Energy Landscape in India: Oil & Gas Infrastructure in India

July 2025

Report Prepared for

Oswal Energies Limited

Disclaimer

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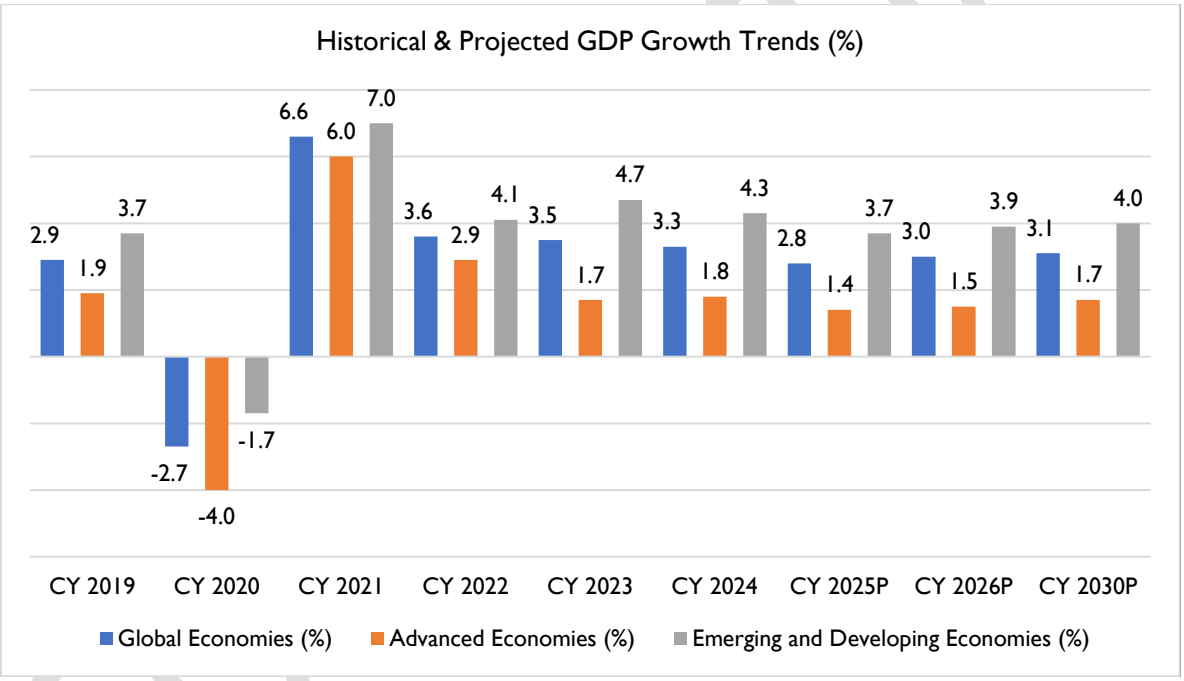
1.1 Global Economic Overview

The global economy, which recorded GDP growth at 3.3% in CY 2024, is expected to show resilience at 2.8% in CY 2025. This marks the slowest expansion since 2020 and reflects a 0.5%-point downgrade from January 2025 forecast. Moreover, the projection for CY 2026 has also reduced to 3.0%. This slowdown is majorly attributed due to numerous factors such as high inflation in many economies despite central bank effort to curb inflation, continuing energy market volatility driven by geopolitical tensions particularly in Ukraine and Middle East, and the re-election of Donald Trump as US President extended uncertainty around the trade policies as well as overall global economic growth. High inflation and rising borrowing costs affected the private consumption on one hand while fiscal consolidation impacted the government consumption on the other hand. As a result, global GDP growth is estimated to moderation by 2.8% in CY 2025 as compared to 3.3% in CY 2024.



Source – IMF Global GDP Forecast Release April 2025

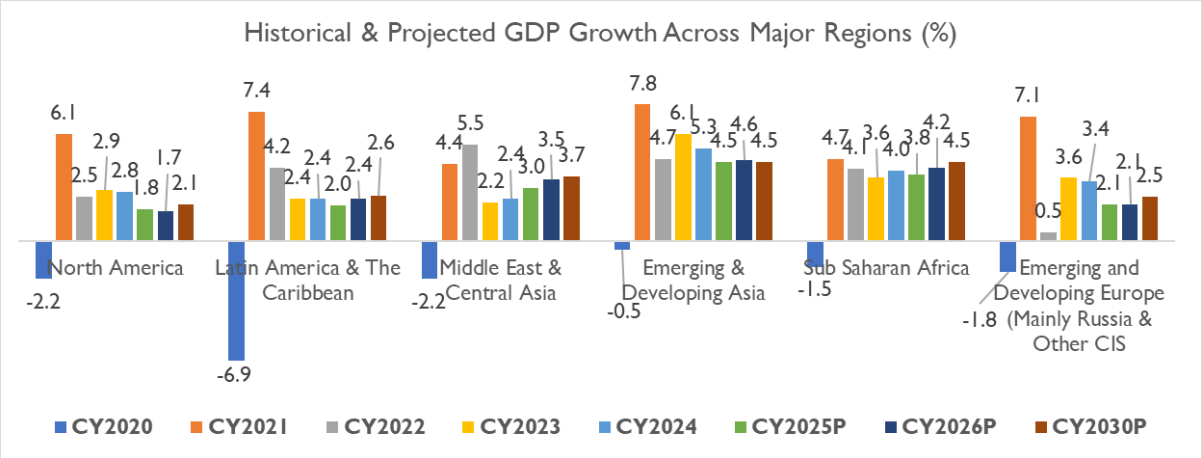
Note: Advanced Economies and Emerging & Developing Economies are as per the classification of the World Economic Outlook (WEO). This classification is not based on strict criteria, economic or otherwise, and it has evolved over time. It comprises of 40 countries under the Advanced Economies including the G7 (the United States, Japan, Germany, France, Italy, the United Kingdom, and Canada) and selected countries from the Euro Zone (Germany, Italy, France etc.). The group of emerging market and developing economies (156) includes all those that are not classified as Advanced Economies (India, China, Brazil, Malaysia etc.)

1.2 Global Economic Outlook

At broader level, the global economy is expected to experience a slowdown in 2025, with GDP growth projected to decline to 2.8%, down from 3.3% in 2024. This deceleration reflects persistent inflationary pressure, geopolitical uncertainties and tightened monetary policies. However, a sightly recovery is anticipated in 2026, with growth projected to improve to 3.0%. Global inflation is expected to decline steadily, to 4.3% in 2025 and to 3.6% in 2026. Inflation is projected to converge back to target earlier in advanced economies, reaching 2.2% in 2026, whereas in emerging market and developing economies, it is anticipated to decrease to 4. 6% during the same period. Trade tariffs function as a supply shock for the countries imposing them, leading to a decrease in productivity and an increase in unit costs. Countries subject to tariffs experience a negative demand shock as export demand declines, placing downward pressure on prices. In each scenario, trade uncertainty introduces an additional layer of demand shock since businesses and households react by delaying investment and spending, and this impact could be intensified by stricter financial conditions and heightened exchange rate volatility. Moreover, Global trade growth is expected to slow down in 2025 to 1.7%. This forecast reflects increased tariff restrictions affecting trade flows and, to a lesser extent, the waning effects of cyclical factors that have underpinned the recent rise in goods trade. Geopolitical tensions such as the wars in Ukraine and the Middle East could further exacerbate inflation volatility, particularly in energy and agricultural commodities.

1.3 Historical and Projected Regional GDP Growth

GDP growth across major regions exhibited a mixed trend between 2022-23, with GDP growth in many regions including North America, Emerging and Developing Asia, and Emerging and Developing Europe slowing further in 2024. In 2025, GDP growth in Emerging and Developing Asia (India, China, Indonesia, Malaysia, etc.) is expected to decrease further from 5.3% in CY 2024 to 4.5%, while in the North America, it is expected to decrease from 2.8% in CY 2024 to 1.8% in CY 2025.



Source-IMF World Economic Outlook January 2025 update.

Except Middle East & Central Asia, all other regions like Emerging and Developing Asia, Emerging and Developing Europe, Latin America & The Caribbean, Sub Saharan Africa and North America, are expected

to record a moderation in GDP growth rate in CY 2025 as compared to CY 2024. Further, growth in the United States is expected to come down at 2.71% in CY 2025 from 2.80% in CY 2024 due to lagged effects of monetary policy tightening, gradual fiscal tightening, and a softening in labour markets slowing aggregate demand.

India and China saw greater-than-anticipated growth in 2023 due to heightened government spending and robust domestic demand, respectively and expected to slow down due gradually in 2024 and in subsequent two years. Mainland China will face a different macroeconomic challenge: the risk of deflation due to subdued consumer spending trends, cautious business investment and ongoing deleveraging in the property sector. This has prompted authorities to announce stimulus measures to prevent exacerbating deflationary pressures.

Indeed, deflation could slow the economic recovery by delaying consumer purchases, eroding corporate revenues and worsening real debt burdens, particularly if property sector weakness and slowing exports continue to weigh on private sector confidence. Emerging markets will grapple with the challenge of curbing inflation while contending with fragile supply chains, volatile commodity prices and foreign exchange fluctuations. Sub-Saharan Africa's expected growth in 2024 is attributed to the diminishing negative impacts of previous weather shocks and gradual improvements in supply issues.

