first green hydrogen blending plant in Tirupati. The 300 kw solar powered unit produce 25 TPA of H_2 for blending with LPG(8-10%) and PNG (3%) cutting about 200 tonnes of CO_2 annually.
June 2025	Adani Group	Kutch, Gujarat	5 MW (1,825 TPA)	India's first off-grid 5 MW green hydrogen plant, 100% solar-powered with battery energy storage system (BESS) and closed-loop automated electrolyser.
July 2025	Deendayal Port Authority	Kandla, Gujarat	1 MW (140 TPA)	India's first Make-in-India 1 MW green hydrogen plant, built in 4 months, producing 140 TPA for clean port operations.
August 2025	TOYO engineering	Vindhyachal, Madhya Pradesh	10 Tons/day (Green methanol)	NTPC and TOYO engineering commissioned a 10 TPD green methanol pilot plant. India's first of its kind demonstration facility converting captured CO_2 and green hydrogen into methanol.
September 2025	VO Chidambaranar Port	Tuticorin, Tamil Nadu	10 Nm^3/hr	VOC Port commissioned a INR 3.87 crore green hydrogen pilot plant producing 10NM^3/hr hydrogen to power streetlights and EV charging.
November 2025	JSW Energy Green Hydrogen Plant	Vijayanagar, Karnataka	3800 TPA (Green hydrogen)	Commissioning of a commercial scale green hydrogen plant (3800 TPA) to supply captive green hydrogen to JSW Steel's Vijayanagar facility, supporting decarbonization of steel production.

Note: The list of projects is not exhaustive
Source: Crisil Intelligence, industry, media reports

Around 8,000 tonnes per annum of green hydrogen production capacity has been commissioned in India till February 2026.[7]

[7] https://www.pib.gov.in/PressReleasePage.aspx?PRID=2245157&reg=3&lang=2

Conclusion

Green hydrogen has high potential to help reduce emissions in hard-to-abate sectors, such as refining, steel and fertilisers, and support India's goal of achieving net-zero emissions by 2070. Additionally, green hydrogen presents an opportunity for India to become a major green hydrogen hub, unlocking export opportunities for hydrogen and its derivatives.

That said, the adoption of green hydrogen comes with its own set of challenges. The primary challenge is the cost competitiveness of green hydrogen compared with incumbent fossil fuels and commodities. Currently, the production of green hydrogen is hindered by high costs. A number of factors contribute to reducing the cost of green hydrogen, which include, low-cost renewable power with low transmission and distribution costs, lower electrolyser capital expenditure through technology learning and manufacturing scale-up, improvement in electrolyser efficiency, and low operating costs. To become competitive, technological advancements, economies of scale and policy support are necessary. Moreover, several challenges must be addressed, including the availability of reliable renewable energy sources, as green hydrogen relies on solar and wind power, which can be intermittent. To overcome this, advanced energy storage and grid infrastructure are essential.

Furthermore, the lack of infrastructure for storing, transporting and distributing hydrogen poses a significant challenge. Establishing a network of pipelines, liquefaction facilities and refuelling stations will require substantial investment and regulatory support. Additionally, R&D is crucial to enhance the efficiency and affordability of green hydrogen production, including advancements in electrolyser technologies, hydrogen storage and fuel cell applications. Collaboration among governments, private companies and academic institutions is essential to drive technological innovation and make green hydrogen a viable option.

Government measures to incentivise green hydrogen demand are a step in the right direction, paving the way for its widespread adoption. By fostering public-private collaborations and attracting foreign investment, India aims to establish a network of green hydrogen hubs that will serve as ecosystems for the production, storage and distribution of this clean energy source.

These hubs will be in regions with substantial renewable energy resources, enabling the creation of efficient supply chains. To stimulate demand and create a market for hydrogen-based solutions, the government is exploring carbon pricing and green hydrogen mandates for industries. India is also collaborating with international partners to leverage global expertise and gain insights into hydrogen technologies, with agreements with countries such as Germany, Japan and the UAE facilitating knowledge sharing, joint research initiatives, and trade.

But the wider adoption of green hydrogen requires addressing the cost disparity with grey hydrogen and diversifying demand beyond refining, fertilisers and chemicals to sectors such as steel and transport. Also, significant capital investment is required for infrastructure upgradation, including storage and transportation and usage in industrial heating, while technological risks and firm offtake arrangements remain key monitorable. Government support through incentives, subsidies and regulatory frameworks will be crucial to bridge the cost gap and stimulate demand.

Hence, while green hydrogen presents significant opportunities for India, the primary advantage is its potential to reduce emissions in hard-to-abate sectors, such as steel and fertilisers, which aligns with India's broader goal of achieving net-zero emission by 2070. It also offers an opportunity for India to reduce its reliance on imported fossil fuels, thereby saving valuable foreign exchange and enhancing energy security, and can be an avenue to strengthen international ties as well, particularly with the US and the EU, creating a promising export market for India, especially for derivatives such as green ammonia.

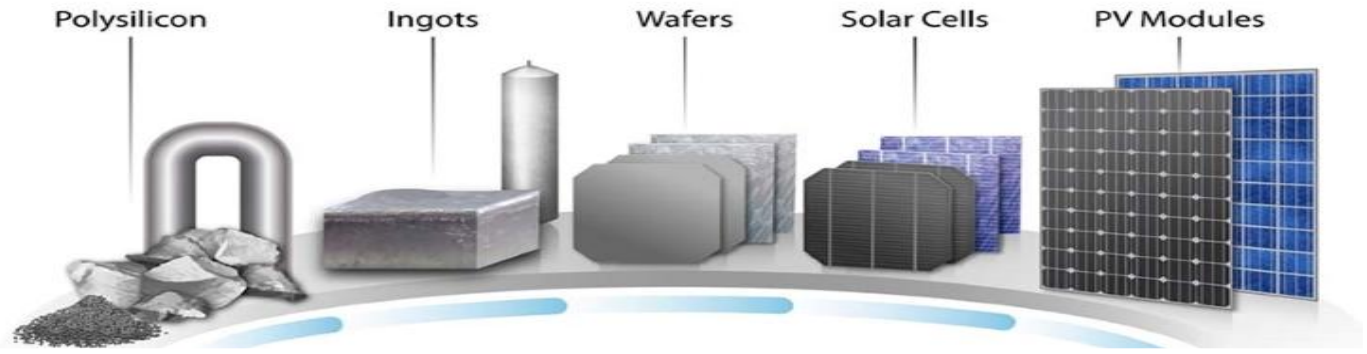
Thus, if the strategy is executed effectively, India can meet its energy needs as well as become a major player in the global green hydrogen economy.

Module 12: Solar photovoltaic segment

Sector background

The solar PV module manufacturing value chain encompasses five critical processes for transforming raw materials i.e., polysilicon into finished solar modules ready for electricity generation. It is a complex and globalised network, with each step contributing to the final product's cost, performance and sustainability.

Figure 139: PV manufacturing value chain



Silica (SiO_2) is refined to metallurgical grade silicon (MG-Si) using a carbothermic process in an electric arc furnace. MG-Si is then purified through a chemical vapour deposition process, converting it into trichlorosilane gas, which is decomposed to produce ultra-pure solar-grade polysilicon.	Solar polysilicon is melted in a crucible to form a cylindrical ingot using crystal pulling or float zone method. The ingot is then sliced into thin wafers using wire saws. These wafers serve as the base material for manufacturing solar cells.	Solar wafers are processed to form solar cells by adding dopants to create a p-n junction, which enables electricity generation. An anti-reflective coating is applied, and metal contacts are added for electrical connections. The cells are then tested for efficiency before being assembled into solar panels.	Solar cells are connected in series and parallel, laminated between layers of protective materials, and sealed with tempered glass and a back sheet. The assembly is framed for structural support, with a junction box added for electrical connections. This creates a durable weather-resistant solar module ready for installation.

Note: Value chain and components used can differ based on the technology of solar cells; the above process is for the widely used cell technology (monocrystalline) in the world as of 2024.
Source: Crisil Intelligence

Brief description of solar cells and modules

Solar cells

A solar cell is an electrical device that converts light energy directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage or resistance varies when exposed to light. Individual solar cell devices are often the electrical building blocks of photovoltaic modules. The following key raw materials and components are used in the manufacturing of solar cells:

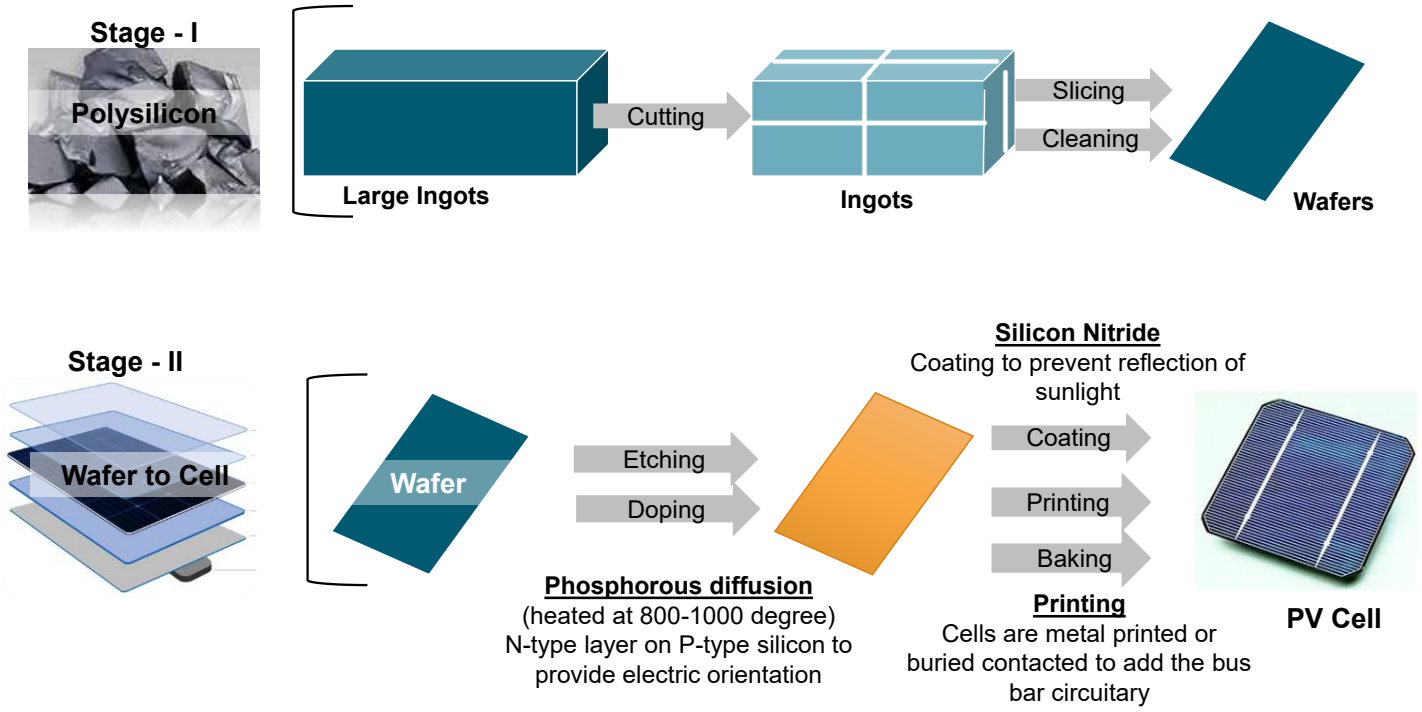
Silicon wafer: The foundation of solar cells lies in silicon wafers, which are sliced from ingots made of ultrapure silicon. The exceptional quality and purity of this silicon material are essential to ensure the optimal performance of solar cells.

Silver paste: A crucial component in solar cell manufacturing is silver paste, which is used to create the conductive contacts on the front side of the cells. Applied through a screen-printing process, this paste plays a vital role in facilitating the collection and transfer of electrical current generated by the silicon wafer, enabling the efficient flow of energy.

Aluminium paste: A layer of aluminium paste is applied to the rear of the solar cell. When heated in a furnace, it creates a reflective surface that bounces electrons back into the silicon, allowing them to be harnessed as electrical current, boosting the cell's overall efficiency.

Other gases and chemicals: The manufacturing process of solar cells relies on a range of gases and chemicals, each playing a critical role at various stages. For instance, specialised dopants such as phosphorus oxychloride are used to create n-type semiconductors, while boron is used for p-type doping. Additionally, a variety of chemicals are used for wafer preparation, including hydrofluoric acid to strip away the silicon dioxide layer and other solvents for thorough cleaning, ensuring that the wafers are pristine and ready for further processing.

Figure 140: Monocrystalline PERC solar cell manufacturing



Source: Crisil Intelligence

The production of solar cells involves a series of complex processes, starting with the inspection and cleaning of raw wafers made of gallium or boron-doped materials. The wafers then undergo texturing, diffusion and selective emitter laser processing to create a p-n junction and improve efficiency. Surface passivation and anti-reflective coating processes, including phosphosilicate glass polishing, oxidation annealing and rear plasma-enhanced chemical vapour deposition are applied to reduce recombination losses and enhance contact adhesion. Metallisation, involving screen printing and co-firing, creates ohmic-contact electrodes, enabling current flow between the metal electrodes and the silicon. Finally, the finished solar cells are tested, sorted and prepared for assembly into solar modules through IV testing, electroluminescence imaging and colour sorting, ensuring that they meet the required standards of efficiency and quality.

Solar modules

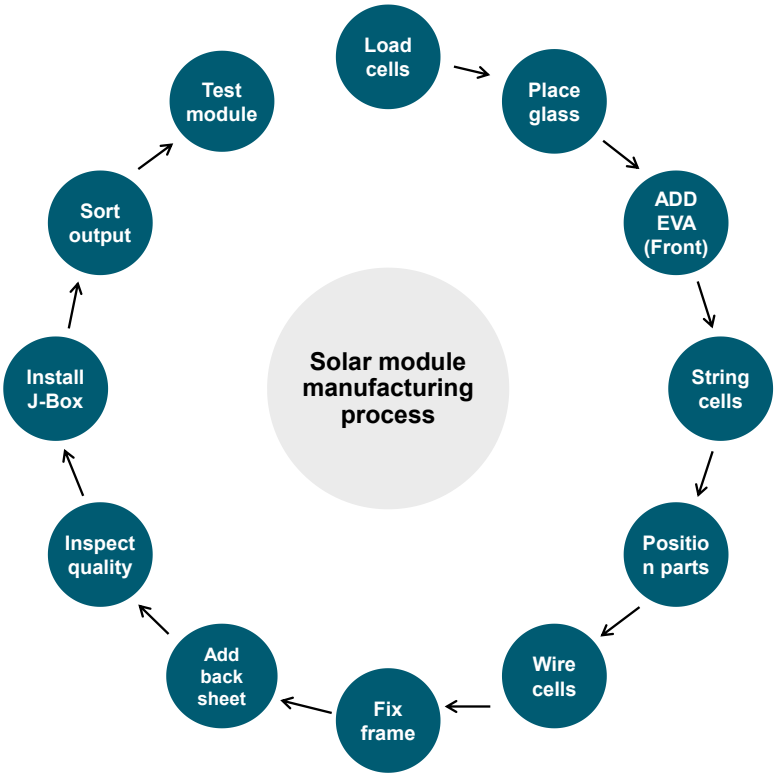
A solar module is an assembly of solar or photovoltaic cells mounted in a framework for installation. Solar panels use sunlight as a source of energy to generate direct current electricity. Solar modules are currently assembled using monocrystalline and TOPCon cells. Solar cells are the primary raw materials and components used to manufacture solar modules. The other key raw materials and components used are as follows:

Backsheet: The backsheet is a critical component of a solar module, serving multiple purposes to ensure optimal performance and longevity. It provides mechanical strength, electrical isolation and moisture resistance, while also acting as a reflective layer to redirect photons back towards the solar cell, enhancing energy generation. Additionally, the backsheet forms a protective barrier against external factors such as ultraviolet rays, temperature fluctuations, and humidity changes, which could otherwise compromise the module's performance. Its inner surface also ensures a secure bond with the encapsulant, holding the entire cell assembly in place for extended periods, while its outer surface provides a safe and shock-resistant interface for installers.

Encapsulants: The encapsulant plays a vital role in solar module performance, serving three primary functions: transmitting light, holding the cell assembly together and adhering to the glass and backsheet. Its high light transmittance ensures that the cell assembly receives an adequate supply of photons to generate maximum power output. The encapsulant also acts as a mechanical bonding agent, keeping the solar cells separated and preventing short circuits through its gel content, which provides intermolecular strength. Additionally, it helps minimize shrinkage, which is critical to prevent misalignments and short circuits. Furthermore, the encapsulant must form a strong and durable bond with the glass on the front side and backsheet on the back of the module, while withstanding elevated temperatures and high UV exposure over extended periods.