2. India Macroeconomic Analysis

India emerged as one of the fastest growth economies amongst the leading advanced economies and emerging economies. In CY 2024, even amidst geopolitical uncertainties, particularly those affecting global energy and commodity markets, India continues to remain one of the fastest growing economies in the world and is expected to grow by 6.2% in CY 2025 and 6.3% in 2026.

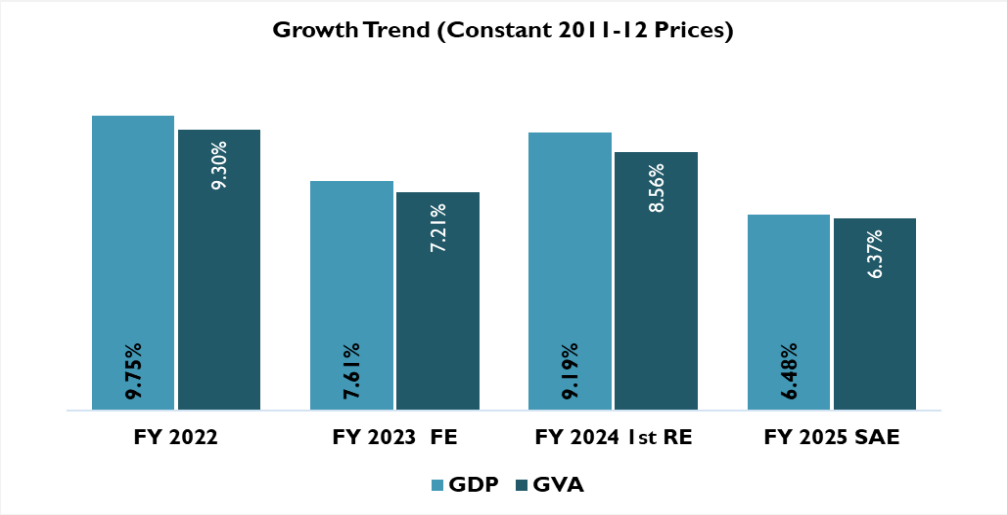
Country	CY 2020	CY 2021	CY 2022	CY 2023	CY 2024	CY 2025	CY 2026 P	CY 2030 P
India	–5.8%	9.7%	7.6%	9.2%	6.5%	6.2%	6.3%	6.5%
China	2.3%	8.6%	3.1%	5.4%	5.0%	4.0%	4.0%	3.4%
United States	-2.2%	6.1%	2.5%	2.9%	2.8%	1.8%	1.7%	2.1%
Japan	-4.2%	2.7%	0.9%	1.5%	0.1%	0.6%	0.6%	0.5%
United Kingdom	-10.3%	8.6%	4.8%	0.4%	1.1%	1.1%	1.4%	1.4%
Russia	-2.7%	5.9%	-1.4%	4.1%	4.1%	1.5%	0.9%	1.2%

Source: World Economic Outlook, April 2025

The Government stepped spending on infrastructure projects to boost the economic growth had a positive impact on economic growth. The capital expenditure of the central government increased by average 26.52% during FY 2023-FY 2024 which slowed to 7.27% in FY 2025 which is expected to translate in moderating GDP growth of 6.5% in 2024. In the Union Budget 2025-2026, the government announced INR 11.21 billion capex on infrastructure (10.12% higher than previous year revised estimates) coupled with INR 1.5 trillion in interest-free loans to states. This has provided much-needed confidence to the private sector, and in turn, expected to attract the private investment.

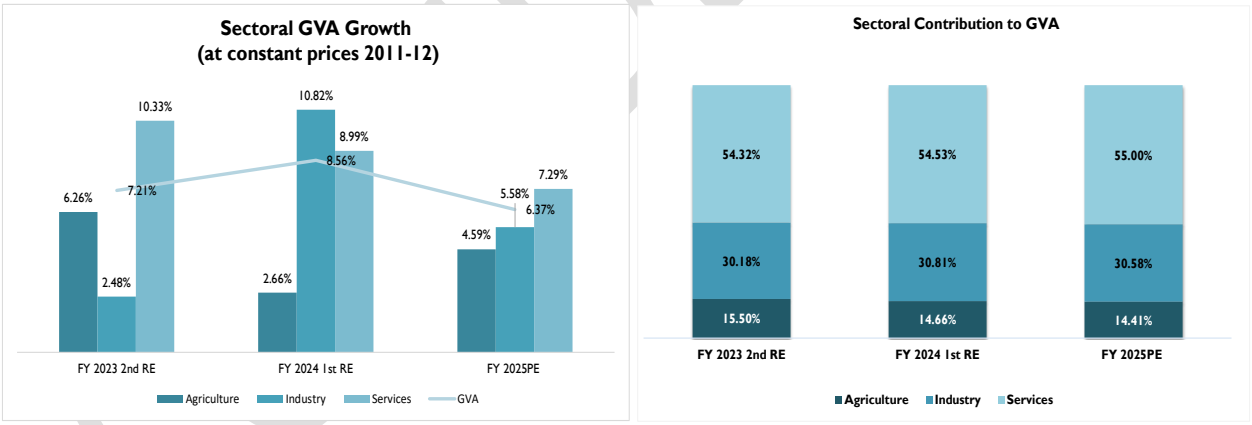
2.1 Historical GDP and GVA Growth trend

As per the latest estimates, India's GDP at constant prices is estimated to grow to INR 187.95 trillion in FY 2025 (Second Advance Estimates) with the real GDP growth rates estimated to be 6.5% for FY 2025. Similarly, real Gross Value Added (GVA) growth stood at 7.2% in FY 2023, rose to 8.6% in FY 2024, and is expected to moderate to 6.4% in FY 2025. Even amidst global economic uncertainties, India's economy exhibited resilience supported by robust consumption and government spending.



Source: Ministry of Statistics & Programme Implementation (MOSPI), National Account Statistics: FY2025

2.2 Sectoral Contribution to GVA and annual growth trend



Source: Ministry of Statistics & Programme Implementation (MOSPI)

Sectoral analysis of GVA reveals that the industrial sector experienced a moderation in FY 2025, recording a 5.58% y-o-y growth against 10.82% year-on-year growth in FY 2024. Within the industrial sector, growth moderated across sub sector with mining, manufacturing, and construction activities growing by 2.76%, 4.29%, and 8.64% respectively in FY 2025, compared to 3.21%, 12.30%, and 10.41% in FY 2024. Growth in the utilities sector too moderated to 6.03% in FY 2025 from 8.64% in the previous year. The industrial sector's contribution to GVA moderated marginally from 30.81% in FY 2024 to 30.58% in FY 2025.

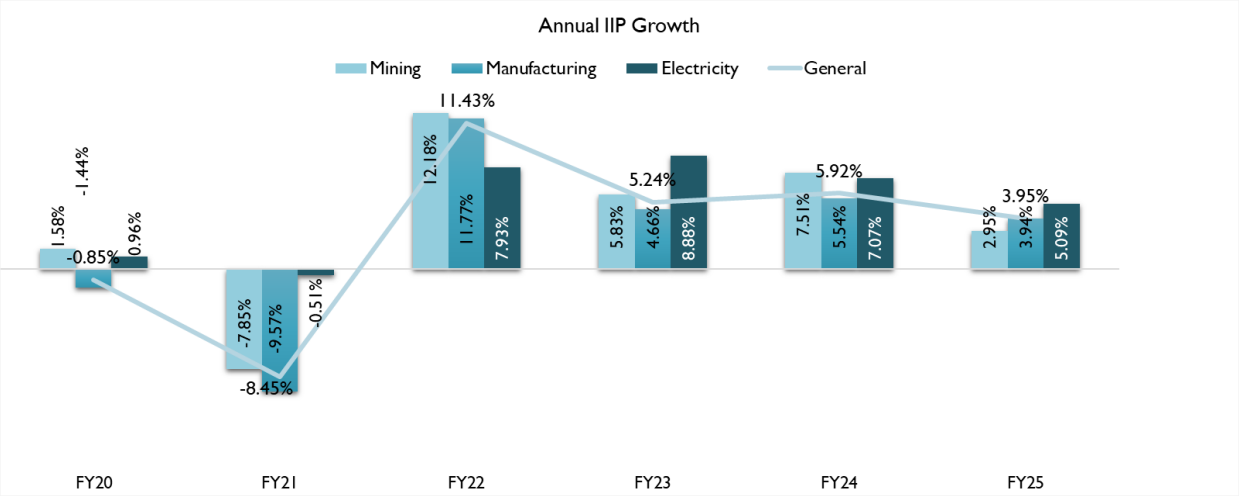
The services sector continued to be the main driver of economic growth, although its pace moderated. It expanded by7.29% in FY 2025 from 8.99% in FY 2024. The services sector retained its position as the largest

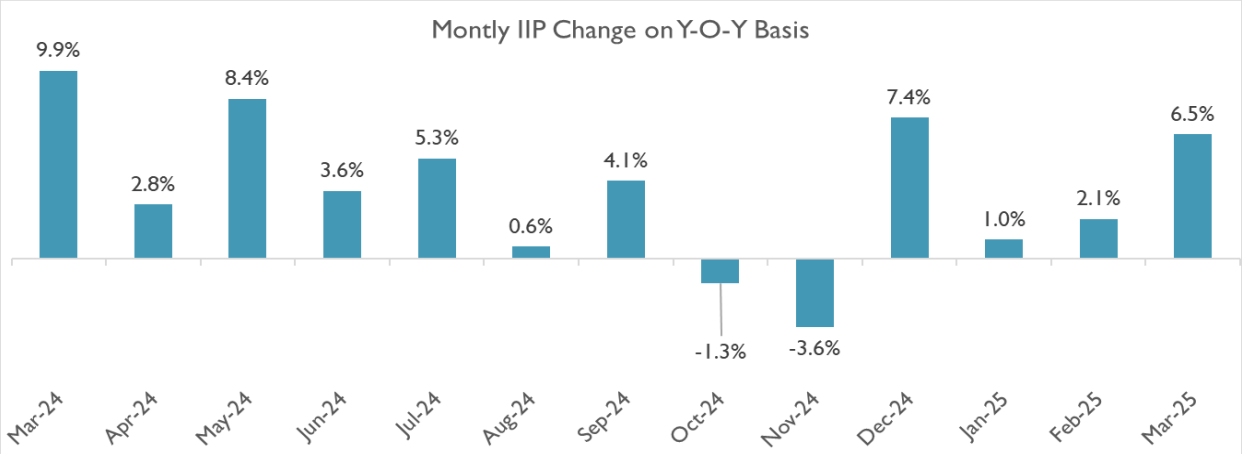
contributor to GVA, rising from 54.32% in FY 2023 to 54.53% in FY 2024, with a further increase to 55.00% projected in FY 2025.

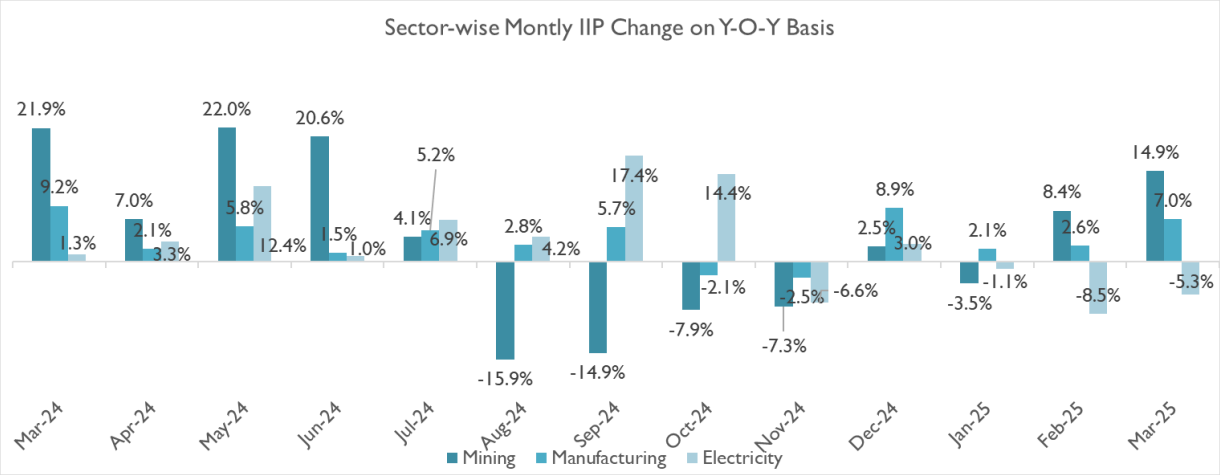
The agriculture sector saw an acceleration, with growth increasing from 2.66% in FY 2024 to 4.59% in FY 2025. However, its contribution to GVA declined marginally from 14.66% in FY 2024 to 14.41% in FY 2025. Overall, Gross Value Added (GVA) growth moderated to 6.37% in FY 2025 from 8.56% in FY 2024

2.3 Annual & Monthly IIP Growth

Industrial sector performance as measured by IIP index shows moderation in FY 2025, recording a 3.95% against 5.92% in FY 2024. The manufacturing index shown moderation by 3.94% in FY 2025 against 5.54% year-on-year growth in FY 2024. Mining sector index too moderated by 2.95% in FY 2025 against 7.51% in the previous years while the Electricity sector Index, also witnessed moderation of 5.09% in FY 2024 against 7.07% in the previous year.





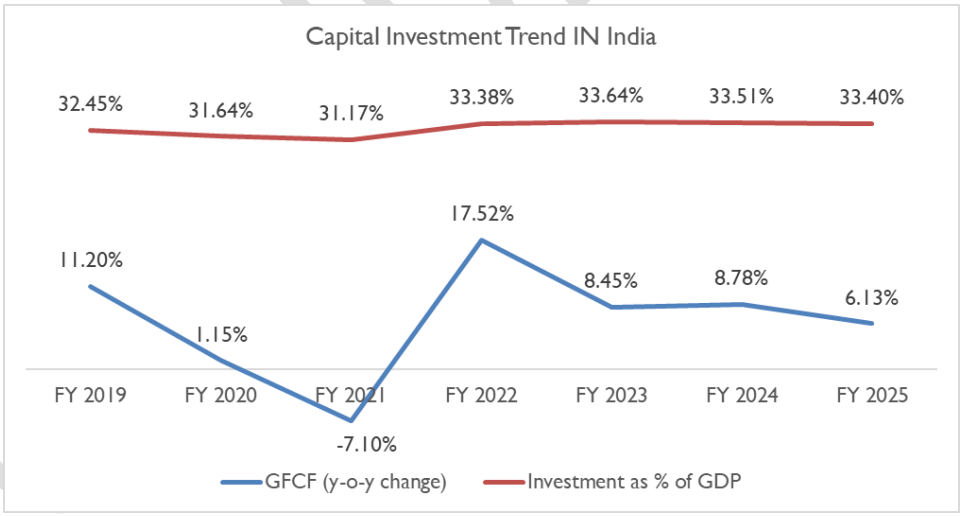


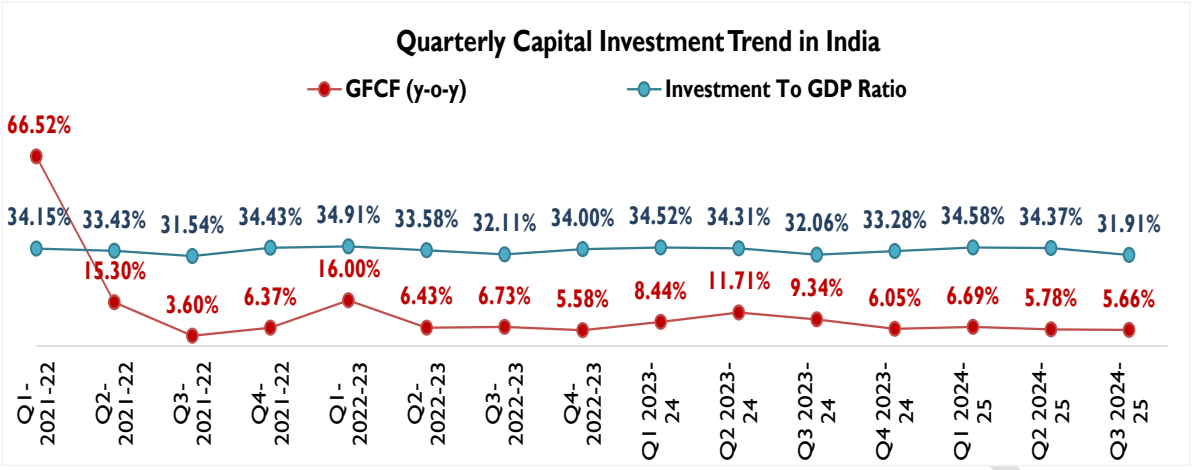
Source: Ministry of Statistics & Programme Implementation (MOSPI)

Overall month IIP index growth grew to 6.5% in March 2025 against 2.1% growth in the February 2025. Both manufacturing and mining index witnessed an improvement in March 2025 over the previous month as well as against January 2025 while growth in electricity Index improved considerably against previous year.

2.4 Annual and Quarterly: Investment & Consumption Scenario

Other major indicators such as Gross fixed capital formation (GFCF), a measure of investments, has shown fluctuation during FY 2025 as it registered 6.13% year-on-year growth against 8.78% yearly growth in FY 2024, taking the GFCF to GDP ratio measured to 33.40%.