Glass and other auxiliary products: The glass component in solar modules plays a crucial role in optimising energy output by minimising reflection and maximising light transmission. As the first point of contact for incoming light, the glass surface must be optimised to reduce reflection, which can result in significant power losses. To address this, an anti-reflective coating is applied to the front surface, reducing reflection to as low as 1% in many cases. Additionally, the glass is tempered to provide mechanical strength and rigidity, protecting the solar module from external weather conditions, shocks and other environmental factors. It is essential to use specialised solar glass with specific components to ensure long-term stability and performance. Beyond solar cells and the components, other critical inputs required for solar module manufacturing include the aluminium frames, ribbon and junction box, all of which work together to create a high-performing and durable solar module.

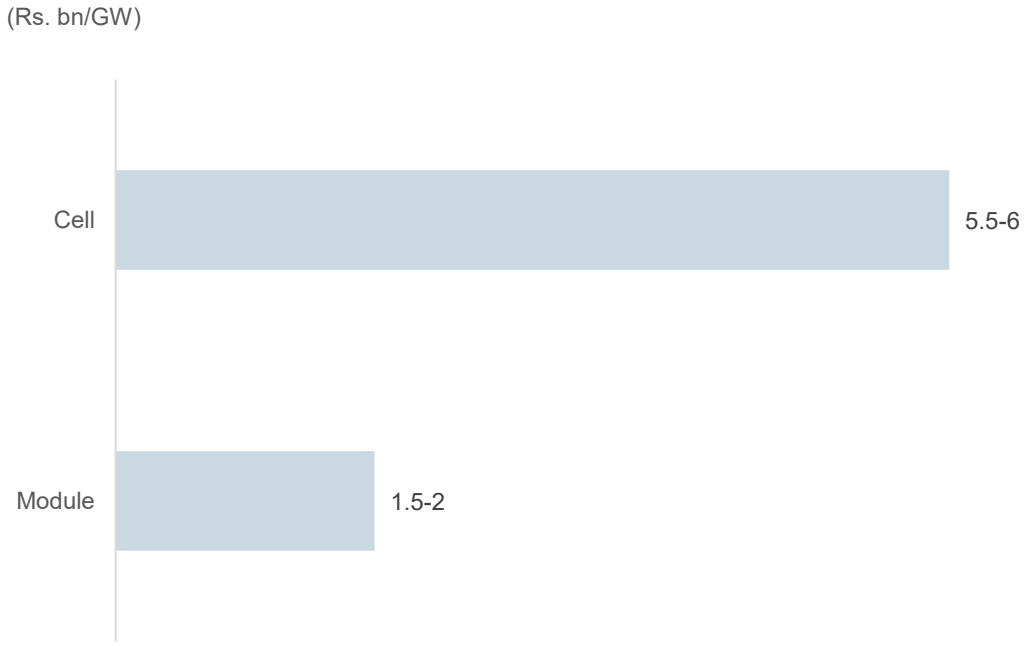
Figure 141: Solar module manufacturing process



Source: Crisil Intelligence

The solar module manufacturing process involves several key steps, starting with sourcing high-quality components such as photovoltaic cells, glass sheets, backing material, frames, and wiring. The cells are then arranged in a matrix layout and interconnected using thin connecting wires, before being sandwiched between the front tempered glass layer and the EVA backing layer. The assembly is then laminated under heat and pressure to create a weatherproof bond and framed with aluminium to provide structural rigidity. A junction box is attached to the rear of the panel, housing the connecting terminals for electrical output wires. Finally, the panels undergo thorough testing and quality checks to ensure they meet international durability and safety standards, before being packaged and shipped for installation.

Figure 142: Capital cost for solar cells is at least 3 times more than that of the module



Source: Crisil Intelligence

The capital cost of installing solar PV manufacturing capacity also varies across the value chain, with cell manufacturing typically requiring higher investment per GW than module assembly due to greater technological complexity and equipment intensity. For solar module manufacturing, the installation cost generally ranges around Rs. 1.5-2 billion per GW, depending on the level of automation, technology (such as mono PERC, TOPCon, or HJT compatibility), and plant scale. The key cost constituents include stringer and tabber machines, laminators, glass loading systems, EL testers, framing and junction box installation lines, and automated packaging systems, along with utilities, cleanroom infrastructure, and quality testing equipment. Module plants are comparatively less capital intensive because they primarily involve assembly processes rather than semiconductor fabrication.

In contrast, solar cell manufacturing facilities typically require around Rs. 5.5-6 billion per GW, as the process involves multiple precision semiconductor fabrication stages. The major cost components include texturing and cleaning equipment, diffusion furnaces, PECVD systems for anti-reflective coating, screen printing lines, firing furnaces, and advanced testing and sorting equipment. Additionally, cell manufacturing requires higher-grade cleanroom environments, advanced process control systems, water treatment plants, and chemical handling infrastructure, which significantly increases capital expenditure. Consequently, while module manufacturing is easier to scale with lower entry barriers, cell manufacturing is far more capital intensive due to the sophisticated process equipment and stringent environmental and operational requirements.

Global solar photovoltaic segment

Review of global solar module demand (2018-2025E)

Global solar module demand is estimated to have been at least 2,100-2,300 GW cumulatively between 2019 to 2025E and accounting for at least 550-600 GW in 2025. Going by installation rates, 50-55% of the demand was driven by China, followed by the US (8-13%), India (3-8%) and Germany and Japan (3-8% total). Cost reduction resulting from the fall in prices and technological advancements globally are major factors that drove additions in 2025.

PV module demand driven by policy and renewable push

The global solar energy installed base is expected to cross 5.5 TW in 2030 resulting in an addition of 2.5-3.0 TW from 2025E to 2030. This will be driven by country-specific renewable energy targets.

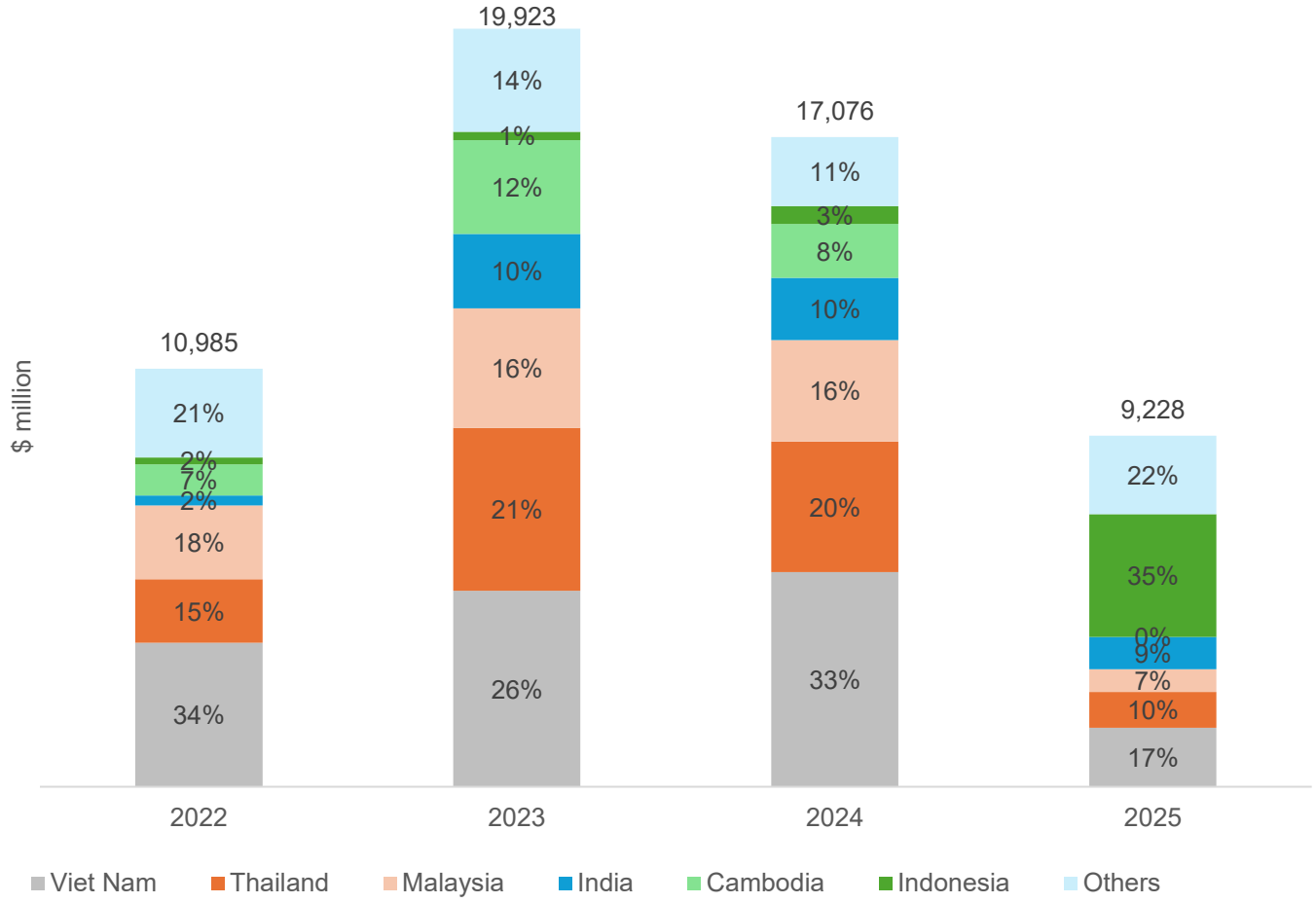
China

Demand from China has been driven by installations propelled by a set of government targets announced in 2020, under which Beijing plans to achieve peak emissions by 2030 and carbon neutrality by 2060. The government is also committed to constructing 1,200 GW of solar and wind capacity by 2030. However, robust installations of 1,800-2,000 GW of solar and wind capacity as of 2025E enabled the nation to overachieve targets.

United States

Demand from the US has been driven by the Energy Efficiency and Renewable Mission (EERE), which aimed to add 30 GW of solar capacity on average until 2025 and 60 GW per year between 2025 and 2030. This resulted in a demand for 180-230 GW of solar modules between calendar years 2019 and 2025. Tax credits, renewable portfolio obligations (RPOs), loans and grants offered by the government, coupled with state-specific incentive mechanisms, have played a pivotal role in the growth of solar energy in the nation. However, in January 2025, the US administration issued a directive to halt funding from the Inflation Reduction Act (IRA). Section 7 of the order, titled ‘Terminating the Green New Deal’, mandates an immediate pause to the disbursement of funds appropriated through both the IRA and the Infrastructure Investment and Jobs Act. The impact of this on the market will bear watching.

Figure 143: ASEAN countries remain major solar component exporters to the US



Source: Trade Map, Crisil Intelligence

US imports majority of its solar components from ASEAN countries with Indonesia being the leading exporter, accounting for 35% in CY2025E, followed by Vietnam and Thailand with 17% and 10% share, respectively. India's share has also grown from 2% in CY2022 to 9% in CY2025.

India

India's solar demand has been driven by its goal to install 500 GW of non-fossil fuel capacity by 2030, with a target of 364 GW of solar power. However, countries relying on solar energy, with a combined target of over 1,000 GW by 2030, lack domestic manufacturing capacity and rely on imports from China.

Review of global solar module manufacturing

The global solar module manufacturing capacity has seen a significant increase, crossing an estimated 1,400 GW in CY2025 from 250 GW at the end of CY2019. This growth in global manufacturing capacity has outpaced global demand. In tandem, the production of upstream components has also seen significant expansion over the past five years, with a notable surge in growth since CY2023, particularly in the polysilicon segment.

From CY2017, the limited availability of PV-grade polysilicon manufacturing capacity emerged as a significant constraint in the photovoltaic (PV) supply chain. This bottleneck became particularly apparent in CY2021, when a combination of underinvestment and a fire at a major manufacturing facility led to a global polysilicon shortage, causing prices to triple.

However, by CY2023, China had significantly expanded its polysilicon production capacity, increasing it threefold compared with CY2021 levels. As a result, global polysilicon capacity caught up with other PV manufacturing segments, such as wafers, cells and modules, resulting in a sharp fall in prices across the value chain. Prices of international-cells fell 76% between fiscals 2023 and fiscal 2025 while prices of international modules and imported cell-based Indian modules (Non DCR) fell 67% and 61% during the period. The prices remained rangebound till December 2025. Overall, all stages of value chain (polysilicon to module) is estimated to have surpassed 1,000 GW of manufacturing base by the end of CY2025.

Geographical concentration across the value chain

China has a significant presence in the global solar photovoltaic (PV) industry, with a huge manufacturing capacity for PV components concentrated within its borders. Although it is possible to source these components from other countries, the global solar PV supply chain is heavily reliant on China for the production of modules and upstream components, including polysilicon, ingots, wafers and cells. On average, China accounted 85-90% of the polysilicon, wafer, cell and modules capacity in CY2025E.

China has gained competitive advantage because of monetary and non-monetary policy support from various government schemes, which has led to a concentration of manufacturing capacity in the region and created a high degree of dependence on China. However, its share in global capacity is estimated to have been marginally reduced going ahead owing to capacity additions in Asia. India has now also implemented various levels of policy support in terms of ALMM and the PLI scheme and has the potential to gain similar competitive advantage over the long term.

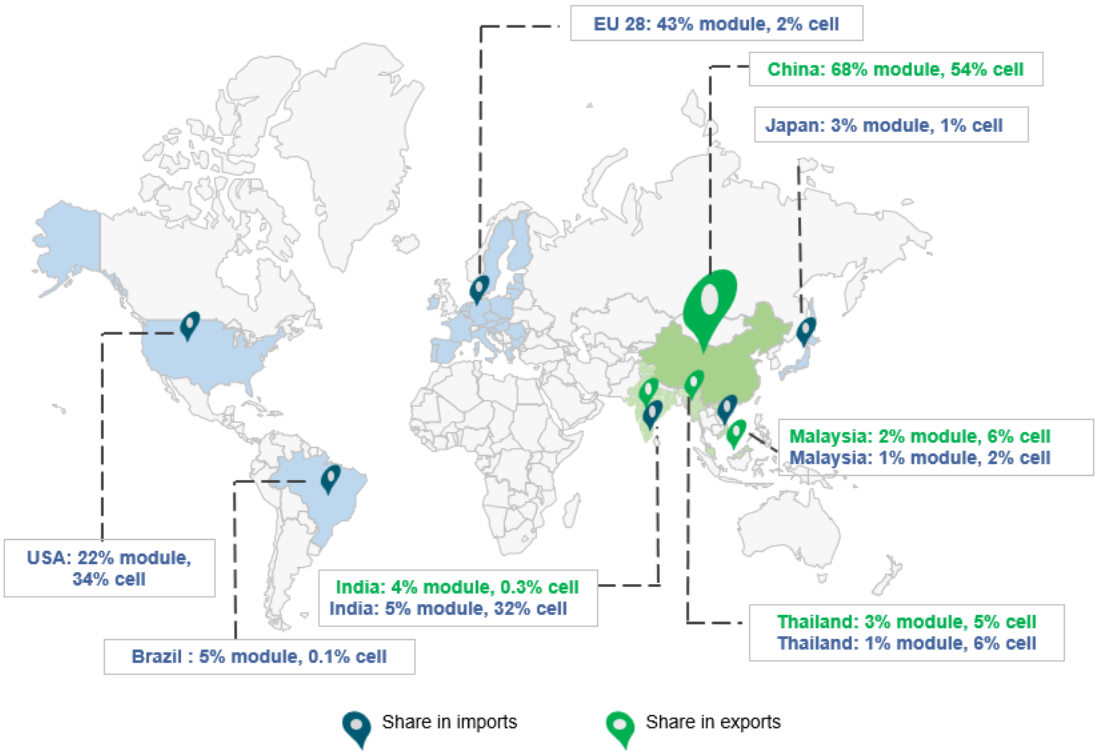
Although China has a monopoly on wafer manufacturing, Southeast Asia also emerged as a significant player in cell and module manufacturing, driven by major Chinese solar cell manufacturers establishing production bases in countries such as Vietnam, Malaysia and Thailand to circumvent US trade restrictions.