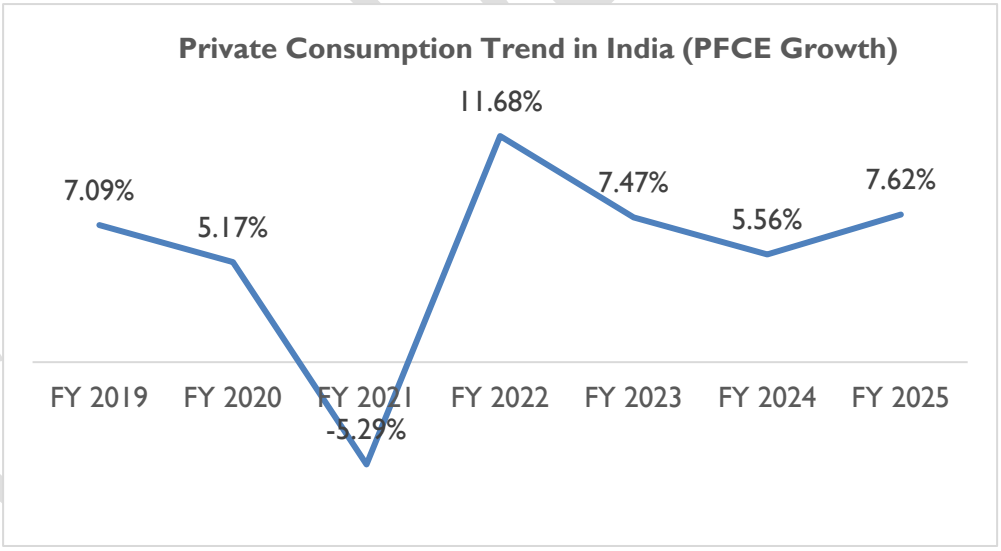


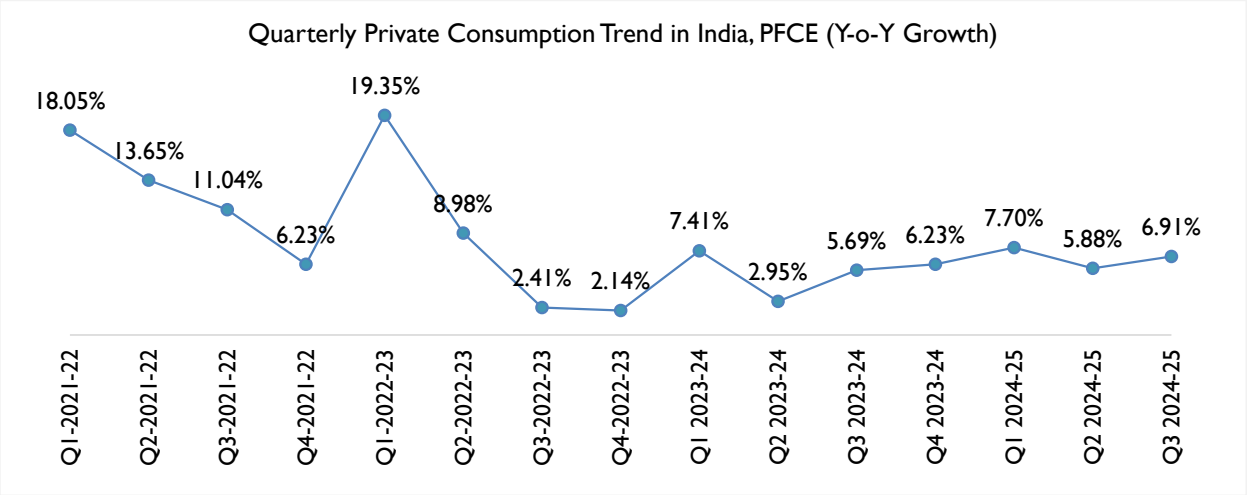


Source: Ministry of Statistics & Programme Implementation (MOSPI)

On quarterly basis, GFCF exhibited a fluctuating trend in quarterly growth over the previous year same quarter. In FY 2024, the growth rate moderated to 6.47% in March quarter against the previous two quarter as government went slow on capital spending amidst the 2024 general election while it observed an improvement in Q1 FY 2025 by growing at 7.47% against 6.47% in the previous quarter. Still, the growth rate remained lower compared to the same quarter in the previous year. The GFCF to GDP ratio measured 31.91% in Q3 FY 2025.

Private Consumption Scenario





Sources: MOSPI

Private Final Expenditure (PFCE) a realistic proxy to gauge household spending, observed growth in FY 2025 as compared to FY 2024. However, quarterly data indicated some improvement in the current fiscal as the growth rate improved over the corresponding period in the last fiscal.

2.5 Inflation Scenario

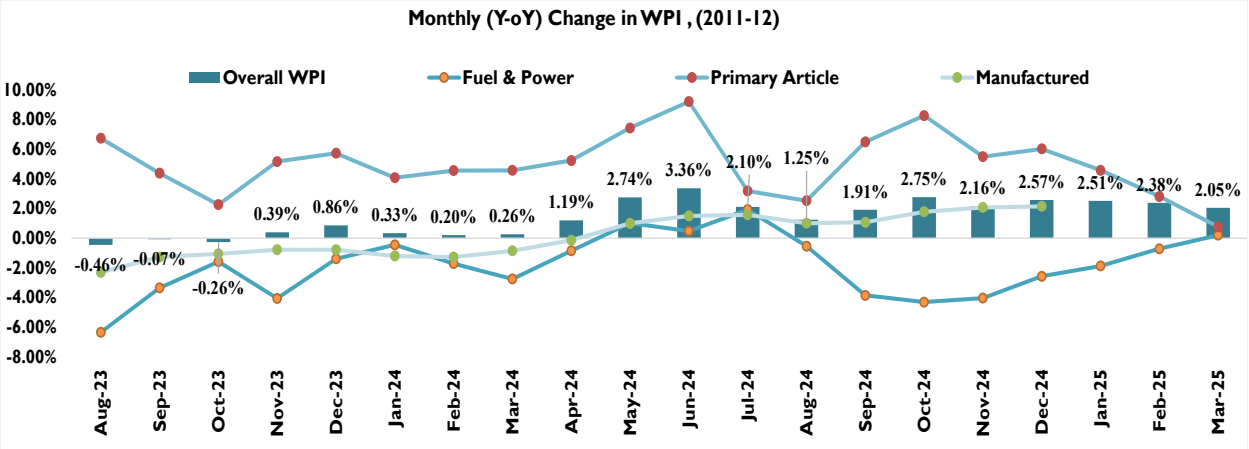
The inflation rate based on India's Wholesale Price Index (WPI) exhibited significant fluctuations across different sectors from August 2023 to March 2025. The annual rate of inflation based on all India Wholesale Price Index (WPI) number is 2.05% (provisional) for the month of March 2025 (over March 2024). Positive rate of inflation in March 2025 is primarily due to increase in prices of manufacture of food products, other manufacturing, food articles, electricity and manufacture of textiles etc.

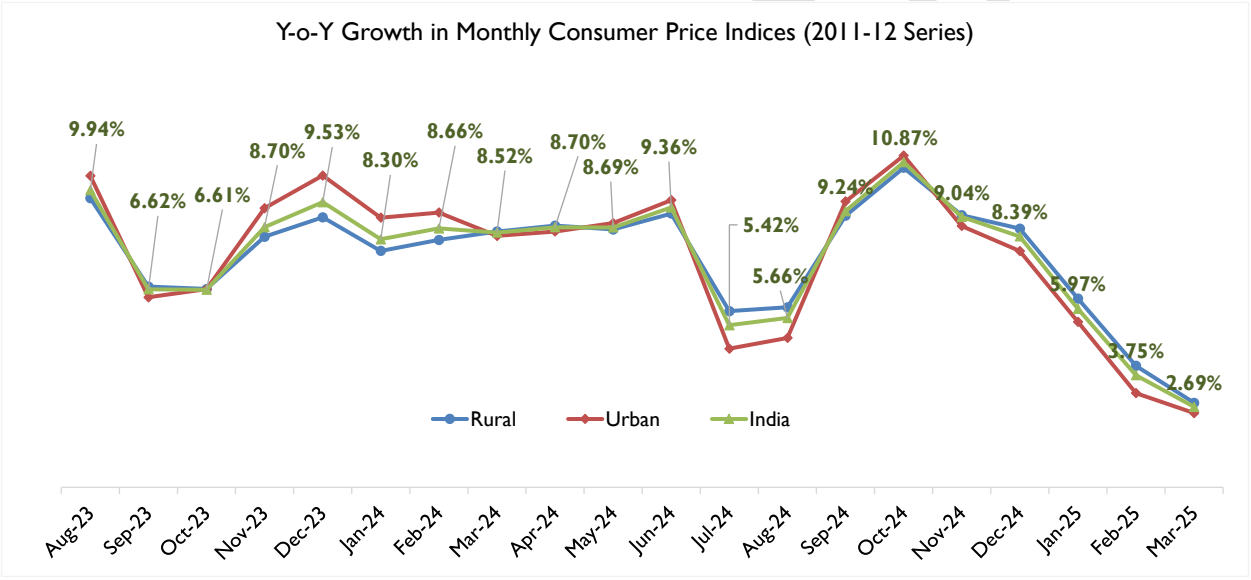
By March 2025, Primary Articles (Weight 22.62%), The index for this major group decreased by 1.07% to 184.6 (provisional) in March 2025 from 186.6 (provisional) for the month of February 2025. Price of crude petroleum & natural gas (-2.42%), non-food articles (-2.40%) and food articles (-0.72%) decreased in March 2025 as compared to February 2025. The price of minerals (0.31%) increased in March 2025 as compared to February 2025.