However, the US Department of Commerce published its final anti-dumping and countervailing duty tariff rates against solar PV cells whether or not assembled into modules from ASEAN countries. Tariff rates vary by country and are as high as 3,404% for Cambodia, 775% for Thailand, 543% for Vietnam and 171% for Malayasia. These tariffs impacted the exports from these four countries to the US, who collectively accounted 77% of module and cell imports of the US import basket in CY2024, fell to 34% of module and cell imports in CY2025.

China dominates global trade in PV

The global demand for solar modules in CY2025 was driven by declining prices resulting from a supply surplus, which led to a substantial increase in imports. The US emerged as the largest importer of solar modules and cells, accounting for approximately 22% of module imports and 34% of cell imports in 9M CY 2025. The EU 28 imported nearly 43% of the modules and 2% of the cells in 9M CY2025. China maintained its position as the leading supplier of solar modules and cells, providing ~68% of module exports and 54% of cell exports. India maintained its share at 4% in solar modules.

Figure 144: China trades 68% of module and 54% of cell exports in 9M CY2025; ASEAN countries catching up



Note: The data in blue represents import share, the data in green shows share in exports.
Source: ITC Trademap, Crisil Intelligence

Over the years, India in global module exports has increased, owing to rising module manufacturing/assembling capacity due to tariff and non-tariff barriers, such as BCD and ALMM.

The overall global PV manufacturing capacity has undergone significant expansion and technological advancements over the years, driven by sustained investments in research and development, which has resulted in rapid price decline and notable improvements in efficiency.

Evolution of PV cell technology

The rapid growth of the sector and intense competition in the supply chain have increased the focus on enhancing product efficiency. As a result, technology has undergone significant advancements, transitioning from multi-crystalline to mono passive emitter rear contact (PERC) cell-based modules, and is now shifting towards more advanced cell technologies, such as tunnel oxide passivated contact (TopCon) and heterojunction (HJT). In addition, consistent increase in solar module wattage has contributed to the conservation of land space for the same electricity output.

From a technological standpoint, mono-PERC cells dominated the market in 2019, followed by back surface field (BSF). While mono PERC remained the dominant technology globally till 2023, TopCon and HJT have started gaining traction. On average, TopCon and HJT cells are expected to offer an incremental efficiency gain of at least 1-2% over mono-PERC cells, which has enabled the possibility of higher electricity generation. TopCon cells have proven to be the technology with higher efficiency compared with all other cell models so far except HJT, which is expected to capture the market in the future. Based on the analysis of a sample set of product portfolios of global manufacturers, product lifespans are in the range of 25-30 years for both technologies. Further, TopCon modules generally show lower degradation rates compared with Mono Perc modules. This advantage comes from superior passivation quality and long-

term thermal stability. TopCon also outperforms multi -crystalline, as mono perc already offers higher efficiency and reduced LID over multi.

However, the capital cost intensity required to establish module manufacturing facilities also increases with the initial capex for HJT estimated to be 2.5-3.0 times that of mono-PERC and 1.5-2.0 times that of TopCon. HJT and TopCon process flow is very complex and extensive, making the entire process flow lengthy. Manufacturing solar cells using the TOPCon technology involves several complex processes, including the precise formation of a thin tunnel oxide layer and the deposition of a highly doped polysilicon layer to create efficient passivated contacts. Advanced techniques, such as high temperature annealing and intricate patterning, are also employed to enhance the cell's efficiency and overall performance. These processes result in solar cells with significantly improved efficiency of up to 26% and longevity, offering better energy conversion rates and reduced degradation over time making them highly efficient and resilient in hot climates. Customers prefer TOPCon solar modules as their increased efficiency and energy output helps reduce the overall costs of their solar projects. Further, potential upgrades and advancements, such as TOPCon tandem and TOPCon back-contacts, also build on the advantages of using this technology by increasing efficiency and potential.

Large-scale manufacturing, combined with ongoing research and development, is expected to bring about economies of scale benefits in the future for these higher-efficiency cell technologies.

Table 33: HJT and TopCon cells: higher efficiency, higher cost

	Mono PERC	TopCon	HJT
Cell efficiency	23-23.5%	24%+	24-25%+
Module efficiency	Up to 22%	22-24%	22-24%
Bifaciality	70-80%	75-85%	75-95%
Losses and damages	P-type Mono PERC cells are prone to LID and PID losses and incur highest losses in the group	PID and LID losses in TopCon are lower compared to Mono PERC, bit higher compared to HJT	Not prone to PID and LID losses because general cell construction is n-type
Complexity	Moderately complex	Less than HJT	Most complex
Module Prices (USD/Wp)	0.07 (210mm)	0.08 (182mm)	0.9 (210mm)

Note: PID stands for potential induced degradation and LID stands for light induced degradation
Module prices are global and are averaged from April 2025 to the 2nd week of March 2026.
Source: Industry, Crisil Intelligence

The solar PV industry is constantly at the risk of technological disruption. According to the data available worldwide in the public domain, theoretically, tandem cells are expected to increase efficiency to up to 40% with material, such as perovskite, showing significant promise. Tandem perovskite cells will build on finished n-type TOPCon solar cells, adding ~25% efficiency to the base.

Meanwhile, several countries are promoting in-house PV manufacturing to enhance self-reliance and mitigate supply chain risks from international markets.

Domestic solar PV manufacturing

Evolution of cell technology in India

The evolution of cell technology in India has mirrored the global market. According to the module batch enlistment in the ALMMs over fiscals 2022-2025, the share of Mono PERC has risen sharply from 16% in March 2022 to 63% in March 2025, with TopCon also making notable gains to reach 14% by the end of the period. Consequently, lower efficiency cells, such as Multi C-Si, have been largely phased out, with their market share dwindling to negligible levels by March

2025, down from a dominant 73% in March 2022. By March 2026, the market moved towards Topcon, with older technologies such Multi C-Si moving out of the ALMM list. The shift in the technology is on account of the shift in the preference of the end-user demand. Developers are increasingly adopting the TopCon technology in solar cells due to its higher efficiency, lower cost and improved performance compared with older technologies.

Thus, a shift is also witnessed in the overall industry scale, with India's solar cell manufacturing shifting significantly to TopCon between fiscal 2020 to March 2026. While mono PERC dominated cell manufacturing in the past fiscals, the share of TopCon cell manufacturing capacity in ALMM II reached an 35% in March 2026 from 26% in July 2025.

This transition was enabled by the similarity in manufacturing processes between the two technologies — both follow the same baseline steps up to diffusion and require only marginal additional capex to enable TopCon compatibility. The fungibility allows manufacturers to retain flexibility based on market demand while gradually shifting production towards higher efficiency cells. Mass production efficiencies for TopCon are at 25% compared with 24% for mono PERC, driving their adoption in both domestic and export markets. TOPCon has emerged as the leading successor to p-type PERC, offering higher efficiency and improved low-light performance. Along with this, TOPCon cells offers potential evolutionary upgrade, which can be further upgraded to create TOPCon Tandem and TOPCon Back-contact (BC) solar cells. TOPCon technology is already a significant step forward from PERC and these advancements build upon on it further increase efficiency and potential.

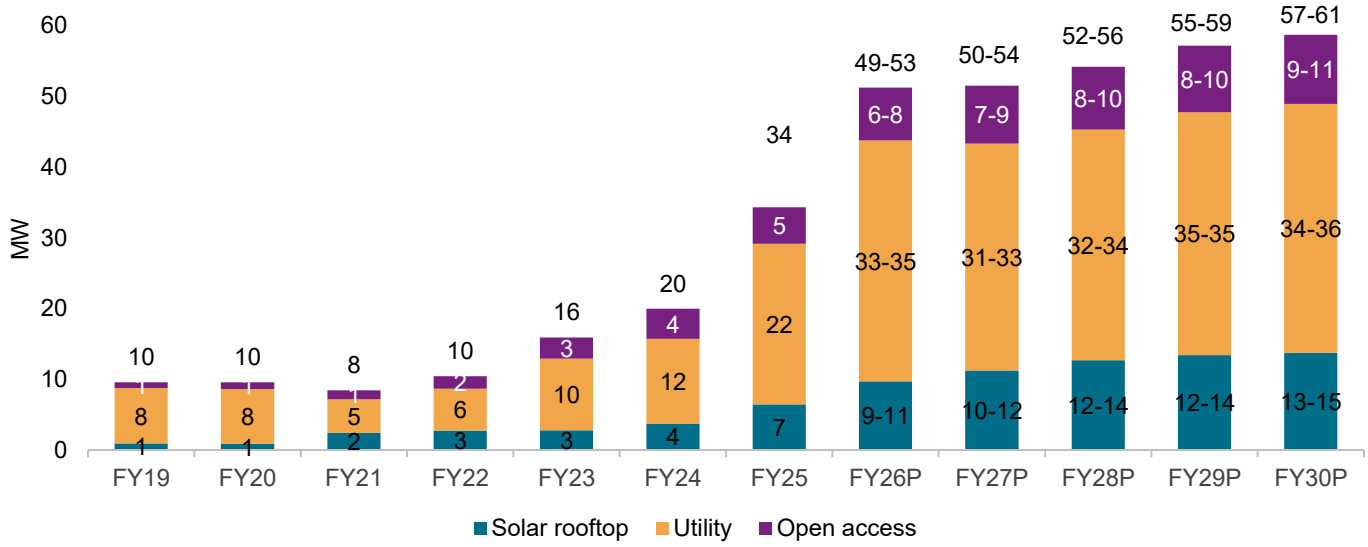
Crisil Intelligence expects that by fiscal 2030, nearly 80% of India's cell manufacturing capacity will be TopCon-capable or fungible. This transition is also aligned with global trends which has already seen TopCon adoption. The early adopters in the industry are expected to benefit from the demand arising from ALMM II from June 2026 as their capacity will be ramped up compared with those expected to commission in the future. However, given that India is expected to witness an average demand of 52-57 GW, the fructification of capacity planned and yet to commission also remains vital to reduce import reliance. Further, on the demand front, the TopCon technology is also emerging as the preferred technology of implementation for solar developers in India. Over the medium to long term, it is expected to be the dominant technology of implementation in the Indian market.

The domestic PV segment has been driven by domestic demand for solar modules through various segments, such as rooftop, utility scale and open access. From the beginning of fiscal 2019 to the end of fiscal 2026, India has witnessed a cumulative solar module demand of 125 GW.

Domestic solar module demand to grow robustly as power goes green

Over fiscals 2019-2026, domestic demand for solar modules was driven by the competitively bid utility segment, with 66% share, followed by the rooftop (19%) and open access (15%) segments. Average demand per annum is expected to be 52-57 GW between fiscals 2027 and 2030.

Figure 145: India to experience module demand of 52-57 GW p.a. between fiscals 2027 and 2030



Note: Demand includes DC overloading
The total of ranges for the subsegments may not add to the range of the total owing to round-off and range limits
Source: Crisil Intelligence

The demand drivers include declining module prices, supportive government policies and increasing awareness of the benefits of solar energy.

The ground mounted segment (competitive bid utility and open access) saw significant growth, with installed solar capacity at 119 GW by the end of fiscal 2026 over fiscal 2019 (26 GW). Competitive utility additions were driven by initiatives under the National Solar Mission, solar parks, renewable purchase obligations and the Panchamrit target pledged under COP26. Central tender allocations, led by SECI, accounted for at least 13% of these additions, while other central and state allocations contributed the remainder. States with high irradiance, such as Rajasthan and Gujarat, witnessed the most significant additions.

The rooftop solar segment also experienced material growth, with installed capacity increasing nearly fourteen-fold by the end of fiscal 2026 over fiscal 2019, driven by subsidies under the national rooftop mission, PM Suryaghar Yojana, and state-specific initiatives such as Gujarat's Surya Urja Yojana. Favourable policies, including net metering in some states, further incentivised adoption. The top three states - Gujarat, Maharashtra and Uttar Pradesh - accounted for 33% of the installed base by March 2026.

Open access solar, which allows consumers to purchase solar energy directly from producers, strengthened the demand for solar modules. This segment attracted large commercial and industrial consumers seeking cost savings and sustainability benefits. The Green Energy Open Access Rules of 2022 stimulated growth by reducing the minimum load requirement, making open access projects more attractive and financially viable.

Domestic demand drivers for manufacturing

Domestic Content Requirement (DCR)

Overview of DCR and its implementation

India introduced the Domestic Content Requirement (DCR) to promote domestic solar manufacturing. The DCR aimed to reserve a portion of the solar market for domestically made panels but was limited to government-sponsored schemes

after a WTO ruling. The government then introduced quality standards, including the Approved List of Models and Manufacturers (ALMM), to ensure domestic equipment meets certain standards. The ALMM features domestic entities that have undergone testing and certification procedures. Guidelines were issued to clarify what constitutes "domestically manufactured" solar PV cells, with the goal of promoting domestic manufacturing while balancing the need for cost-effective renewable energy

DCR schemes prior to ALMM guidelines had tapped into smaller segments

DCR bids emerged through various schemes such as CPSU, PM-KUSUM and grid-connected rooftop solar program, which had DCR as a prerequisite, providing a guaranteed market for domestic PV (cells and modules) even before the ALMM guidelines.

CPSU scheme

The CPSU scheme was launched in 2015 to promote domestic solar manufacturing, with an initial target of 1 GW of grid-connected solar projects. The program was expanded to 12 GW in 2019, but tenders were undersubscribed. However, a 5 GW tender by IREDA was fully allocated and is under construction, with some projects already commissioned.

Grid-connected rooftop solar programme and PM Surya Ghar Muft Bijli Yojana

The PM Surya Ghar Yojana launched in February 2024 is expected to boost residential offtake of solar rooftop, specifically by addressing cost hurdles. The government emphasized providing for the installation of solar panels to 10 million households, translating to 30 GW of potential. It will provide subsidies for installing rooftop solar for residential houses, which will help save money on electricity bills.

The subsidy under the scheme, has been increased to Rs 30,000 per kW from Rs 18,000 for plant sizes up to 2 kW. For plant sizes of 3 kW, the maximum subsidy available is Rs 78,000, which also serves as the cap for project sizes larger than 3 kW. Under this scheme, the government estimates the electricity benefit to be up to 300 units per month per household. This essentially means the 66% jump in subsidy support has been directed to smaller rooftop projects, which, as per market estimates, would represent most of the solar rooftop potential in India and may face affordability challenges due to their small size.

Table 34: State/UT-wise Rooftop Solar capacity installed, and total solar power installed capacity (March 2026)

S. No.	STATES / UTs	RTS (including PM-Surya Ghar Yojana) (MW)	Solar Power Total (MW)
1	Andhra Pradesh	775	7,495
2	Arunachal Pradesh	7	15
3	Assam	344	570
4	Bihar	218	435
5	Chhattisgarh	168	1,813
6	Goa	72	82
7	Gujarat	6,882	29,303
8	Haryana	1,188	2,608
9	Himachal Pradesh	67	358
10	Jammu & Kashmir	42	79
11	Jharkhand	95	255

12	Karnataka	843	11,102
13	Kerala	1,850	2,216
14	Ladakh	5	12
15	Madhya Pradesh	893	5,985
16	Maharashtra	5,442	19,622
17	Manipur	11	17
18	Meghalaya	0.2	4
19	Mizoram	5	33
20	Nagaland	1	3
21	Odisha	156	883
22	Punjab	581	1,585
23	Rajasthan	2,090	41,013
24	Sikkim	5	8
25	Tamil Nadu	1,532	13,580
26	Telangana	696	5,065
27	Tripura	12	35
28	Uttar Pradesh	715	4,123
29	Uttarakhand	274	838
30	West Bengal	67	321
31	Andaman & Nicobar Islands	7	32
32	Chandigarh	72	79
33	Dadra & Nagar Haveli and Daman & Diu	121	135
34	Delhi	410	421
35	Lakshadweep	2	7
36	Puducherry	80	82
37	Others	-	45
	Total	25,728	150,261

Source: MNRE

So far, multiple lenders have registered to provide financing for solar rooftops under the scheme. These lenders provide loans at floating rate of interest and for maximum tenure of 5-10 years. While most lenders provide maximum loan of Rs 0.2 million, a few lenders also provide maximum loan of Rs 4-5 million. Independent agencies also offer loans to the tune of Rs 2 crore and 100% project cost respectively.

As of May 19, 2026, the residential rooftop capacity was nearly 11.5 GW. Under the PM SuryaGhar Yojana, financial assistance of Rs 220 billion has been released as of May 2026.

PM-KUSUM

The PM-KUSUM scheme was launched in 2019.

The scheme is divided into three components:

- Component A: Setting up of 10,000 MW of decentralised ground-mounted grid-connected solar or other renewable energy-based power plants

- Component B: Installation of 20 lakh standalone solar agriculture pumps
- Component C: Solarisation of 15 lakh existing grid-connected agriculture pumps

The DCR mandate applies only to components B and C.