Moreover, power & fuel, the index for this this major group decreased by 0.91% to 152.4 (provisional) in March 2025 from 153.8 (provisional) for the month of February 2025. Price of electricity (-2.31%) and mineral oils (-0.70%) decreased in March 2025 as compared to February 2025. The price of coal remained same as in the previous month.

Furthermore, Manufactured Products (Weight 64.23%), the index for this major group increased by 0.42% to 144.4 (Provisional) in March 2025 from 143.8 (Provisional) for the month of February, 2025. Out of the 22 NIC two-digit groups for manufactured products, 16 groups witnessed an increase in prices, 5 groups witnessed a decrease in prices and 1 group witnessed no change in prices. Some of the important groups that showed month-over-month increase in prices were manufacture of basic metals; food products; other transport equipment; other manufacturing and machinery and equipment etc. Some of the groups that

witnessed a decrease in prices were manufacture of textiles; chemicals and chemical products; computer, electronic and optical products; printing and reproduction of recorded media and furniture etc in March 2025 as compared to February 2025.

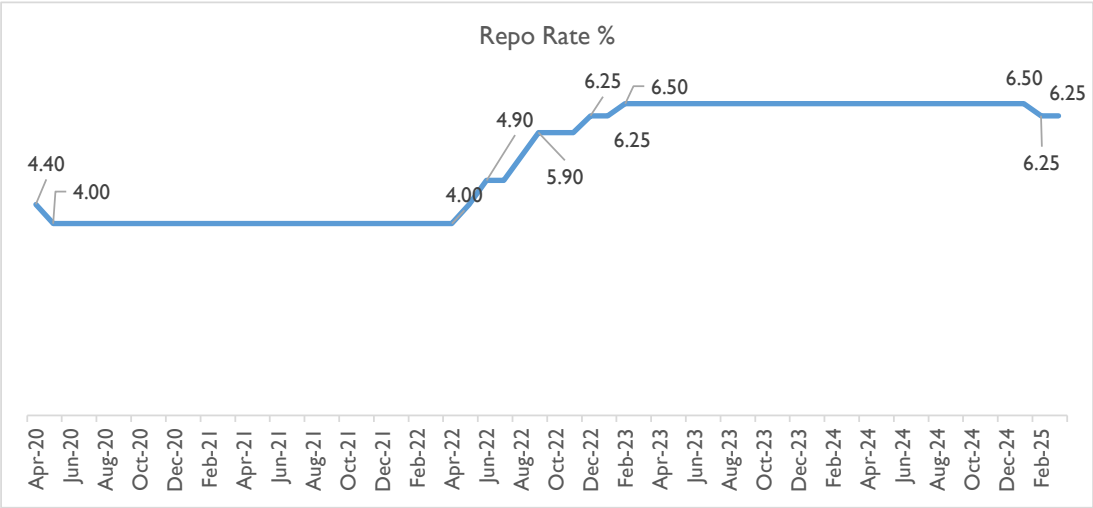




Source: MOSPI, Office of Economic Advisor

Retail inflation rate (as measured by the Consumer Price Index) in India showed notable fluctuations between August 2023 and March 2025. Overall, the national CPI inflation rate increased to 9.94% in August 2023 but moderated to 2.69% by March 2025, indicating a gradual easing of inflationary pressures across both rural and urban areas. Rural CPI inflation peaked at 9.67% in August 2023, declining to 2.82 % in March 2025.

Urban CPI inflation followed a similar trend, rising to 10.42% in August 2023 and then dropping to 2.48% in March 2025. CPI measured above 6.00% tolerance limit of the central bank since July 2023. As a part of an anti-inflationary measure, the RBI has hiked the repo rate by 250 bps since May 2022 and 8 Feb 2023 while it held the rate steady at 6.50 % till January 2025. In February, RBI reduced the repo rate for the first time in the last 5 year by 25 basis point to 6.25% from 6.50% previously.



Sources: CMIE Economic Outlook

2.6 Growth Outlook

India's H1 FY2024-25 GDP slowdown is cyclical, influenced by credit tightening and delayed fiscal spending, but strong fundamentals should drive growth in the latter half. The continuity of the NDA government supports ongoing reforms, including labour and land reforms, and efforts to control retail inflation by managing food prices. Inflation eased to 5.5% in November 2024, but risks from high food prices and geopolitical tensions remain. Rural demand has been resilient due to favourable monsoons and agricultural output, while urban demand faces pressure.

Externally, global geopolitical tensions, including the Gaza conflict, pose risks to global stability. The Indian rupee weakened in October 2024 but outperformed its peers, supported by RBI interventions and high FX reserves. Despite this, external pressures, including US monetary policy, will continue to strain the rupee in the near term.

India's projected GDP growth for CY 2026 is 6.3%, the fastest among major emerging markets, and is expected to maintain this growth rate through 2030. Inflation is expected to slow, with improvements in infrastructure, digital technology, and ease of doing business supporting long-term growth. The Union Budget 2025-26 also targets a reduced fiscal deficit of 4.4% (lower than the revised estimate of 4.8% of GDP in 2024-25), highlighting India's capacity to grow while adhering to fiscal goals. Capital expenditure has been significantly boosted, projected at 3.4% of GDP (INR 11.1 trillion) for FY2025-26, the highest in 21 years. Investments in port connectivity and commodity corridors aim to enhance manufacturing competitiveness and achieve export targets.

With a focus on stimulating demand, driving investment and ensuring inclusive development, the budget introduces measures such as tax relief, increased infrastructure spending and incentives for manufacturing and clean energy. These initiatives aim to accelerate growth while maintaining fiscal discipline, reinforcing India's long-term economic resilience. The expansion of tax relief i.e. zero tax liability for individuals earning up to INR 12 lacs annually under the new tax regime is expected to strengthen household finances and, consequently, boost consumption.

3. Overview of Energy Sector

The global energy sector is entering a transformative phase, shaped by growing populations, rising consumption, energy security concerns, and the urgent need to address climate change. The world's population is expected to reach around 8.5 billion by 2030 and 9.7 billion by 2050, with much of this growth occurring in regions like Africa, India, and Southeast Asia driving a significant increase in energy demand, particularly in emerging markets. While demand remains relatively stable in Organization for Economic Cooperation and Development (OECD) countries, rapid growth is evident in developing regions such as India, Southeast Asia, Africa, and the Middle East.

The energy landscape is evolving with dynamic markets and shifting consumption patterns. Governments and institutions are under pressure to ensure reliable, affordable, and sustainable energy supply. The COP28 commitments to limit global warming to below 1.5°C reinforce the need for a low-carbon transition. In 2023, global energy markets began to stabilize following the 2022 energy crisis, with declining natural gas prices, especially in Europe. Global energy demand rose by 2.1%, but is expected to slow to 0.7% annually through 2030, with growth concentrated in emerging economies.

India plays a crucial role in this evolving landscape. As one of the largest and fastest-growing energy consumers, India relies heavily on coal but is also expanding its use of oil, natural gas, nuclear energy, hydropower, and renewables like solar and wind. The Indian government is actively promoting renewable energy to meet increasing demand and environmental goals, with oversight by multiple ministries and state-level departments.

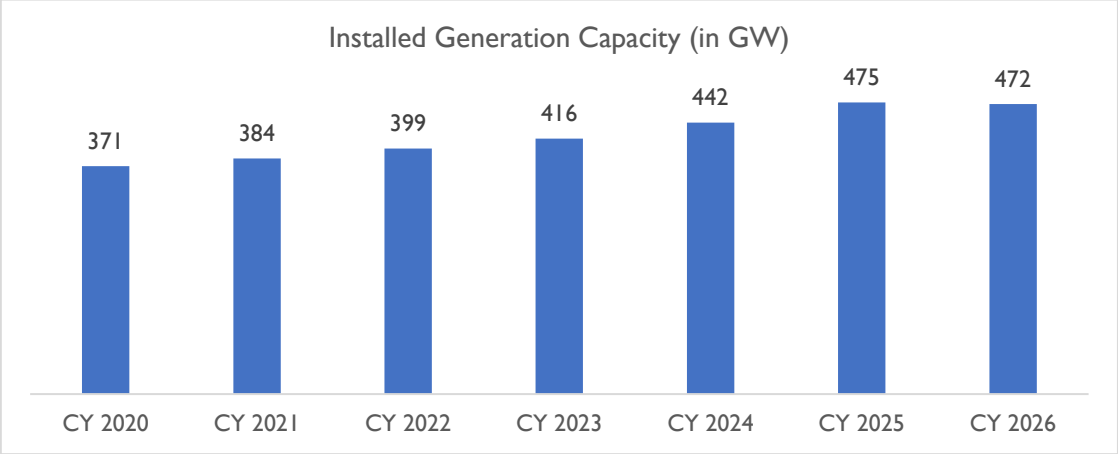
The joint Modi-Trump statement marks a strategic pivot toward fossil fuel cooperation, with Trump announcing increased U.S. oil and gas exports to India aligned with his "Drill, Baby, Drill" agenda. Modi emphasized energy security and diversification to reduce dependency. The statement also included collaboration on nuclear energy, particularly small modular reactors (SMRs), offering economic and technological benefits for both nations.