While the DCR categories have shown tremendous potential, their progress under the PM-KUSUM scheme has been gradual. As on March 31, 2026, component B had sanctioned over 13.3 lakh standalone pumps, with more than 10.6 lakh already installed. Similarly, in component C, nearly 14,806 individual pumps and 14 lakh feeder-level pumps had been solarised, out of the 55,392 and 35 lakhs sanctioned, respectively. Although the pace of progress may be slower than expected, the PM-KUSUM scheme has made significant strides in promoting solarisation of pumps.

PLI for backward integration

Backward integration is a viable strategy for future expansion of PV value chain, particularly with the potential for increased capacity in wafer and ingot manufacturing facilities. One of the ways the government is promoting backward integration is through the PLI scheme.

Table 35: Solar PLI results of Tranche I and II

Players	Polysilicon (GW)	Wafer (GW)	Cells (GW)	Modules (GW)
Shirdi Sai Electricals Ltd	4.0	4.0	4.0	4.0
Reliance New Solar Energy Ltd	4.0	4.0	4.0	4.0
Adani Infrastructure Pvt Ltd	0.7	0.7	0.7	0.7
Total PLI Tranche I	**8.7**	**0.7**	**8.7**	**8.7**
Indosol Solar Pvt Ltd	6.0	6.0	6.0	6.0
Reliance New Energy Solar Ltd	6.0	6.0	6.0	6.0
FS India Solar Ventures Pvt Ltd	3.4	3.4	3.4	3.4
Waaree Energies Ltd	0.0	6.0	6.0	6.0
Avaada Ventures Pvt Ltd	0.0	3.0	3.0	3.0
ReNew Solar (Shakti Four) Pvt Ltd	0.0	4.8	4.8	4.8
JSW Renewable Technologies Ltd	0.0	1.0	1.0	1.0
Grew Energy Pvt Ltd	0.0	2.0	2.0	2.0
Vikram Solar Ltd	0.0	0.0	2.4	2.4
AMPIN Solar One Pvt Ltd	0.0	0.0	1.0	1.0
TP Solar Ltd	0.0	0.0	4.0	4.0
Total PLI Tranche II	**15.4**	**32.2**	**39.6**	**39.6**
Total PLI Tranche I+II	**24.1**	**32.9**	**48.3**	**48.3**

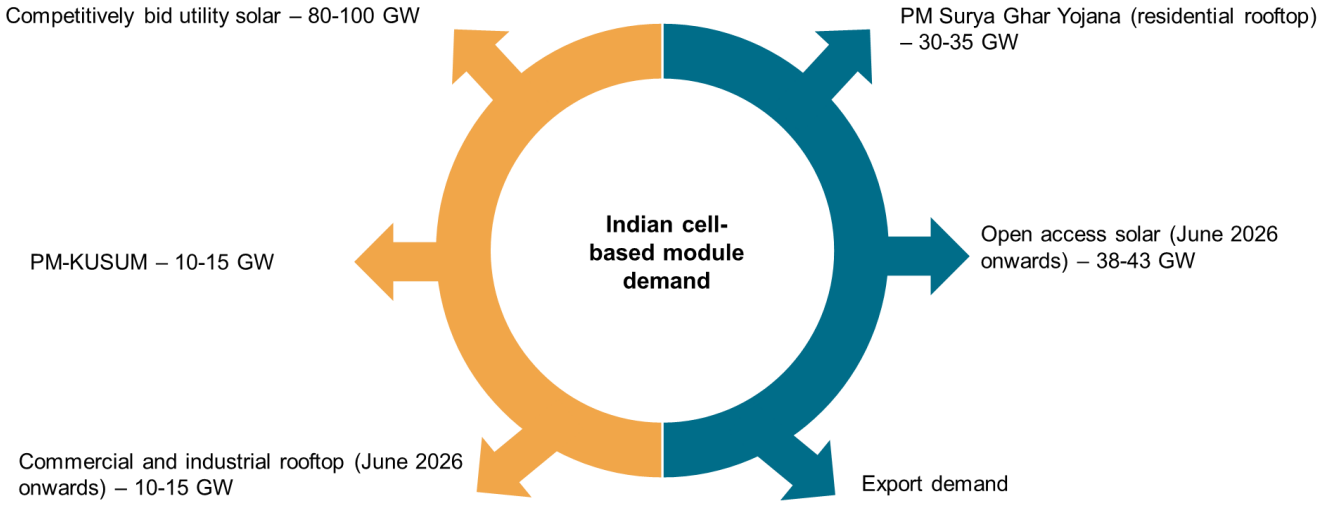
Source: MNRE

Demand outlook for domestic content (fiscals 2027-30)

The Approved List of Models and Manufacturers (ALMM) will be applicable to all segments from June 2026, mandating the use of domestic cells in locally assembled modules. This is expected to drive demand for domestic solar modules,

190-200 GW (excluding PM KUSUM) of capacity to be commissioned from fiscals 2027 to 2030. While the mandate will be applicable on rooftop and open access from June 2026, the government tenders were allowed a cut-off date of one month after the publication of ALMM list for solar cells, i.e. August 31st, 2025. Existing solar cell manufacturers can cater to this demand, and over 100 GW of cell capacity expansions are planned, attracting companies with strong balance sheets to invest in the industry.

Figure 146: Solar capacity additions to create demand avenues for Indian cell-based modules



Note: Some of the capacity mentioned in the graph may be commissioned beyond fiscal 2030 owing to the slow pace of progress on the ground.
Source: Crisil Intelligence

Domestic manufacturing capabilities grew rapidly over the past 4 years

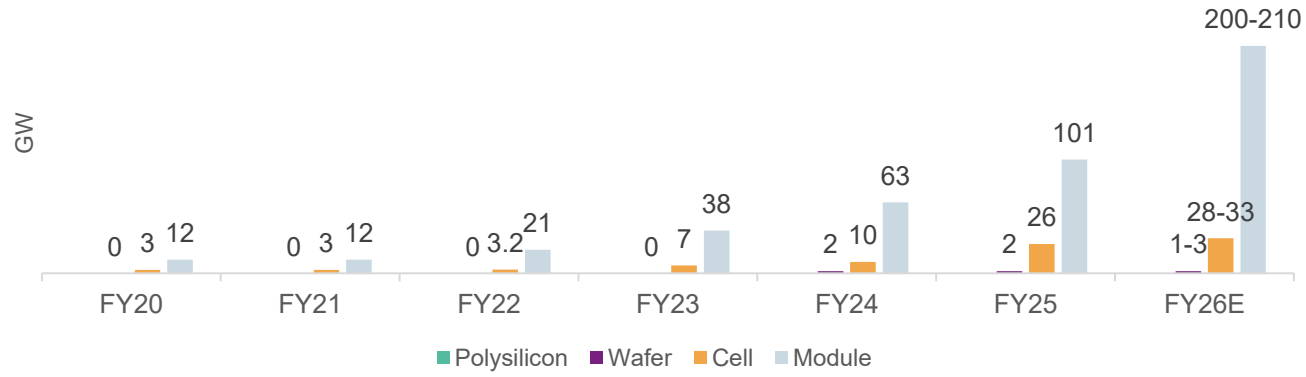
India's solar PV module and cell manufacturing capacities surged from 12 GW and approximately 3 GW in March 2020 to 200-210 GW and 28-33 GW by March 2026, respectively, driven by a strategic combination of government policies, market dynamics and a growing commitment to renewable energy.

Often manufacturers quote manufacturing capability in terms of effective capacity. This term is used to denote the variation as compared with full manufacturing potential due to various factors such as operational period during the year and technological wattage/ module configurations actually produced. The production of a lower Wp module in a higher-rated line can lead to a different effective capacity when compared with nameplate, i.e., the full potential.

Despite robust demand for solar modules, the domestic manufacturing ecosystem remained focused on the downstream component stage, primarily due to the capital-intensive nature of upstream components such as wafers and polysilicon. The availability of cheaper alternatives from China further contributed to this concentration.

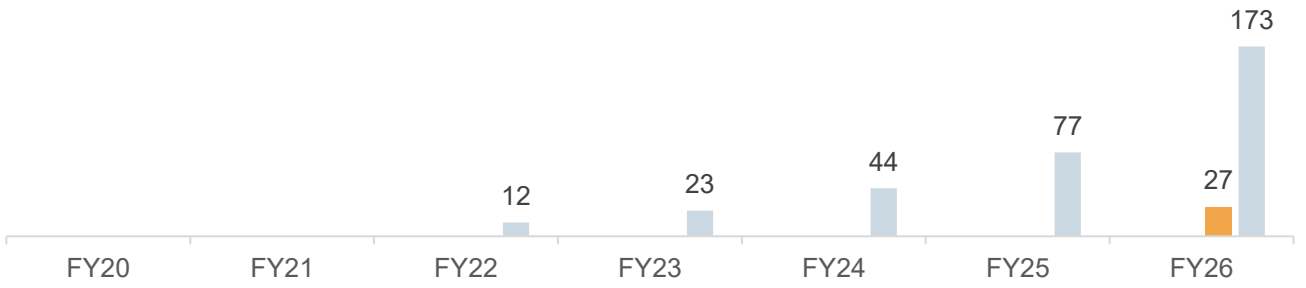
Along with this, in terms of supply-capacity addition, solar manufacturing lines require a substantial amount of time for stability and ramp-up, typically ranging from 6 to 12 months for polysilicon to cell. Some manufacturers have reported that it can take up to 2 years to achieve full production capacity.

Figure 147: Expansion of capacity in cell to module stage



Source: Industry, Crisil Intelligence

Figure 148: ALMM module enlisted capacity reaches 173 GW by March 2026



Note:
1) ALMM capacity considered for fiscal 2023 is as of February 2023 as per MNRE release. March capacity is considered for the other fiscals.
2) Due to the fragmented nature of the industry and the presence of unorganised entities, the latest and full disclosure on capacity is unavailable for small players for fiscal 2025 and the total capacity is estimated.
Source: Company reports, Crisil Intelligence

India's module manufacturing capacity has grown significantly between fiscal 2022 and fiscal 2026E, largely due to government efforts to reduce reliance of imported solar components, particularly from China. During this period, module and cell manufacturing capacity expanded by approximately 175-185 GW and 25-30 GW, respectively. Prior to this growth, most players had portfolio of up to 1 GW- Tata power solar, for instance, began with a 3 MW plant in 1991, and Adani solar started its manufacturing in 2017 with 1.2 GW capacity. A major catalyst for this transformation was the introduction of ALMM, which played a crucial role in scaling domestic capacity tenfold between fiscals 2022 and 2026E.

While module manufacturing capacity has expanded significantly, cell production capacity is also increasing at a rapid pace.

The government also implemented measures such as ALMM to ensure quality control and encourage capacity additions in the downstream stages. Furthermore, the PLI scheme for high-efficiency solar modules, launched in 2021, provided financial incentives to manufacturers based on their incremental production. These schemes played a crucial role in encouraging manufacturers to expand capacity, invest in new technologies and pursue backward integration.

The industry has undergone significant consolidation in recent years, with new large-scale entrants gaining a significant market share. While the industry was highly fragmented in fiscal 2019, the emergence of major players has led to

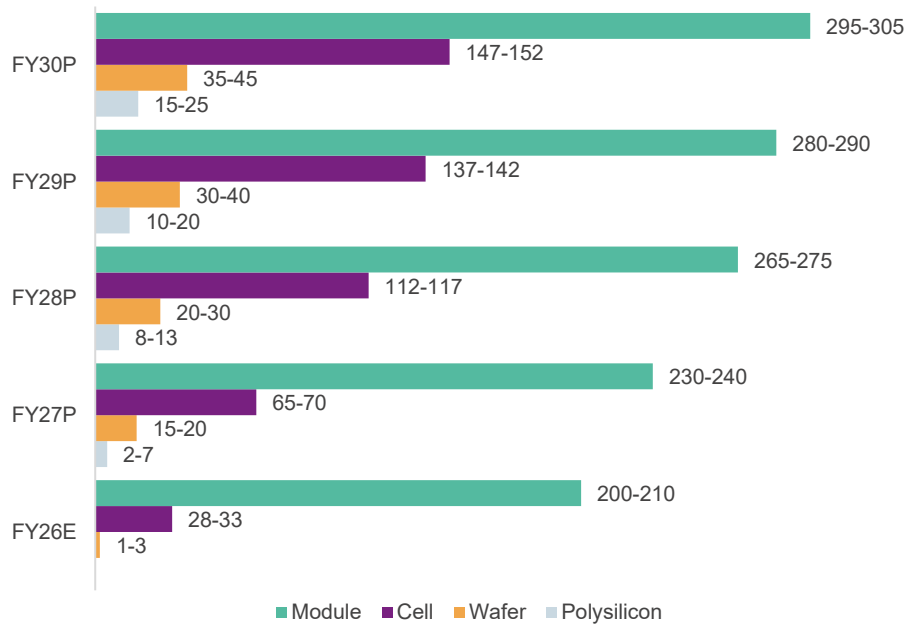
consolidation. The large players, along with others, are expected to expand their presence across the value chain under the PLI scheme.

Rapid expansion of domestic PV manufacturing to continue

By the end of fiscal 2030, the domestic module and cell manufacturing industries' nameplate capacity (rated capacity or maximum manufacturing capability) are expected to increase approximately 2 times and 4 times, respectively, from fiscal 2025 levels. Overall, the module manufacturing space has seen announcements of over 100 GW owing to rising demand. However, Crisil Intelligence expects that with the implementation of ALMM-II from June 2026, the usable domestic manufacturing capacity for domestic consumption in applicable solar segments will be limited to the manufacturers listed in the cell list. On the other hand, large-scale wafer and polysilicon segment has seen announcement of 35-45 GW and 15-25 GW, respectively. This increase in manufacturing capacity provides an opportunity for India to expand its production and establish its position in export markets such as the US. The imposition of anti-dumping duties ranging from 15-3404% on Cambodia, Vietnam, Thailand and Malaysia, along with restrictions on imports from China, is expected to be beneficial for Indian manufacturers despite imposition of reciprocal tariff on India. However, increase of cost of imports in the US and policy shocks coupled with rising local manufacturing capacity presents a downside to the export forecast for Indian manufacturers. The situation will remain a monitorable.

This substantial expansion in capacity, particularly in upstream components, is expected to be driven by a combination of trade, non-trade interventions and the PLI scheme, which aims to encourage investment and growth in the domestic solar manufacturing industry.

Figure 149: Indian PV manufacturers announce 90-110 GW of solar module and cell expansion plan by fiscal 2030



Note: The above capacity is based on market announcements available in the public domain.
Source: Company reports, Crisil Intelligence

The integration of solar PV manufacturing plants that produce wafers, cells and modules under one roof offers advantages such as improved efficiency and cost reduction. With reduced transportation costs and economies of scale, these plants can optimise their production flow and maintain better quality control. Additionally, integrated solar PV manufacturing plants provide greater flexibility and supply-chain security. Manufacturers can respond efficiently to

changes in demand, reduce their dependence on external suppliers and gain access to advanced technologies, achieving competitive advantages in terms of both quality and price.

Import reliance to fall, exports to stay supportive

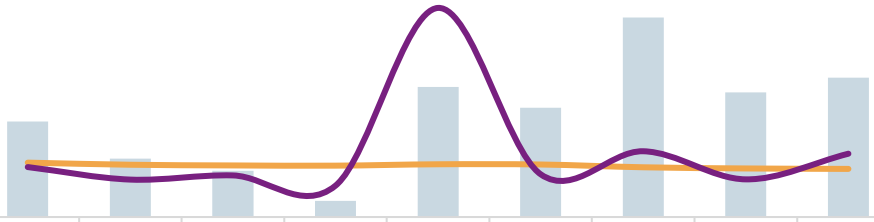
Imports continue to fall in fiscal 2026 owing to ALMM

Between fiscals 2019 and 2026E, Indian companies invested significantly in solar cell and module manufacturing. Despite the potential for growth, some domestic solar manufacturers have historically relied more on export revenue, as Indian solar developers, in the past, have preferred imported modules, except in specific market segments where domestic content requirements apply, which account for a smaller portion of the overall renewable energy sector.

As a result, more than 50% of solar modules installed in India during fiscals 2019-2026E were imported, primarily due to inadequate domestic capacity, competitive pricing and technology preferences.

As of March 2026E, India had an installed capacity of ~28-33 GW for solar cells and ~200-210 GW for modules. Although India is one of the top 10 solar module producers, it is far behind its biggest competitor, China. While imports fell (28% on-year) in fiscal 2023, they rose sharply (184% on-year) in fiscal 2024 owing to ALMM abeyance to meet rising solar power demand in the country. The reimposition of ALMM from April 2025, led to reduction in imports to Rs 322 billion in fiscal 2025, a 38% decline over fiscal 2024. Imports during April-March 2026 stood at Rs 360 billion, as cell imports rise.

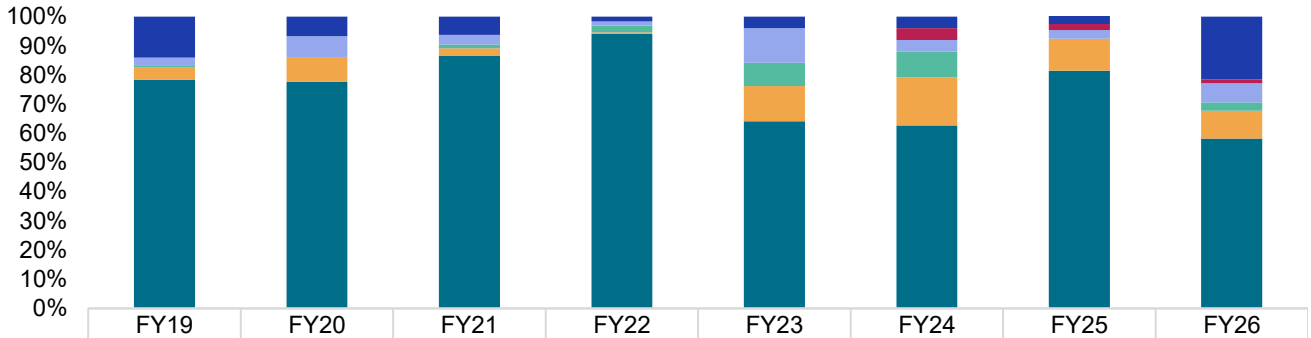
Figure 150: ALMM reimposition results in increase of cell imports in fiscal 2026



	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26
Imports (Rs billion)	247	151	119	42	336	282	515	322	360
International module price (USD/Wp)	0.34	0.25	0.22	0.21	0.27	0.26	0.14	0.09	0.07
% Change in imports	15%	-39%	-21%	-65%	700%	-16%	83%	-38%	72%

Notes: *HS Code 85414011 & 12 used until fiscal 2022, and 85414200 & 300 used from fiscal 2023*
Multi-crystalline solar module prices considered for fiscals 2018-2020, and mono-crystalline module prices considered for fiscals 2021-2025
Module prices are based on international prices. These exclude GST
Source: Ministry of Commerce and Industry, Crisil Intelligence

Figure 151: Share of China volatile in India's import basket



	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26
Others	14%	7%	6%	2%	4%	4%	3%	21%
Hong Kong				0%	0%	4%	2%	1%
Thailand	3%	7%	3%	1%	12%	4%	3%	7%
Malaysia	1%	0%	1%	2%	8%	9%	0%	3%
Vietnam	4%	8%	3%	1%	12%	16%	11%	10%
China	78%	78%	87%	94%	64%	63%	81%	58%

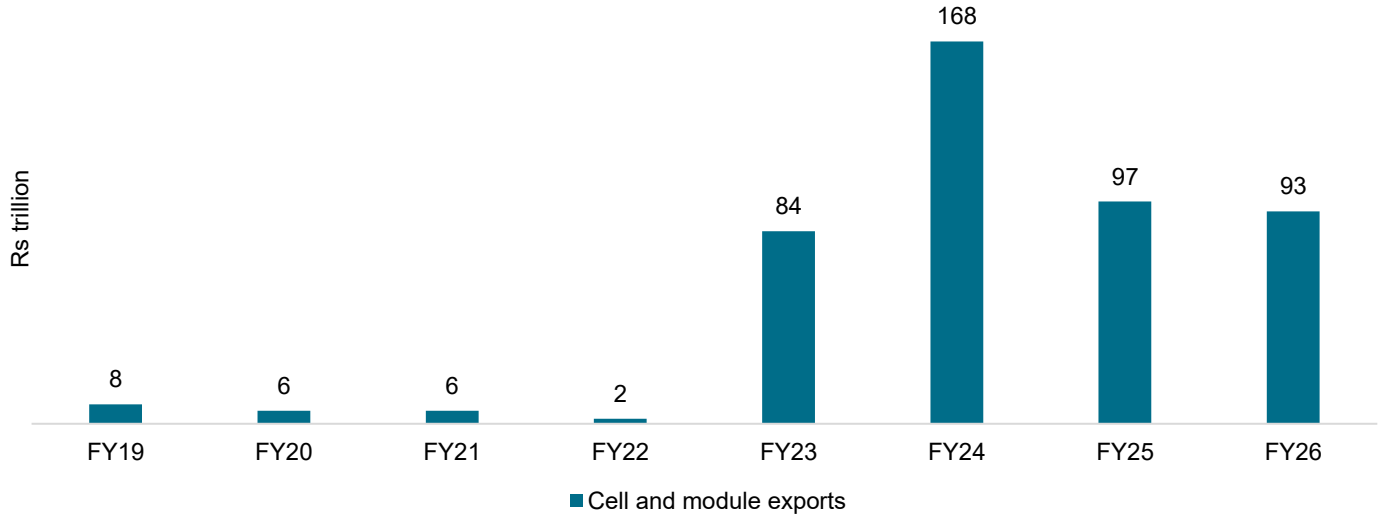
Note: HS Code 85414011 & 12 used until fiscal 2022, and 85414200 & 300 used from fiscal 2023
Source: Ministry of Commerce and Industry, Crisil Intelligence

While supply chain diversification resulted in 31% loss of share for Chinese cells and modules in India's import basket in fiscal 2024 over fiscal 2022, the share increased to 81% in fiscal 2025 with increase in cell imports. Countries such as Vietnam, Thailand and Hong Kong have gained 11%, 3% and 2% market share, respectively, in fiscal 2025. Imports were concentrated to the exemptions offered under the ALMM and cells. The share then fell to 58% in fiscal 2026 owing to increased production within the country.

Exports grow multi-fold in India

India's solar cell and module exports averaged a modest Rs 5.51 billion between fiscals 2019 and 2022. However, a significant increase in manufacturing capacity and shifting geopolitical dynamics led to a remarkable 39-fold increase in exports in fiscal 2023, compared with the previous year, followed by a 2-fold increase in fiscal 2024. Driven by the reimposition of ALMM, domestic demand rose sharply in fiscal 2025, resulting in increased use of domestic produce. The fall in value of exports was also attributable to the reduced prices of solar modules on-year in fiscal 2025. Exports fell in fiscal 2026 owing to impact on tariffs.

Figure 152: Tariffs impact exports in fiscal 2026



Note: HS Code 85414011 & 12 used until fiscal 2022, and 85414200 & 300 used from fiscal 2023
Source: Ministry of Commerce and Industry, Crisil Intelligence

Between fiscals 2019 and 2026, the US accounted for over 80% of India's exports on average.

Figure 153: US accounts for 96% of India's solar module exports

	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26
Others	33%	12%	12%	21%	2%	2%	3%	4%
Nepal	1%	1%	1%	2%	0%	0%	0%	0%
Canada	1%	0%	1%	2%	0%	0%	0%	0%
Nigeria	1%	1%	1%	8%	0%	0%	0%	0%
Turkey	0%	3%	0%	0%	0%	0%	0%	0%
Vietnam	18%	0%	0%	0%	0%	0%	0%	0%
South Africa	4%	1%	3%	2%	0%	0%	0%	0%
US	43%	82%	82%	66%	97%	97%	97%	96%

US South Africa Vietnam Turkey Nigeria Canada Nepal Others

Note: HS Code 85414011 & 12 used until fiscal 2022, and 85414200 & 300 used from fiscal 2023
Source: Ministry of Commerce and Industry, Crisil Intelligence

The US imposed sanctions on imports from China's Xinjiang region in 2022, due to concerns over forced labour. This has led to a ban on imports of polysilicon and other components from the region. As a result, Indian module manufacturers using domestic cells have a unique opportunity to export to the US. The Solar Energy Industries Association (SEIA) has released a draft industry standard to improve supply-chain transparency and comply with US laws. This has impacted Southeast Asian nations, which may face higher US tariffs due to dumping and subsidies. The US has also imposed tariffs on imports from these nations and is reviewing expansions under the Inflation Reduction Act (IRA). India remains vulnerable to the US's plans to develop its own cell, wafer, and ingot capacity, which could substitute

Indian imports in the future. However, for now, India has a favourable price differential and an opportunity to export backward-integrated components to the US.

Table 36: Reciprocal duties on solar cell and modules exports to the US

Country	Duties imposed	Rate
India	Custom duty	10% + (249%*)
Vietnam	Custom duty + ADD/CVD	10% + (68%-543%)
Malaysia	Custom duty + ADD/CVD	10% + (15%-171%)
Thailand	Custom duty + ADD/CVD	10% + (255%-775%)
Cambodia	Custom duty + ADD/CVD	10% + (535%-3404%)
Laos	Custom duty	10% + (103%*)
Indonesia	Custom duty	10% + (121-178%*)

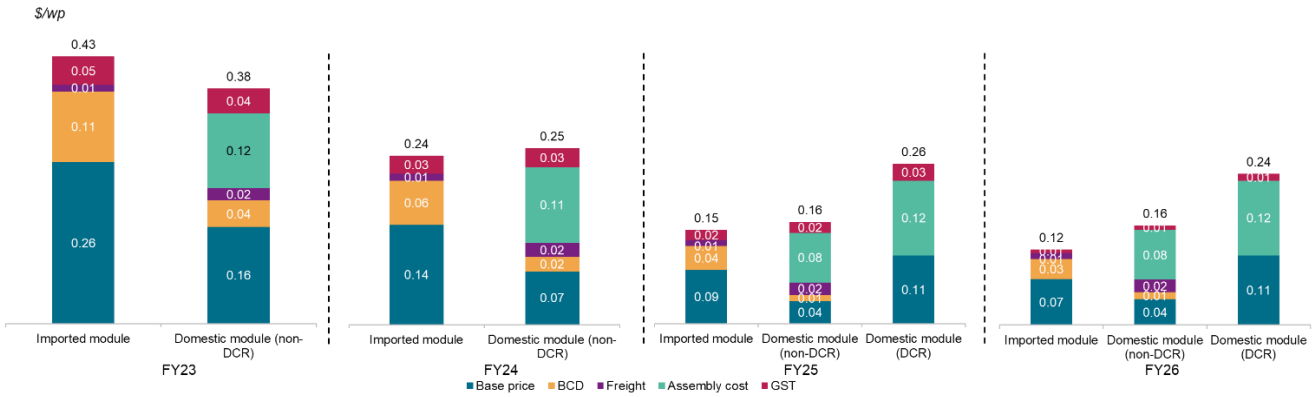
*Note: ADD refers to Anti-dumping duty, while CVD refers to Countervailing duty. *Preliminary affirmative determination in the countervailing duty and antidumping duty investigations.*
Source: U.S. Presidential order, Crisil Intelligence

Countries such as Vietnam, Malaysia, Thailand, and Cambodia are subjected to both reciprocal duty and ADD/CVD, which leads to higher overall duty levels. The applicable ADD/CVD percentages vary by country and, in some cases, by manufacturer, resulting in the wide duty ranges shown in the table.

Cost of Indian cell-based modules and imported modules

Economies of scale and backward integration are essential to achieve competitive pricing for domestically manufactured modules. Currently, the prices of imported cell based Indian module remain $0.04/Wp higher than imported modules. The cost of Indian cell-based module is $0.08/Wp higher than imported cell based Indian module.

Figure 154: Cost comparison of imported vs domestic modules (DCR and non-DCR)



Note: BCD here comprises BCD+AIDC. The above calculations for FY26 is based on GST rate of 12%
Source: Crisil Intelligence

Despite the high price of Indian cell-based modules, they continue to be priced below US-made modules, reflecting differences in scale and cost of production.

Table 37: Domestic cell-based modules half of US-made (DCR) modules

US-made module (USD cent/W)	Indian cell-based module (USD cent/W)	Imported cell-based domestic module (USD cent/W)
45-50	24	16

Note: Above prices do not consider reciprocal tariffs.

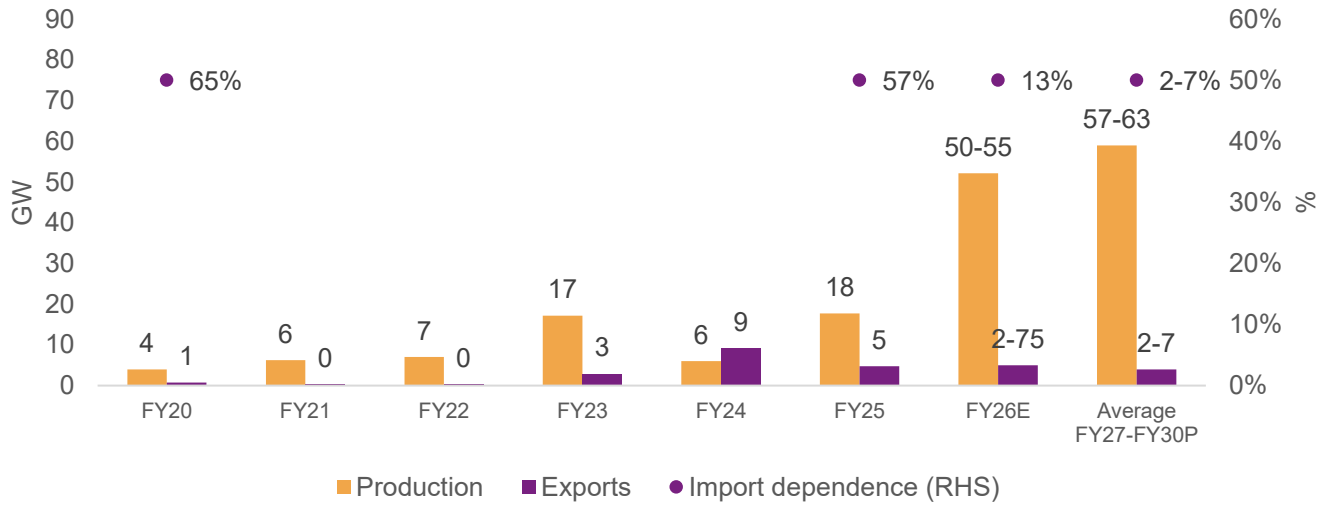
Source: Crisil Intelligence

Export-import balance to improve over the fiscals 2027 and 2030

While the demand in India for solar modules is expected to remain robust and average 52-57 GW between fiscals 2027 and 2030, the growth in production of modules is expected to be sufficient from fiscal 2026 onwards, leaving room for exports. India exported modules and cells worth Rs 93 billion during the fiscal 2026. Between fiscals 2027 and 2030, module manufacturing is expected to outpace domestic demand, thereby creating an export opportunity. While absolute exports will increase, the share of exports in production is expected to moderate to 2-7% over the years, owing to rising domestic consumption. That said, tariffs and trade dynamics between the US and other countries remain a key monitorable. The US imposed 25% tariff duty in July 2025 and incremental 25% applicable from August 2025. However, it has been revised to 10% in 2026. An additional 249% CVD and ADD ratification on Indian manufacturers by the US could result in a downside to the exports call. While Indian exporters are expected to procure cells from nations with lower tariffs and CVD, the growing protectionist measures in the US may limit large scale exports going ahead. The FTA with EU and UK are expected to offset the loss of exports partially.

With rising nameplate capacity and the reimposition of ALMM from fiscal 2026, import dependency (calculated as imports divided by consumption) for modules is expected to fall from 65% in 2020 to 2-7% in average of fiscal 2027-2030. However, a low base of fully integrated capacity would still result in high import reliance for upstream components such as polysilicon, wafers and cells.