While the focus shifted away from previous clean energy commitments under the Strategic Clean Energy Partnership (SCEP), climate efforts were not entirely dismissed. Initiatives like the U.S.-India partnership with Indian Railways targeting net-zero emissions by 2030 were acknowledged. However, Trump's reiteration of the U.S. withdrawal from the Paris Agreement signals a continued prioritization of fossil fuels.

The move raises concerns about global emissions, as oil and gas account for a significant share of CO_2 emissions. Nevertheless, the agreement offers economic and geopolitical opportunities, with enhanced trade, technological collaboration, and energy innovation. Ultimately, the statement reflects a balancing act between energy security and environmental sustainability, strengthening bilateral ties while potentially challenging global climate goals

3.1 India's Energy Sector: Historical Investments and Future Growth Forecast

India's power sector has undergone substantial growth and transformation over the last several years, driven by a combination of government policies, technological advancements, and a strong push toward sustainable energy source. Renewable energy sources, such as solar and wind, has started playing an increasingly prominent role in the country's energy mix. Although, traditional sources like coal and gas continue to be a significant part of the energy landscape, their share is gradually decreasing. This shift represents India's commitment to enhancing energy security, promoting environmental sustainability, and meeting international climate targets.



Source: Central Electricity Authority of India & National Power Portal, GW - Giga Watt

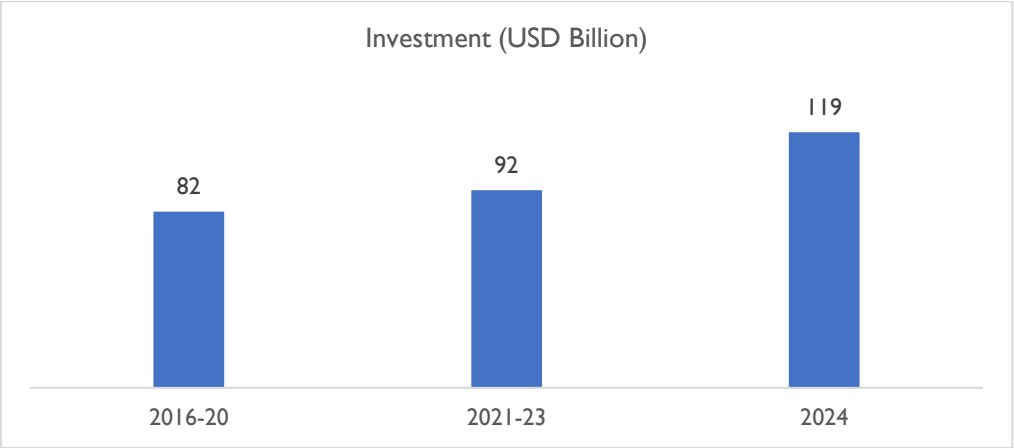
India's power sector has seen impressive growth, from 371 GW in 2019 to a projected 441 GW by 2025. The increase in capacity comes from both traditional and renewable energy sources, with a noticeable shift towards a cleaner, greener energy mix. The push for renewable energy has been a key driver, supported by government policies, technological advancements, and international climate goals.

The rising investments in energy capacity expansion are being driven by both government initiatives and private sector engagement, which are essential for meeting India's growing energy needs, achieving sustainability targets, and ensuring long-term energy security.

Over the last 5 years, India's energy sector has seen significant investments which is the renewable energy sector in India received a record investment of **USD 14.5 billion in FY 2022**, marking a 125% increase compared to the previous year. Between 2019 and 2024, India added approximately 18.48 GW of renewable energy capacity. Between **April 2020 to September 2024**, the renewable energy sector attracted ~ **USD 20 billion** in Foreign Direct Investment (FDI).

Primarily in expanding renewable energy capacity, with a strong emphasis on solar power. Government initiatives such as the "National Solar Mission" and "Production Linked Incentive (PLI)" schemes have played a key role in driving this growth. As a result, the country has witnessed a substantial increase in installed renewable energy capacity, with the Ministry of New and Renewable Energy (MNRE) reporting notable expansion in both solar and wind power generation.

Energy sector investments over the past years in India:



Source: D&B Research

Notable Private Sector Investments:

- **Reliance Industries** has committed USD 10 billion to develop its green energy portfolio.
- **Hero Future Energies** plans to invest USD 20 billion over the next six years to increase its renewable energy capacity from 1.9 GW to 30 GW by 2030.
- **Total Energies** invested USD 444 million in a 1.15 GW portfolio of solar power projects in Gujarat in partnership with Adani Green Energy Limited (AGEL).
- **DEG** plans to more than double its investments in India to USD 1 billion, focusing on energy and infrastructure projects, particularly in renewable energy, green hydrogen, and power transmission.

International Collaborations

TotalEnergies and Adani Green Energy Limited (AGEL): TotalEnergies has strengthened its partnership with Adani Green Energy Limited (AGEL) through a new 50:50 joint venture (JV). TotalEnergies invested **USD 444 million** to acquire a 50% stake in AGEL's 1,150 MWac (1,575 MWp) solar projects located in Khavda, Gujarat. The electricity generated will be sold through Power Purchase Agreements (PPAs) with the Solar Energy Corporation of India (SECI) and on the wholesale market. This collaboration supports AGEL's goal of achieving 50 GW of renewable power capacity by 2030. AGEL will manage the operation, maintenance, and construction of the projects5.

DEG's Investment Plans: DEG, a unit of German state lender KfW, plans to more than double its investments in India to USD 1 billion, focusing on energy and infrastructure projects, particularly in renewable energy, green hydrogen, and power transmission.

Growth Forecast: India's Energy Sector:

India's energy sector is witnessing remarkable growth, driven by ambitious government policies and significant investments in renewable energy. As of January 2025, the country's non-fossil fuel energy capacity has surged to 217 GW, with renewable sources contributing around 209 GW. Solar energy has seen a steep rise—growing from

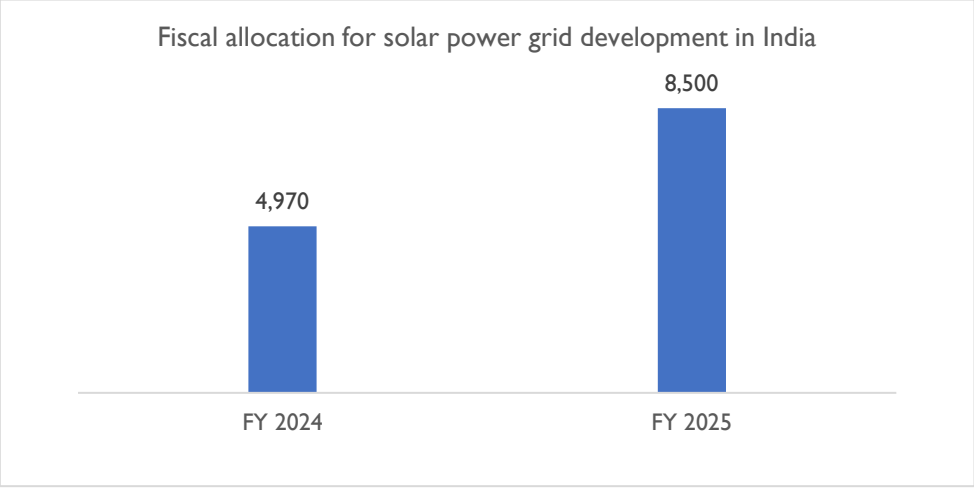
just 2.8 GW in 2014 to an estimated 100 GW in 2025, now accounting for approximately 46% of the non-fossil fuel capacity. This reinforces solar energy's role as the cornerstone of India's clean energy transition

According to the International Energy Agency (IEA), India's electricity generation is expected to grow significantly, with forecasts showing 1.6 times increase from 2021 to 2030, driven by strong economic activity and a growing renewable energy sector, making India one of the fastest growing energy markets globally; with most of this new demand expected to be met by renewables like solar power.

Due to the rising energy demand of energy sector, the Indian government has planned a significant expansion of renewable energy capacity. From the fiscal year 2023-24 to 2027-28, the country aims to add 50 GW of renewable energy capacity each year. This initiative is part of a broader strategy to achieve a **total installed capacity of 500 GW from non-fossil fuel sources by 2030**. The plan focuses on increasing solar, wind, hydro, and bioenergy capacity to reduce dependence on conventional fossil fuels and support the transition to a cleaner energy mix. This large-scale expansion aligns with India's long-term sustainability goals and commitment to reducing carbon emissions.

Further, by December 2024, India's total installed renewable energy capacity reached 209.44 GW, marking a 15.84% increase from the previous year, reflecting the nation's commitment to clean energy. With India's primary energy demand expected to nearly double to 1,123 million tonnes of oil equivalent by 2040, in line with a projected GDP growth to **USD 8.6 trillion,** the country is preparing for a massive scale-up in energy infrastructure.

In the fossil fuel sector, India's refining capacity has expanded from 215.1 MMTPA to 256.8 MMTPA over the past decade and is set to reach 309.5 MMTPA by 2028. Additionally, the Exploration and Production (E&P) sector is projected to offer investment opportunities worth **USD 100 billion by 2030**, according to Minister of Petroleum & Natural Gas, Mr. Hardeep Singh Puri.