Figure 155: Import dependence to fall to 2-7% by fiscal 2030



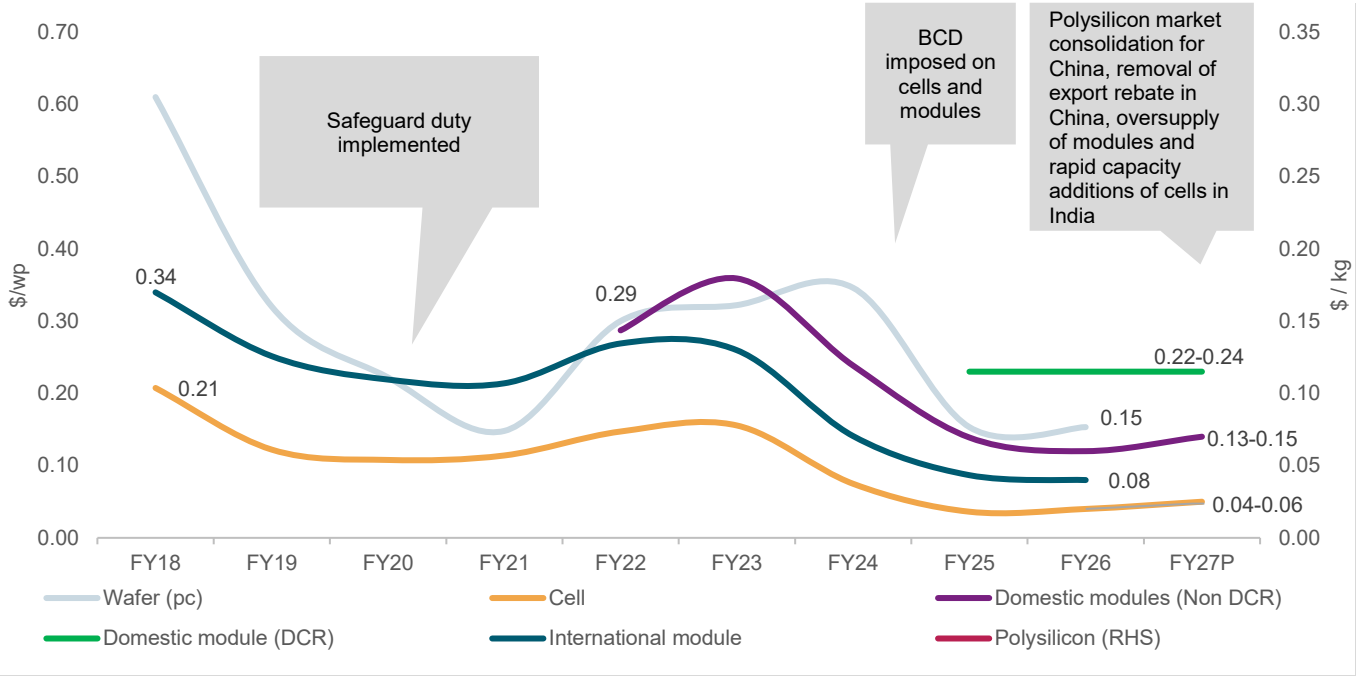
P – Projected
Notes:
1. Export potential may remain dynamic owing to US reciprocal tariffs.
2. The balance capacity in the above chart is attributed to the inventory in the industry at the manufacturer and end-user.
Source: Crisil Intelligence

Sharp fall in prices of PV components due to surplus supply

The prices of upstream components, such as polysilicon, shot up to $39 per kg in the second quarter of fiscal 2023 from $29 per kg in fiscal 2022 on account of power rationing in China's solar provinces, followed by its energy crisis due to low stock of coal and higher demand. However, the global polysilicon base expanded 68% on-year by the end of December 2022, reaching 1,000-1,100 tonne from 600-650 tonne, resulting in oversupply despite strong demand. The surplus caused a dramatic drop in the price to $12 per kg as of March 2026.

Consequently, downstream components also witnessed significant price reductions, with that of wafer plummeting over 53% to $0.15 a piece in fiscal 2025 from $0.32 per piece in fiscal 2023. Prices remained flat at $0.15 per piece in fiscal 2026. The oversupply of polysilicon also prompted the world's largest monocrystalline solar wafer supplier to cut prices of its PV wafers twice between April and May 2023 by 33% as cell manufacturers sought to fulfil their order requirements. In addition, cell prices dropped by 75% in fiscal 2025 from fiscal 2023, and as of March 2026, cell prices are $0.05 wp. While module prices fell 62% in fiscal 2025 over fiscal 2023. The price of module touched $0.15 wp in March 2026.

Figure 156: Prices to remain subdued due to oversupply of upstream components



Note: Above prices do not include GST of 12% till September 2025 and 5% there onwards.
Source: Crisil Intelligence

The prices of the upstream components are expected to rise in fiscal 2027 owing to consolidation of polysilicon capacity in China and removal of export rebates in China, resulting in the prices of domestic modules (non-DCR) modules ranging between $0.13 and 0.15/Wp. However, prices of modules assembled using Indian cells remained are expected to remain range bound over to owing to sharp ramp up in cell and module manufacturing capacity.

Policy support key for expansion of PV manufacturing

The PV manufacturing industry has received demand and supply incentives over fiscals 2019-26, the benefits of which are expected to materialise over the years.

Figure 157: Policy drivers for domestic PV manufacturing

Source: Crisil Intelligence

1. **50 GW annual tendering capacity:** The government will invite bids for 50 GW of RE capacity annually from fiscals 2024 to 2028, aiming to add 250 GW capacity since such projects take 18-24 months to be commissioned to ensure 500 GW of installed capacity by 2030.

2. **ALMM:** The ALMM, introduced in 2021, is an initiative by the Ministry of New and Renewable Energy of India to ensure that only high-quality solar models are used in projects supported by the government. The initiative has acted as a non-tariff barrier for global manufacturers to enter the Indian market. The list has been updated multiple times between March 2021 and May 2026. The enlisted capacity touched 173 GW in March 2026, which is ~22 times more than that listed in March 2021.

   The initiative does not involve plant owned by any foreign manufacturer as of March 2025, providing price resilience to domestic manufacturers. The ministry has also announced ALMM for cells from June 2026. With over 100 GW cell manufacturing capacity announced, the ALMM for cells is expected to help expand manufacturing in the value chain stage as well. For this, timely commissioning of the cell capacity is crucial. The list also sets minimum required efficiency of module for installations.

Table 38: Minimum module efficiency set under ALMM

Category	Application/Use	Minimum Module Efficiency required to be eligible for enlistment in ALMM for Solar PV modules	
		For c-Si technology based solar PV modules	For cdTe thin film technology based solar PV modules
Category-I	Utility/Grid Scale Power Plants	20.00%	19.00%

Category-II	Rooftop and Solar Pumping	19.50%	18.50%
Category-III	Off-grid projects/applications like solar lamps, solar lights, solar streetlights, solar fans, etc. (other than solar powered agricultural pumps and solar PV rooftops) requiring individual capacity of each solar PV module deployed, to be of less than 200-Watt peak	18.00%	18.00%
		(not to be included in main ALMM List-I but to be included in a separate ALMM list called ALMM-I (DRE)	
Category-IV	Any other application	19.00%	18.00%

Source: MNRE

3. **Domestic content requirements (DCR):** The DCR mandates the use of solar cells and modules manufactured domestically as per specifications and testing requirements fixed by MNRE. Various schemes have been announced by the government such as CPSU, PM-KUSUM and grid connected rooftop solar programmes to promote the use of domestically manufactured modules. The schemes have a Central Financial Assistance/ VGF component to cover the cost difference between imported and domestic solar cells and modules. It is mandatory to use DCR cells and modules to avail of the financial aid provided by the central/ state government. Cumulatively, these projects provide at least 40 GW opportunity for Indian manufacturers.

4. **China-plus-one strategy:** The strategy encourages businesses to diversify operations from China. India is one of the potential destinations for solar manufacturing due to its low labour cost as well as favourable political and regulatory environment for manufacturing. The expanding manufacturing base has enabled domestic manufacturers to tap the export potential with nearly 96% exports focused on the US alone.

5. **PLI scheme:** MNRE launched the first tranche of the PLI scheme for high-efficiency solar modules in April 2021 to allocate 8.7 GW to three manufacturers at Rs 45 billion. However, the outlay was increased, and a second round of allocation was conducted based on the oversubscription in the first tranche. MNRE then announced the second tranche in September 2022 to allocate 36 GW of fully/ partially integrated solar manufacturing at Rs 195 billion. While the scheme remained technologically agnostic, technologies that yielded better module performances were to be incentivised. The scheme witnessed allocations to 13 unique manufacturers in India across various stages of the value chain. While the players will only be eligible for PLI on half of the capacity allocated, the scheme is expected to be pivotal in setting up a capital-intensive upstream value chain (polysilicon and wafer) as over 80% of the expected additions in these segments will be driven through it by fiscal 2030, resulting in lower reliance of Indian PV manufacturers on imports. As of December, 2025, an investment of ~Rs 529 billion was made under the National Programme on High Efficiency Solar PV Modules to enable the building of vertically integrated solar manufacturing capacity for better quality control and competitiveness.

6. **BCD:** The government regularly intervenes to address the price disparity between Indian and international modules in the form of safeguard duties and BCD. In the past, rising imports discouraged the expansion of manufacturing capacity forcing domestic solar component manufacturers (mainly modules) to file additional duty petitions against imports.

   Despite the safeguard duty, imports dominated module supplies. Indian producers sought an extension, and the duty was extended for a year before being lifted post July 2021. However, the Ministry of Power alternatively levied a ~40% BCD on modules and 25% on cells effective April 1, 2022. While this led to higher capital cost, the price disparity between a domestically assembled module and an imported one reduced to $0.01-0.02/Wp from $0.07-0.08/Wp, resulting in demand for domestic manufacturers.

   The recent simplification of duty structure in the budget for fiscal 2026 changed the duty structure.

Table 39: New and simplified duty structure

Solar module	Old duty structure	New duty structure
BCD	40%	20%
SWS	4%	-
AIDC	-	20%

Solar cell	Old duty structure	New duty structure
BCD	25%	20%
SWS	2.5%	-
AIDC	-	7.5%

Note: SWS: Social welfare surcharge, AIDC: Agriculture infrastructure and development cess.
Source: Crisil Intelligence

While the landed price of imported cells and module is estimated to decrease marginally, the implementation of ALMM and ALMM II is likely to protect demand for domestic make.

7. **GST reduction to boost solar affordability:** The Goods and Services tax (GST) council of India has announced a major tax reduction on solar equipment, lowering the GST rate on solar cells from 12% to 5% effective September 22, 2025. This revision applies to both standalone solar cells and those assembled into modules. The reduction is expected to make solar cells and modules more affordable, thereby promoting greater adoption across residential, commercial, and industrial sectors.

8. **SPECS:** The Scheme for Promotion and Manufacturing of Electronic Components and Semiconductors was launched to boost domestic manufacturing of electronic components, including those essential for solar PV modules. The scheme aims to reduce dependence on imports, particularly from China. The incentives include a financial subsidy that covers 25% of capex on new plants or machinery analogy upgrades and R&D activities, aimed at enhancing India's production capacity and technological capabilities. The solar industry relies heavily on semiconductors, particularly for inverters, storage systems and other components. The ability to produce them domestically is crucial for building a resilient solar supply chain. The scheme also contributed to India’s China-plus-one strategy by encouraging global companies to invest in India's solar component manufacturing, positioning itself as a reliable alternative to China for solar equipment.

9. **Domestic tariff area (DTA):** The DTA refers to the geographical region within a country where goods and services are freely available for trade, subject to domestic duties and taxes, as opposed to export-oriented units or special economic zones, where special exemptions apply. For domestic solar cells and module manufacturers, the DTA policy framework plays a pivotal role in fostering domestic production. By ensuring that imported goods, such as solar cells or modules, incur tariffs under the BCD or other trade protective duties, the DTA helps create a level playing field for domestic manufacturers. This measure is particularly relevant given India’s target of 500 GW of RE capacity by 2030, with solar energy constituting a significant share. The imposition of duties on imported solar cells and modules, particularly from China, helps reduce dependence on imports and provides a competitive edge to local manufacturers.

10. **State incentives for manufacturing:**

    a. Gujarat – The state disburses a 6-12% capital subsidy based on location annually, capped at Rs 400 million per year. Additionally, it offers a long-term lease of government land for up to 50 years at 6% of the market rate.

b. Tamil Nadu – The state provides land for solar system component manufacturing, with incentives for co-utilisation of land. The Industry Policy 2021 provides a structured package of incentives.

c. West Bengal – The state provides a 100% exemption from land conversion fees, stamp duty and electricity duty for expansion and new units for five years. Additionally, it offers an exemption from water cess.

d. Rajasthan – The state provides a seven-year land tax exemption and 10-year electricity duty exemption for solar power equipment manufacturers. It also allots land at a 50% concessional rate, with a 100% stamp duty exemption. Additionally, an investment subsidy of 90% of the state goods and services tax due and deposited is offered for seven years.

e. Karnataka – The state provides a capital subsidy between 10% and 25% on the value of fixed assets depending on the zone of operation. It also offers PLI for large, mega and ultra mega enterprises. Under its Industrial Policy 2025-30, the state also proposes exemption on stamp duty up to 100% in Zone 1 and 75% in Zone 2. Similarly, it also proposes providing concessional registration charges and reimbursement of land conversion fees.

11. **Special Economic Zones ACT, 2005:** The primary goals of the SEZ Scheme include stimulating economic activity, enhancing export capabilities, attracting investments, fostering job creation, and advancing infrastructure development. SEZs, marked as duty-free zones beyond India's customs jurisdiction, facilitate authorized operations without the need for import licenses. Manufacturing or service ventures are permitted within SEZs, providing units with the freedom to subcontract and benefiting from simplified customs procedures that exempt them from regular cargo inspections. Solar component manufacturing facilities situated within a Special Economic Zone (SEZ) are regulated by the SEZ Act and are eligible to receive incentives and subsidies.

12. **Solar manufacturing zones:** The power sector plays a crucial role in India's economic and industrial growth. However, India relies heavily on imports to meet the growing domestic demand for renewable power equipment. The target of 500 GW of non-fossil energy capacity by 2030 presents a tremendous opportunity to create skilled job facilitate technology transfer and contribute to the "Make in India" campaign, thereby reducing import reliance. The Ministry of New and Renewable Energy (MNRE), along with the Ministry of Power (MoP), has proposed a scheme to establish three manufacturing zones - two brownfield manufacturing zones, which are already under development, and one greenfield manufacturing zone in a coastal area. The proposed funding under the scheme is Rs 10 billion for the two brownfield manufacturing zones and one greenfield manufacturing zone, which is flexible and can be used to support common infrastructure and testing facilities, with a ceiling of Rs 4 billion in the manufacturing zones. The scheme will run for 5 years, from FY23 to FY27.

    The purpose of the initiative is:

    - To establish a manufacturing facility utilising cutting-edge, clean, and energy-efficient technology to reduce reliance on imported equipment, critical components, and spares required for the power sector and renewable energy equipment.
    - To support the "Make in India" and "Aatmanirbhar Bharat" initiatives, aiming to position India as a global leader in the power and renewable energy equipment manufacturing sector.
    - To encourage indigenization through domestic manufacturing of currently imported items.
    - To facilitate the creation of an exclusive manufacturing zone in the country by ensuring hassle-free land allocation and clearances, and by providing state-of-the-art Clean Technology Fund (CTF) and Climate Investment Funds (CIF), thereby significantly reducing manufacturing costs and making the domestic industry competitive and self-reliant in the production of power and renewable energy equipment.

Player profiles

Table 40: Overview of major domestic players in the market

Parameter	Waaree Energies	Goldi Solar	Tata Power Solar	ReNew Power	Emmvee Photovoltaic	Adani Enterprises	Premier Energies	FS India	Rayzon Solar	RenewSys India
Enlisted capacity as per ALMM I list (March 1st, 2026 - MW)	18,645	15,565	5,706	5,434	8,774	4,406	5,153	3,433	9,065	5,217
Market share as a percentage of total enlisted capacity (as per ALMM I)	10.8%	8.9%	3.3%	3.1%	5.1%	2.5%	2.9%	1.9%	5.2%	3%
Enlisted capacity as per ALMM II list (April 13th, 2026 - MW)	5,251	NA	4,813	1,766	1,553	4,237	3,283	3,433	NA	NA
Market share as a percentage of total enlisted capacity (as per ALMM II)	17.5%	NA	16%	5.9%	5.2%	14.1%	10.9%	11.4%	NA	NA
Operational Ingot-Wafer capacity (GW)	-	-	-	-	-	2	-	-	-	-
Products and services	Solar PV modules, inverters, batteries, EPC services, rooftop solutions, O&M services, solar home appliances, and solar water pumps	Solar modules, EPC services, Solar Water Pumps	Solar PV cells and modules, EPC services and O&M services	Solar PV cells and modules	Solar PV cells and modules, EPC services, rooftop solutions, O&M services, and solar water heater solutions	Solar PV cells and modules, EPC services, O&M services	Solar PV cells and modules, EPC services, O&M services, water pumps, power	Solar PV modules and cells, encapsulants, back sheets	Integrated Solar energy solutions provider with a presence in solar PV modules, EPC services, and O&M services	Solar PV modules, EPC services, Solar Water Pumps
Module technology as per ALMM I	Mono c-Si PERC and TOPCon	Mono c-Si PERC and TOPCon	Mono c-Si PERC and TOPCon	Mono c-Si PERC and TOPCon	Mono c-Si PERC and TOPCon	Mono c-Si PERC and TOPCon	Mono c-Si PERC and TOPCon	TOPCon and Cadmium Telluride Thin Film	Mono c-Si PERC and TOPCon	Mono c-Si PERC and TOPCon
Cell technology as per ALMM II	NA	NA	NA	Mono c-Si PERC	TOPCon	Mono c-Si PERC and TOPCon	Mono c-Si PERC	NA	NA	NA

Source: ALMM I released on 1st March 2026 and ALMM II released on 13th April 2026

Adani Enterprises Limited set up India's first ingot-wafer manufacturing capacity of 2 GW that commenced operations in March 2024

The company established India's largest solar cell and module integrated plant of 1.2 GW in May 2017, which was later expanded to 4 GW in fiscal 2023.

The company had the 15th largest enlisted capacity of 4.4 GW in solar ALMM I release on 1st March 2026.

Similarly, the company had the third-largest enlisted capacity of 4.2 GW of solar cell in the solar ALMM II release on 13th April 2026 with Mono Perc and TOPCon technologies.

The company has received financial closure for its under-construction 6 GW cell and module TOPCon technology.

Risks and monitorable factors

The risks associated with solar cell and solar module manufacturing are multifaceted, impacting the environment as well as overall economic stability.

Table 41: Risks in solar cell and module manufacturing

Risk category	Solar cell manufacturing	Solar module manufacturing
Capital requirement	High initial capital investment 	Low initial capital investment 
Barrier to entry	High entry barrier, low competitive intensity 	Low entry barrier, high competitive intensity 
Technological risks	High risk of obsolescence due to rapid advancements 	Less risk of obsolescence in the assembly process 
Complexity	High complexity, design and engineering requirements 	Low complexity, design and engineering requirements 
After-sales risks	No warranty 	25–30-year warranty 
Environmental and health risks	Handling of hazardous materials in manufacturing process 	Waste management and recycling of panel components 

Note: Red indicates high risk, amber moderate risk and green low risk

Source: Industry, Crisil Intelligence

Module manufacturers are also vulnerable to risks such as change in government regulations, exchange rate or input price volatility, and market and competition risk.

Figure 158: Regulations, commissioning capability and technological progress key for the industry

Risks and monitorable factors	Impact meter	Impact
Changes in import-export regulations		India's limited upstream component base is expected to result in continued reliance on imports. Thus, change in global trade policies, particularly in duties, could significantly impact manufacturers
Foreign currency fluctuations		The impact of rupee depreciation on imports of upstream components is anticipated to be offset by a surge in exports of downstream components
Changes in government policy		The domestic industry relies heavily on government interventions in the form of tax and non-tax barriers to remain resilient. Any shifts in government policy could, thus, severely impact the industry
Rise in competition from domestic market and imports		Increased investment from Chinese players in Vietnam, Thailand and Malaysia is expected to intensify export competition for Indian manufacturers. Timely commissioning of large-scale vertically integrated capacities will be crucial to maintaining competitiveness
Technology upgrades		While innovation improves efficiency and lowers costs, a fast pace of change can render existing systems obsolete and introduce compatibility problems. This poses risks related to performance, reliability and the ability of new modules to seamlessly integrate into existing infrastructure
Price volatility and market risks		The limited base of upstream components, such as polysilicon, wafers and cells, is expected to leave India vulnerable to supply and price shocks from the international market. However, rising upstream domestic capacity over the longer term will mitigate this risk
Development of local value chains in export markets		Diversification of the export basket will remain a crucial monitorable factor in the future as major importing economies develop their own manufacturing setups

Note: The red zone denotes high risk, amber moderate risk and green low risk

Source: Crisil Intelligence

Module 13: Indian wind manufacturing

Modes of wind project operations

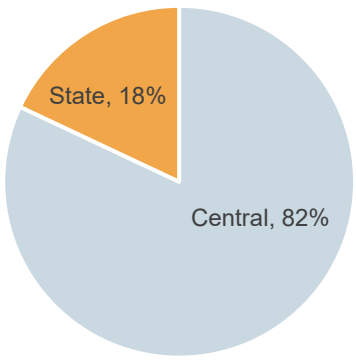
The wind energy sector operates through competitive bidding and open access markets:

1. Competitive bidding

Under this model, nodal agencies such as state discoms or central intermediaries such as SECI or NTPC issue tenders for allocation of wind power capacity to service power demand. States issue such tenders for wind power to fulfil their own requirements, driven also by state specific renewable purchase obligation (RPO) targets. On the other hand, the central intermediaries issue these requirements to procure power to trade further by selling to state distribution utilities, essentially acting as a hedge between developers being directly exposed to the state entities.

During FiT Regime, state contribution for wind energy procurement was higher as most installations were under direct discom PPA route and higher tariffs during the regime covered for the project risks associated in the wind energy sector. However, the transition to competitive bidding has resulted in central auctions finding favour with participating bidders due to the lower risks associated with central intermediaries. Central allocations offer several key advantages over state bids, some of which are: better off-taker credibility (SECI/NTPC), a three-tier payment security mechanism, and provision of land and infrastructure in solar parks. These three factors make developers perceive lower risk for central counterparty auctions compared with state auctions, where these factors may or may not be present. This, coupled with poor financial position of state authorities, restricts the latter's ability to conduct new allocations.

Figure 159: Wind allocations by state and central nodal agencies till March 2026



Source: MNRE; Crisil Intelligence

2. Open access

The open access wind installed capacity is estimated to be around 16-18 GW as of March 2026, which forms around ~28-32% of cumulative installed capacity for wind. The open access market is primarily driven by commercial and industrial (C&I) consumers. Growth is expected in the market through the following business models:

- Captive or Group captive – 100% or 26% equity contribution is needed in captive and group captive models respectively in the project with a consumption of a minimum 51% of annual generation by the C&I consumer
- Third-party PPA – An OPEX oriented model in which the project is set up by a third-party developer and the power is supplied to the C&I consumer at a mutually agreed price

- Sale on power exchange – Short-term power supply through GTAM & GDAM markets via IEX, or even in the original DAM segment of the market
- Bilateral transaction – Similar to sale on exchange however done through traders or a direct agreement on short to medium term basis with procurer

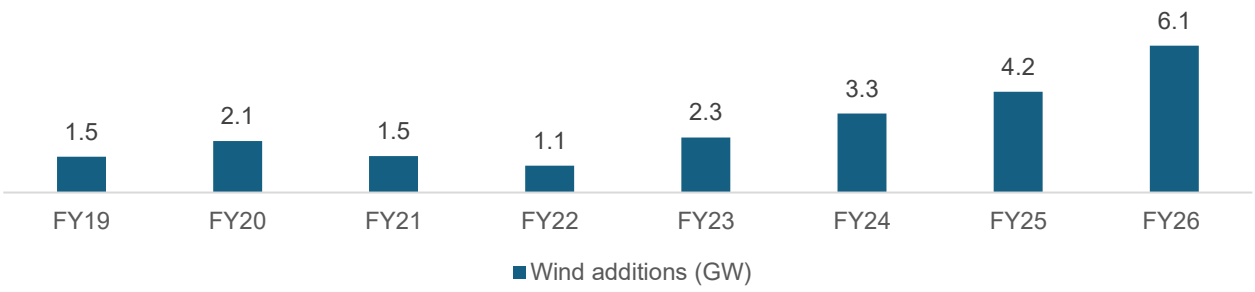
Demand under the open access market will be driven by sustainability and ESG initiatives planned by corporates and businesses, which would lead them to procure more renewable power at scale to meet clean energy commitments. Overall, the competitiveness of clean energy vs conventional power / grid power due to lower tariffs coupled with concessions on transfer of power is expected to continue help drive growth in the segment.

Capacity addition momentum continued in fiscal 2026

SECI projects drive installations

The wind energy segment has witnessed 6,057 MW of capacity additions during FY26, surpassing the total additions recorded in FY25 (4,151 MW). This represents an increase of ~46% over the total wind capacity additions recorded in FY25. These new additions continued to be concentrated in Gujarat (49%), Karnataka (23%), Maharashtra (11%) and Tamil Nadu (7%), which together accounted for nearly 90% of the total wind capacity additions during FY26. A significant portion of these installations was executed under SECI standalone schemes, including Tranches V, VIII, IX, X and XI and XIII driven by execution of the pent-up pipeline where PPAs had been signed between fiscals 2019 and 2022.

Figure 160: Wind capacity additions remain strong in FY26



Source: MNRE, Crisil Intelligence

The average monthly wind capacity additions during FY26 stood at ~505 MW, reflecting a sustained improvement in installation momentum. The pickup in activity is seen to have continued from fiscals 2024 and 2025 which saw 3,253 MW and 4,151 MW respectively in terms of total additions.

That said, the sector faces delay due to execution challenges such as grid connectivity issues, congestion of good wind resource regions, limited choice in OEM suppliers, land acquisition, right of way for logistics of WTG and transmission line, turning radius and movement of material. SECI and other state entities cumulatively allocated ~22.7 GW of standalone wind capacity between fiscals 2017- fiscal 2026. Out of this, 16.7 GW had PPAs signed, of which ~6.4 GW (39%) has been commissioned and ~3.6 GW (21%) was cancelled. With commissioning timelines of 18-24 months, projects are now lined up for commissioning over the next few fiscals.

Evolution of wind energy and state trends

Capacity additions plummeted from the peak of fiscal 2017, mainly because of the abrupt phasing out of the feed-in tariff (FiT) regime and implementation of the competitive bidding mechanism at the end of fiscal 2017. Moreover, halving the

accelerated depreciation benefit (from 80% in fiscal 2017 to 40% in fiscal 2018) and elimination of generation-based incentives of Rs 0.5 per unit had also reduced investments in the sector from non-independent power producers.

In February 2017, the government conducted the first reverse e-auction for wind power, which saw tariffs falling to Rs 3.46 per unit, 17% lower than the lowest wind FiT of Rs 4.16 per unit in Tamil Nadu. With such a sharp drop in tariffs, several discoms in Gujarat, Andhra Pradesh, Rajasthan and Karnataka expressed their unwillingness to buy power under the FiT regime even for approved and under-construction projects as PPAs were not signed.

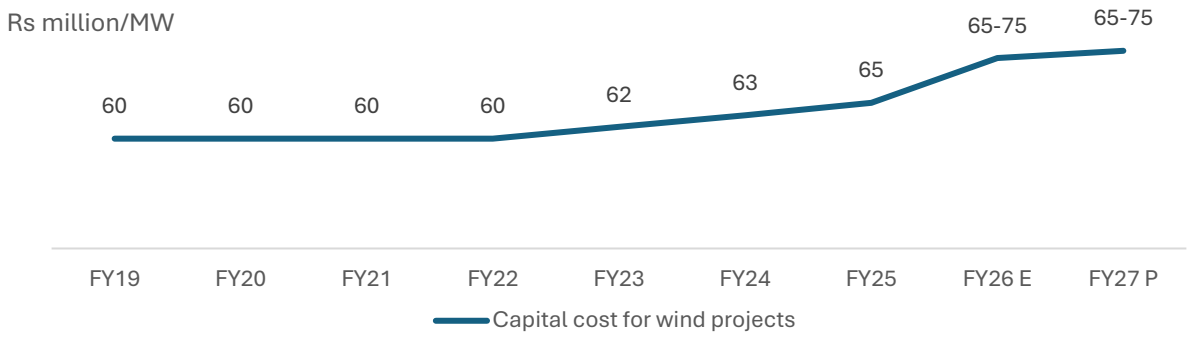
Wind power tariffs then fell to Rs 2.5 per unit level, with tariffs as low as Rs 2.43 per unit in December 2017 in the Gujarat wind auctions of 500 MW. However, tariffs have since reached a weighted average of Rs 3.4 and Rs 3.7 per unit in fiscal 2024 and 2025, respectively, a rise compared with those recorded in the previous years. The weighted average tariffs were Rs 2.89, Rs 2.80 and Rs. 2.97 per unit in the fiscals 2021, 2022 and 2023, respectively.

Three central allocations concluded in fiscal 2025, two by SJVN and one by SECI. SJVN Wind Tranche-I and Tranche-II recorded weighted average tariff of Rs 3.99 and 3.77 per unit respectively while the SECI auction under Wind Tranche-XVII saw a weighted average tariff of Rs 3.81 per unit. A sole state led allocation was concluded by GUVNL under Tranche-VIII witnessed weighted average tariff of Rs 3.59 in fiscal 2025. Overall, the standalone wind tariff was Rs 3.7 per unit in fiscal 2025 and fiscal 2026 witnessed a weighted-average tariff of Rs 3.68 per unit.

Previously, volatility in prices of key commodities, such as cement and steel (4% and 26% on-year, respectively) in fiscal 2022 and a further increase (of ~3% and 4%) in fiscal 2023 because of supply-chain disruptions amid geopolitical challenges, contributed to cost escalations and higher capital cost for wind projects.

With demand for wind-solar hybrid (“WSH”) projects on the rise, driven by corporate buyers and discoms seeking reliable green power, the MNRE introduced the National Wind-Solar Hybrid Policy in 2018 to promote better grid stability and reduce renewable energy variability. Several states, including Gujarat, Andhra Pradesh, and Rajasthan, have also implemented their own WSH policies.

Figure 161: Capital cost of wind projects



Note: Fiscal 2026 is Crisil estimate.

Source: CEA, Crisil Intelligence

The higher input prices seeping into turbine costs, compared with the past have reduced project returns, impacting execution of delayed projects bid at lower tariffs. This has also caused bid tariffs to increase 10% CAGR between fiscals 2022 and 2024 as developers treaded cautiously for new allocations. Tariffs in fiscal 2025 continued to rise, growing by 12% on year, despite relief in commodity prices, but maintained stability in fiscal 2026. The rise can be attributed to issues with regards to acquisition of land, concentration in type I wind sites, availability of adequate transmission infrastructure, falling cost of solar energy leading to developers favouring it over wind.

Going ahead, both concrete and steel prices are expected to increase marginally in fiscal 2027. Despite this, Crisil Intelligence expects the bid tariffs to remain range bound at Rs 3.6-3.9 per unit in fiscal 2027. With this, wind is expected to remain on parity with fossils which combined with rising share of hybrid and continued government support, will help the wind base to continue to increase.

Table 42: State-wise yearly capacity additions fiscal 2019- fiscal 2026

State	Installed base	Capacity additions								Installed base
	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	March 2026
Andhra Pradesh	3,967	124	2	4	-	-	-	281	39	4,416
Gujarat	5,613	460	1,468	1,020	647	770	1,744	955	2,965	15,642
Karnataka	4,608	87	96	148	192	164	725	1,331	1,379	8,730
Kerala	53	-	10	-	-	-	1	8	-	72
Madhya Pradesh	2,520	-	-	-	-	324	-	351	484	3,679
Maharashtra	4,784	10	206	-	13	-	195	77	643	5,927
Rajasthan	4,298	2	-	27	-	867	2	13	140	5,349
Tamil Nadu	8,197	772	335	304	258	151	586	1,136	407	12,147
Telangana	101	27	-	-	-	-	-	-	-	128
Pan India	34,145	1,481	2,118	1,503	1,111	2,276	3,253	4,151	6,057	56,095

Source: MNRE, Crisil Intelligence

Collectively, Gujarat, Tamil Nadu and Karnataka account for 38% of India's 1,164 GW of wind energy potential at 150 m above the ground (as per National Institute of Wind Energy).

The Government, through National Institute of Wind Energy (NIWE), has installed over 900 wind-monitoring stations all over country and issued wind potential maps at 50m, 80m, 100m, 120m and 150m above ground level. The recent assessment indicates a gross wind power potential of 695.50 at 120 meter and 1,163.9 GW at 150 meter above ground level.