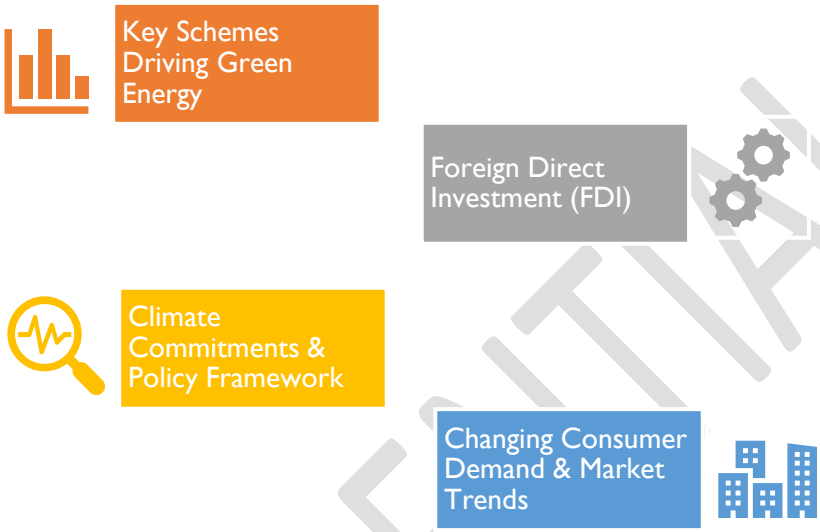


Source: D&B Research

Recognizing the need for infrastructure expansion, the Union Budget 2025–26 allocated INR 1,500 crore under the programme component for solar power grid development a notable reduction from the INR13,000 crore allocated in the Revised Budget 2024 25. While this marks a shift in short-term fiscal priorities, India's broader commitment to clean energy remains strong. Leading Indian conglomerates have announced investment plans totalling USD 800

billion (₹67.42 lakh crore) across green hydrogen, renewable energy, semiconductors, and electric vehicles (EVs), reinforcing the nation's long-term vision for a sustainable and resilient energy future.

The country's ethanol blending rate with petroleum reached an estimated **11.5% in 2023** and is on track to achieve **20% blending by FY 2026**. Additionally, India has several upcoming refinery and petrochemical projects, including expansion initiatives for existing refineries, with plans to **double its refining capacity from 5 million barrels per day to 10 million barrels per day by FY 2030E**.



Key Schemes Driving Green Energy: Initiatives such as the National Green Hydrogen Mission, PM-KUSUM, PM Surya Ghar, and the Production-Linked Incentive (PLI) Scheme for Solar PV Modules are designed to accelerate the adoption of clean energy. Investments in modernizing smart grids and developing energy storage solutions are crucial for managing the intermittent nature of renewable energy sources

Foreign Direct Investment (FDI) in the Energy Sector: The allowance of 100% FDI through the automatic route for renewable energy projects is attracting global investors to India. Key international stakeholders are investing in projects related to solar energy, wind power, green hydrogen, and battery storage, thereby strengthening India's clean energy sector.

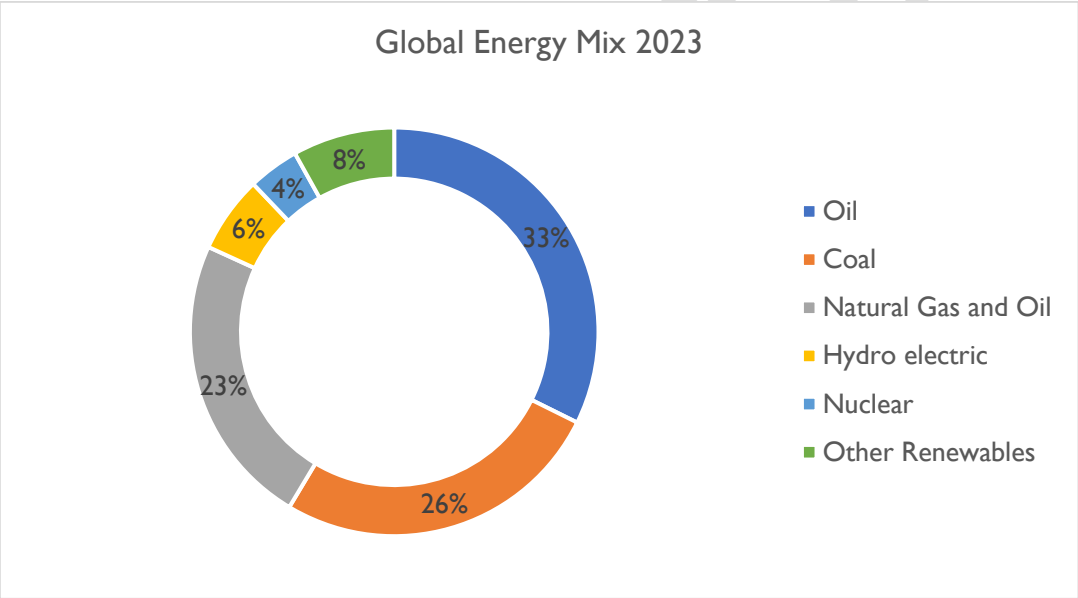
Climate Commitments & Policy Framework: India has pledged to reduce its carbon intensity by 45% by 2030, aiming to cut the emissions intensity of its GDP by 45% compared to 2005 levels. Policies such as carbon trading, renewable purchase obligations (RPOs), and incentives for emission reduction are expediting the transition to cleaner energy sources. India is promoting the adoption of green hydrogen to decarbonize industries and reduce dependence on fossil fuels.

Changing Consumer Demand & Market Trends: Increasing energy demand, urbanization, and greater environmental awareness are driving industries and consumers toward adopting solar rooftops, electric mobility, and energy-efficient solutions. The promotion of ethanol blending (with a target of 20% by 2025) and the increasing adoption of electric vehicles (EVs) are reshaping patterns of fuel consumption.

The swift expansion of renewable energy, green hydrogen, electric mobility, and energy storage is transforming India's energy landscape, decreasing dependence on fossil fuels and strengthening energy security. Backed by favourable FDI policies, carbon pricing strategies, and large-scale infrastructure advancements. Moving forward, sustained investments, technological advancements, and policy-driven initiatives will be crucial in ensuring a resilient, cost-effective, and sustainable energy ecosystem, paving the way for India's transition to a low-carbon economy.

3.2 Key Energy Sources & Contribution to Global Energy Consumption

The Asia-Pacific region, led by China, India, Indonesia, and Australia, contributed nearly 80% of global coal production, with coal consumption surpassing 164 exajoules (EJ) for the first time. China remained the largest coal consumer (56%), while India's usage exceeded that of Europe and North America combined. Oil demand rebounded sharply in 2023, driven by China's post-COVID reopening. Renewables accounted for 14.6% of global primary energy, and together with nuclear, made-up 18%, with solar and wind at 8%, hydro at 6%, and nuclear at 4%.



Source: International Energy Agency (IEA) Here's a breakdown of the global energy mix in 2023:

Oil remains the dominant energy source, constituting approximately one-third of global energy consumption, and is essential for transportation, industrial processes, and heating. Despite the push for electric vehicles and alternative fuels, oil's high energy density and established infrastructure maintain its dominance. Coal stands as the second-largest energy source, primarily used for electricity generation and industrial sectors like steel and cement production. Despite developed nations phasing out coal due to its high carbon emissions, it remains a primary energy source in countries such as China and India, where there are increasing demands for electricity and industrial production.

Natural gas is a significant part of the global energy mix because it has lower carbon emissions compared to coal and oil. It is used for electricity generation, heating, and as an industrial raw material. Liquefied Natural Gas (LNG) has also become important, facilitating energy transport to regions that have limited natural gas reserves. Hydropower is a well-established renewable energy source, providing a stable electricity supply, especially in regions