Table 43: Most of wind potential exists in eight windy states

Sr No.	State	Wind potential at 120 m (GW)	Wind potential at 150 m (GW)
1	Andhra Pradesh	75	123
2	Gujarat	143	181
3	Karnataka	124	169
4	Madhya Pradesh	15	55
5	Maharashtra	98	174
6	Rajasthan	128	284
7	Tamil Nadu	69	95
8	Telangana	25	55

	Total 8 windy states	**677**	**1137**
9	Others	19	27
	Total	**696**	**1164**

Source: MNRE

Growth drivers

Policy initiatives taken by the government to boost wind capacity additions over the long-term

New tender opportunities, technology and exposure to central intermediaries are key drivers

1. **Large scale allocations**

   After the competitive bidding of 1 GW by SECI in February 2017, SECI further allocated ~15.9 GW (excluding cancelled contracts) over March 2017-March 2026 through wind-only tenders. MNRE has outlined plans to tender 10 GW of capacity each year, of which the majority portion should be expected from SECI/NTPC. This bodes well as central sector PPAs have lower counterparty risk, compared with PPAs directly with state discoms. The latter are known to delay payments to developers and have poor financial ratings, while SECI and NTPC are better rated and provide various payment security mechanisms (LCs, payment security fund and SECI being party to the tripartite agreement). SECI acts as the procurement intermediary between project developer and DISCOMs, offering payment security to developers SECI helps to aggregate bids through a transparent e-bidding process followed by an e-reverse auction, ensuring competitiveness in tariffs and encouraging innovation.

Table 44: SECI wind allocations since fiscal 2017

Fiscals	Standalone capacity allocation (MW)	Weighted average tariff (Rs per unit)	Hybrid capacity allocation (MW)	Weighted average tariff (Rs per unit)
FY17	1,050	3.46		
FY18	3,000	2.51		
FY19	4,340	2.48	840	2.68
FY20	920	2.82	1,800	3.64
FY21	1,200	2.78	2,370	2.69
FY22	1,200	2.69	3,700	2.92
FY23	1,700	2.93	1,170	2.53
FY24	1,865	3.48	2,580	4.34
FY25	100	3.82	2,630	4.15
FY26	1,500	3.68	1,620	5.97

Note: Hybrid capacity include plain hybrid, RTC, Peak Power Supply and FDRE. Excludes solar with storage hybrid.
Source: SECI, Crisil Intelligence

Similarly, SJVN has also allocated ~9 GW of wind (including hybrid) capacity till March 2026.

2. **Revision in RPO targets**

a) The Ministry of Power (MoP) has provided a new renewable purchase obligation (RPO) long-term trajectory for wind energy till fiscal 2030, which proposes increasing the target for wind from 0.81% in fiscal 2023 to 6.94% in fiscal 2030. The target, however, needs to be met from wind plants commissioned after March 31, 2022, thus requiring installation of new capacity.

b) To meet the increased targets, states would have to procure more RE either via the REC route (which still leads to capacity additions) or competitively bid-out capacity. The waiver of ISTS charges by Central Electricity Regulation Commission (CERC) for all projects set up until June 2025 also enabled the states with low renewable potential to procure renewable power from more able states. However, RPO compliance is dependent on strict enforcement by regulatory authorities.

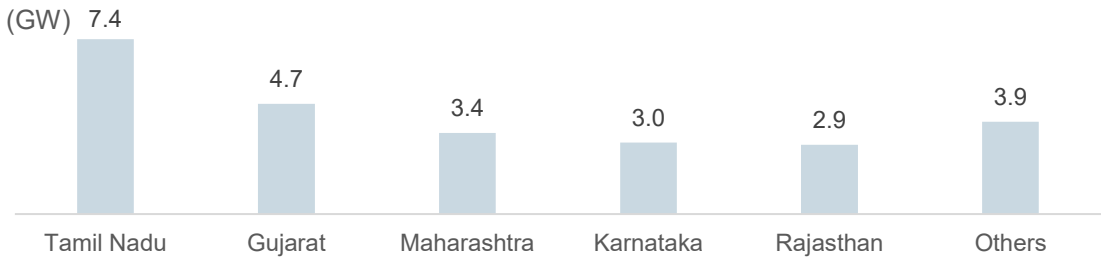
3. **Improved technology**

Manufacturers are seen to innovate technology to solve the issue of land availability by manufacturing turbines with higher hub height to get better PLF. This can also be seen from the evolution of wind turbines at the global level. The world has evolved towards the solution of increasing hub heights and size of turbines, to maximise generation potential at a location. It started with 0.05 MW turbines at a hub height of 26 m in 1980 and gradually moved to 10 MW capacity turbines at a hub height of 245 m currently. India has followed similar suit by manufacturing turbine size of 0.05 MW capacity at 25-30 m hub height when it first started in 1986 and gradually followed the global trend where it recently developed turbine of 5.2 MW capacity at hub height above 150 m. Hence, India is developing its technology, and the turbine size and capacity is doubling almost every decade.

4. **Repowering of wind assets**

While the addition in the next five years is expected to be driven by an existing pipeline of over 20 GW on account of new tendering. Concentration in wind sites already impacts the sector, wherein lies an opportunity to improve the PLF by repowering old projects with the latest technology which the Government is also focusing on. With legacy projects of almost 32 GW installed under the feed-in tariff regime which may have PPAs near expiry, almost 78% of such projects have turbine capacity of 2 MW or below and have the potential of repowering. The states which have the highest potential to go for repowering include Tamil Nadu and Gujarat which account for 47% of such capacity. Hence, because of repowering of old plants, demand for better turbines will be boosted. Additionally, decommissioned wind turbines also have the potential to offer good salvage value, particularly for steel components. This also provides economic benefits to the developer.

Figure 162: Wind re-powering potential



Source: MNRE

5. **The 50 GW bidding trajectory**

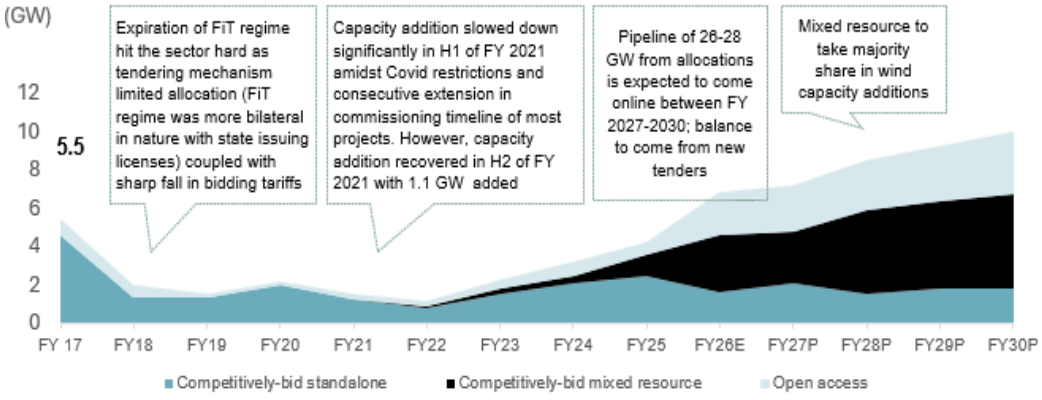
The MNRE in fiscal 2023 announced a 50 GW of bidding trajectory per annum by the Renewable Energy Implementing Agencies (REIA) between fiscal 2024 to fiscal 2028. In order to promote installation of wind energy, the plan earmarked 10 GW of the total bidding trajectory per annum to wind energy. Between fiscal 2023 to December 2025, the industry has witnessed nearly 6 GW of standalone wind energy tenders. The push to hybrid tenders is also expected to drive up wind allocations.

6. **State targets**
   Multiple states have set targets to push renewable energy installations. Andhra Pradesh and Telangana have a target of installing 37.5 GW of wind energy by 2030. While other states such as Rajasthan aim to install 125 GW of renewable energy by 2030. Gujarat also aims to achieve 50% of its energy requirement from renewable energy sources by 2030. This is expected to aid wind energy additions by fiscal 2030.

7. **Offshore wind**
   India is blessed with a coastline of about 7600 km surrounded by water on three sides and has good prospects of harnessing offshore wind energy. Considering this, the Government had notified the National offshore wind energy policy. As per the policy, MNRE will act as the nodal Ministry for development of Offshore Wind Energy in India and work in close coordination with other government entities for Development and Use of Maritime Space within the Exclusive Economic Zone (EEZ) of the country and shall be responsible for overall monitoring of offshore wind energy development in the country. National Institute of Wind Energy (NIWE), Chennai will be the nodal agency to carryout resource assessment, surveys and studies in EEZ, demarcate blocks and facilitate developers for setting up offshore wind energy farms.

Capacity additions expected to accelerate over fiscal 2027-2030

Figure 163: Wind expected to add 34-36 GW between fiscal 2027-2030



*Note: *: This excludes additions from green hydrogen*
Source: MNRE, Crisil Intelligence

Crisil Intelligence estimates the wind energy base to reach 90-92 GW by the end fiscal 2030, registering a robust growth of ~1.6 times on the 56.1 GW installed base at the end of March 2026.

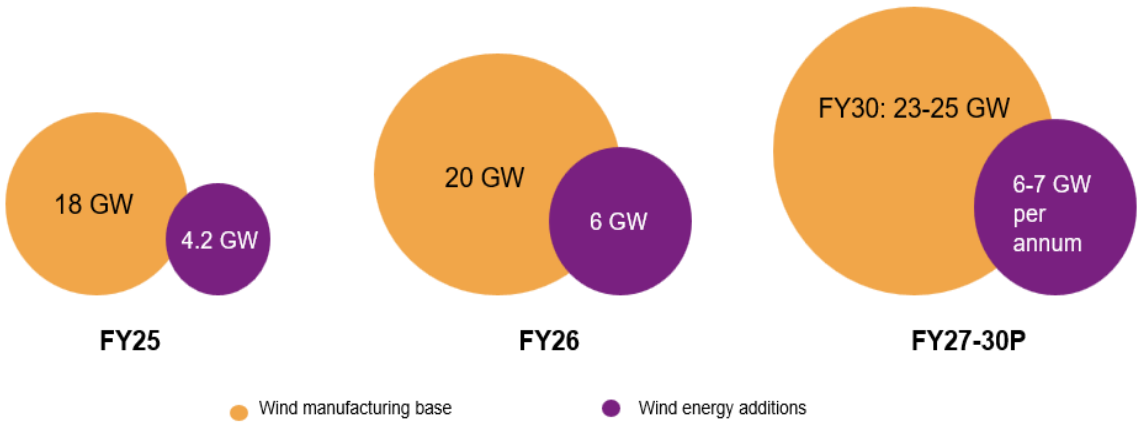
Wind manufacturing

The domestic wind turbine manufacturing ecosystem has evolved into one of the largest in the world, with an estimated annual production capacity of over 20 GW as of March 2026 according to MNRE and the Indian Wind Turbine

Manufacturers Association. This capacity spans the complete value chain of wind turbine component that is rotor blades, nacelles, gearboxes, hubs, and tubular towers with an indigenisation level ranging between 70-80% for commercially developed wind turbines the industry is supported by long standing domestic players such as Suzlon energy, Inox wind and Adani Enterprises as well as multinational OEMs including GE Vernova, Vestas, Senvion and the TPG-led Indian operations of Siemens Gamesa put together produced turbines largely in the 3 MW segment, with certified models extending up to 5.2 MW.

The country's component manufacturing footprint has matured in both volume and technological ability. Rotor blade production in India now caters to machines with rotor diameters of 110 to 181 meters, with facilities spread across Gujarat, Karnataka, Maharashtra, Tamil Nadu, Uttar Pradesh, and Haryana. The fabrication supports hub heights of 50 to 140 meters, with capacity to serve repowering and high wind class projects. Across all components Indian manufacturing is aligned with MNRE's approved list of models and manufacturers previously known as the RLMM, ensuring quality and certification compliance. The manufacturing capacity as of March 2026 is sufficient to cater to the upcoming wind energy installations and it is further expected to expand by 6-7 GW by fiscal 2030 as per market announcements.

Figure 164: Manufacturing capacity to expand to 23-25 GW by fiscal 2030; 4 times the average demand per annum



Source: Crisil Intelligence

In line with the present capacity, the MNRE on July 31, 2025, issued a pivotal amendment transforming the RLMM into ALMM-Wind with significant implications for OEMs. The new framework mandates that all ALMM listed wind turbines must source five key components – blades, towers, gearboxes, generators, and special bearings - from domestic facilities. It also requires that OEMs must maintain onshore R&D centers, operational control servers and data repositories within India. This institutionalizes a domestic manufacturing regime that favors integrated OEMs with established domestic operations

From an OEM perspective the current policy and market environment present multiple structural growth drivers first, the ALMM-wind framework creates entry barriers that reward vertically integrated manufacturing allowing OEM's with in-house blade, nasal, and tower capacity to maintain RLMM certification and thus market access. Second, push towards higher MW platforms with turbine sizes rising above 3 MW and hub heights reaching 140 to 160 meters requires OEMs to scale local component lines for longer plates, higher torque drive trains, and site adaptive tower designs, thirdly the mandate for onshore R&D centers and design ownership incentivizes innovation within India and facilitates faster time to market for models tailored to India's low to moderate wind regimes.

In terms of cost economics, blades, towers, gearboxes, generators and special bearings account for 65-70% of the total cost of a wind turbine. With high localization levels and strong domestic steel and composite supply chains, Indian OEM's can be competitively positioned to serve both domestic and export demand.

On the player front, *Adani Enterprises has an integrated manufacturing capacity of 2.25 GW as of March 2026.*
It has following 4 models listed in RLMM

- 5.2 MW 160m RD 120m HH – TT
- 5.2 MW 160m RD 140m HH – HT
- 3.0 MW 147m RD
- 3.3 MW 164m RD

The company has enlisted one of the largest turbine sizes of 5.2 MW in the ALMM-wind list as on 01.10.2025 released and has installed India's largest wind turbine prototype of 5.2 MW at Mundra SEZ.

Sehul S. Bhatt

Crisil Limited MUMBAI

Mr. Sehul Bhatt
Director, Crisil Intelligence

About Crisil Intelligence (formerly Market Intelligence & Analytics)

Crisil Intelligence is a leading provider of research, consulting, risk solutions and advanced data analytics, serving clients across government, private and public enterprises. We leverage our expertise in data-driven insights and strong benchmarking capabilities to help clients navigate complex external ecosystems, identify opportunities and mitigate risks. By combining cutting-edge analytics, machine learning and AI capabilities with deep industry knowledge, we empower our clients to make informed decisions, drive business growth and build resilient capacity.

For more information, visit Intelligence.Crisil.com

About Crisil

Crisil is a global, insights-driven analytics company. Our extraordinary domain expertise and analytical rigour help clients make mission-critical decisions with confidence.

Large and highly respected firms partner with us for the most reliable opinions on risk in India, and for uncovering powerful insights and turning risks into opportunities globally. We are integral to multiplying their opportunities and success.

Headquartered in India, Crisil is majority owned by S&P Global.

Founded in 1987 as India's first credit rating agency, our expertise today extends across businesses: Crisil Ratings, Crisil Intelligence, Crisil Coalition Greenwich and Crisil Integral IQ.

Crisil's global workforce operates in the Americas, Asia-Pacific, Europe, Australia and the Middle East, setting the standards by which industries are measured.

For more information, visit www.Crisil.com

Connect with us: LinkedIn | Twitter

Crisil Privacy

Crisil respects your privacy. We may use your personal information, such as your name, location, contact number and email id to fulfil your request, service your account and to provide you with additional information from Crisil. For further information on Crisil's privacy policy please visit https://www.crisil.com/content/crisilcom/en/home/crisil-privacy-notice.html.

Crisil Disclaimer

Crisil Intelligence, a division of Crisil Limited (Crisil) has taken due care and caution in preparing this report (Report) based on the Information obtained by Crisil from sources which it considers reliable (Data). However, Crisil does not guarantee the accuracy, adequacy or completeness of the Data / Report and is not responsible for any errors or omissions or for the results obtained from the use of Data / Report. This Report is not a recommendation to invest / disinvest in any entity covered in the Report and no part of this Report should be construed as an expert advice or investment advice or any form of investment banking within the meaning of any law or regulation. Crisil especially states that it has no liability whatsoever to the subscribers / users / transmitters/ distributors of this Report. Without limiting the generality of the foregoing, nothing in the Report is to be construed as Crisil providing or intending to provide any services in jurisdictions where Crisil does not have the necessary permission and/or registration to carry out its business activities in this regard. The Client will be responsible for ensuring compliances and consequences of non-compliances for use of the Report or part thereof outside India. Crisil Intelligence operates independently of and does not have access to information obtained by Crisil Ratings Limited, which may, in their regular operations, obtain information of a confidential nature. The views expressed in this Report are that of Crisil Intelligence and not of Crisil Ratings Limited. No part of this Report may be published/reproduced in any form without Crisil's prior written approval.