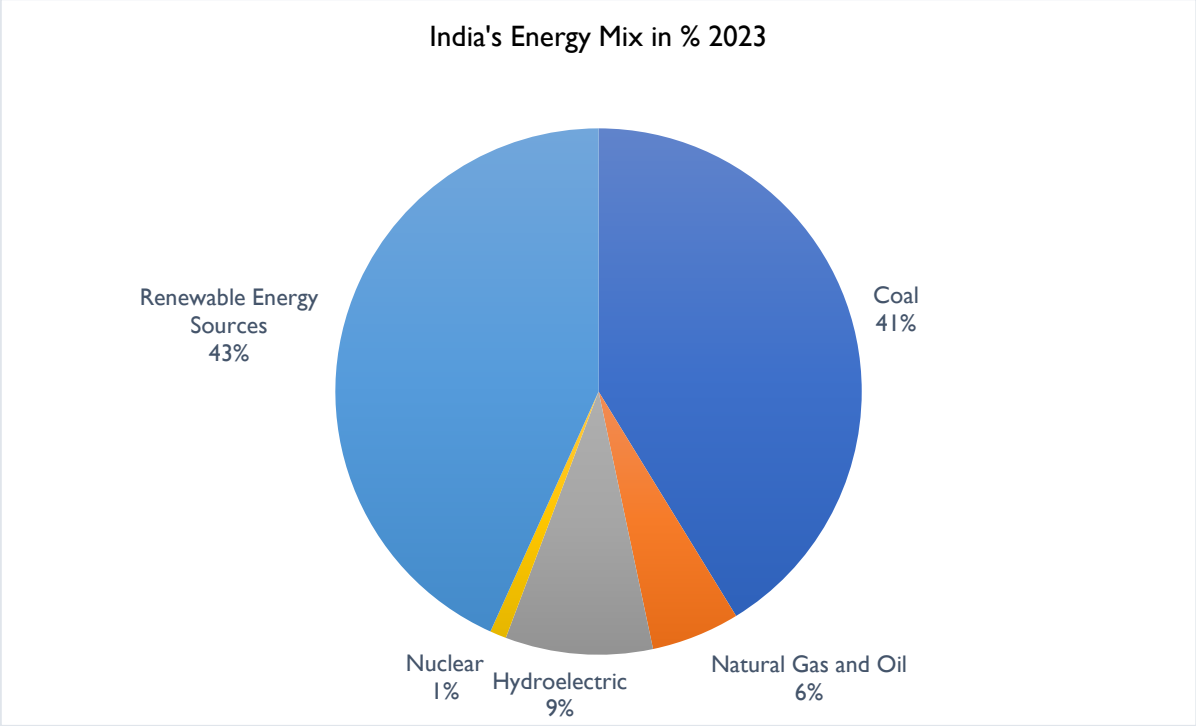
with plentiful water resources. However, large dam construction can lead to habitat destruction and community displacement, raising environmental and social concerns.

Nuclear energy, while contributing a smaller portion, is a crucial source of low-carbon electricity that provides a stable and continuous power supply, unlike weather-dependent sources like solar and wind. However, concerns about radioactive waste, safety, and high initial costs have limited its growth in some countries. Other renewables, including solar, wind, biomass, and geothermal energy, are expanding due to technological advances, lower costs, and government support. Wind and solar are playing an increasingly significant role in electricity generation, especially in Europe, the US, and China.

The global energy landscape is marked by the continued dominance of coal and oil, particularly in Asia, despite a growing shift toward renewables. While coal consumption reached record highs, driven largely by China and India, oil demand rebounded with the easing of COVID-19 restrictions. At the same time, renewables and nuclear energy made steady gains, together for global primary energy consumption. This highlights the ongoing energy transition, where fossil fuels remain essential, but cleaner energy sources are gradually expanding their share.

3.3 Overview of Indian Energy Mix: Contribution by Key Energy Sources.

India's energy mix is undergoing a gradual transformation, with renewable energy capacity now nearly matching coal. While fossil fuels, especially coal, still dominate, the government's aggressive push for renewables is reflected in the growing share of clean energy sources. Hydropower remains a significant contributor, providing stable electricity, whereas natural gas and nuclear energy continue to play smaller roles**.** Although natural gas is cleaner than coal, its share remains relatively low; the government aims to increase this to 15% by 2030 through infrastructure expansion and investments in liquefied natural gas (LNG).



Source: D&B Research

India's renewable energy sector has experienced substantial growth, reaching a total capacity of 209.44 GW, which constitutes 43% of the nation's overall installed power capacity. **Solar power** is a leader, accounting for 90.76 GW, driven by governmental initiatives such as the Solar Mission and rooftop solar programs. **Wind power** contributes significantly with 47.36 GW, supported by favourable wind conditions, especially in Tamil Nadu, Gujarat, and Maharashtra. **Bio power** accounts for 11.35 GW, utilizing biomass and waste-to-energy projects, thus bolstering India's sustainability objectives by using agricultural and industrial waste. **Small hydro power**, with a capacity of 5.10 GW, is essential for decentralized electricity generation, particularly in hilly and rural regions. Collectively, these renewable energy sources strengthen India's energy security, decrease reliance on fossil fuels, and support its commitments to combating climate change.

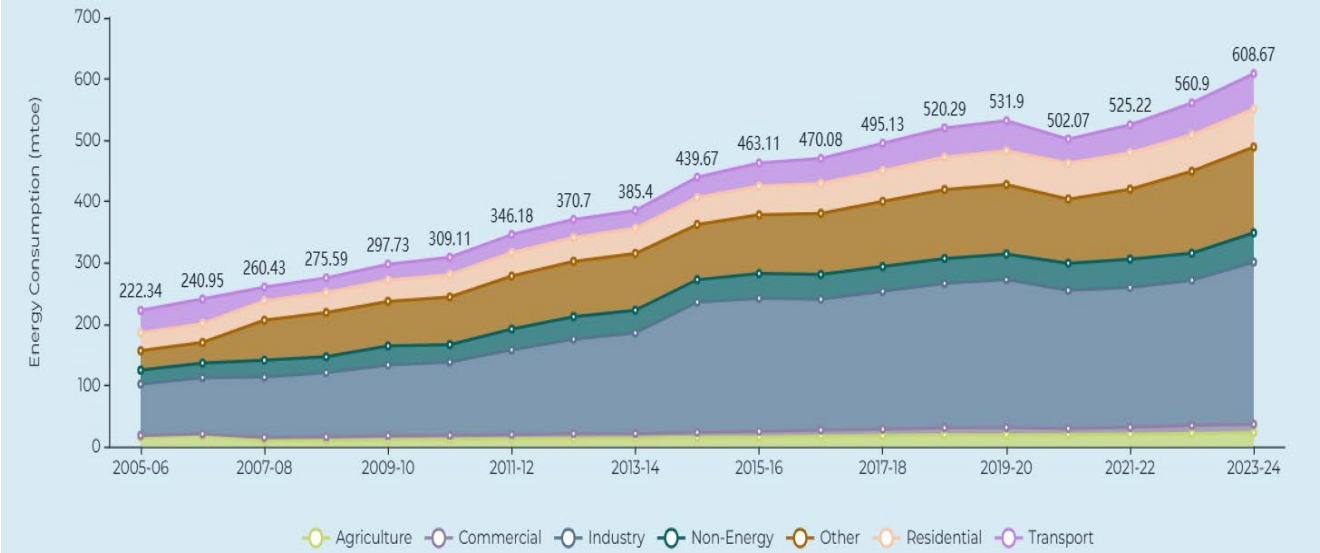
Nuclear energy accounts for a small fraction of India's power generation but offers a stable, low-carbon source of electricity, with expansion plans in place to increase nuclear capacity, though high costs and regulatory challenges slow its growth.

India's energy transition is evident in the increasing share of renewables, aligning with its climate goals and sustainability commitments. However, the high dependence on coal underscores the challenges of achieving a fully green energy transition. Future policies and investments will determine how quickly India can shift toward a cleaner, more sustainable energy mix while ensuring energy security and economic growth.

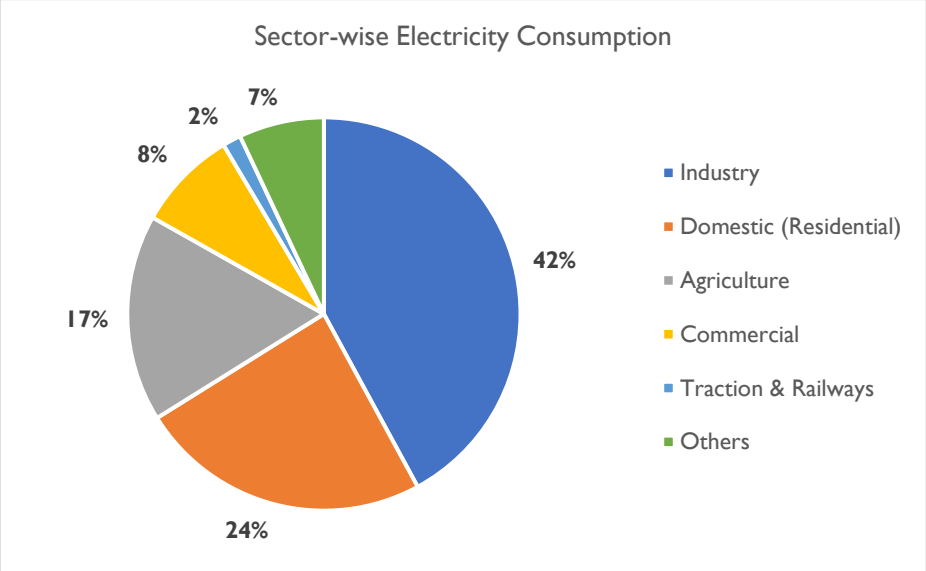
3.4 Energy Consumption Pattern in India: Consumption by Key Sectors

The country's current energy consumption is primarily concentrated in domestic cooking and lighting, agriculture, transport, and industrial sectors. India's energy mix comprises various resources, including renewables, with coal being the dominant source, followed by petroleum and traditional biomass. In the fiscal year 2022-23, India's **per capita electricity consumption** was recorded at **1,014.83 kilowatt-hours (kWh)**. As of **February 2024**, the country's **total installed power capacity** reached **434,195 MW**.

Sector-wise energy consumption in India till 2024:



Source: National Institution for Transforming India (NITI Aayog)



Source: Energy Statistics India

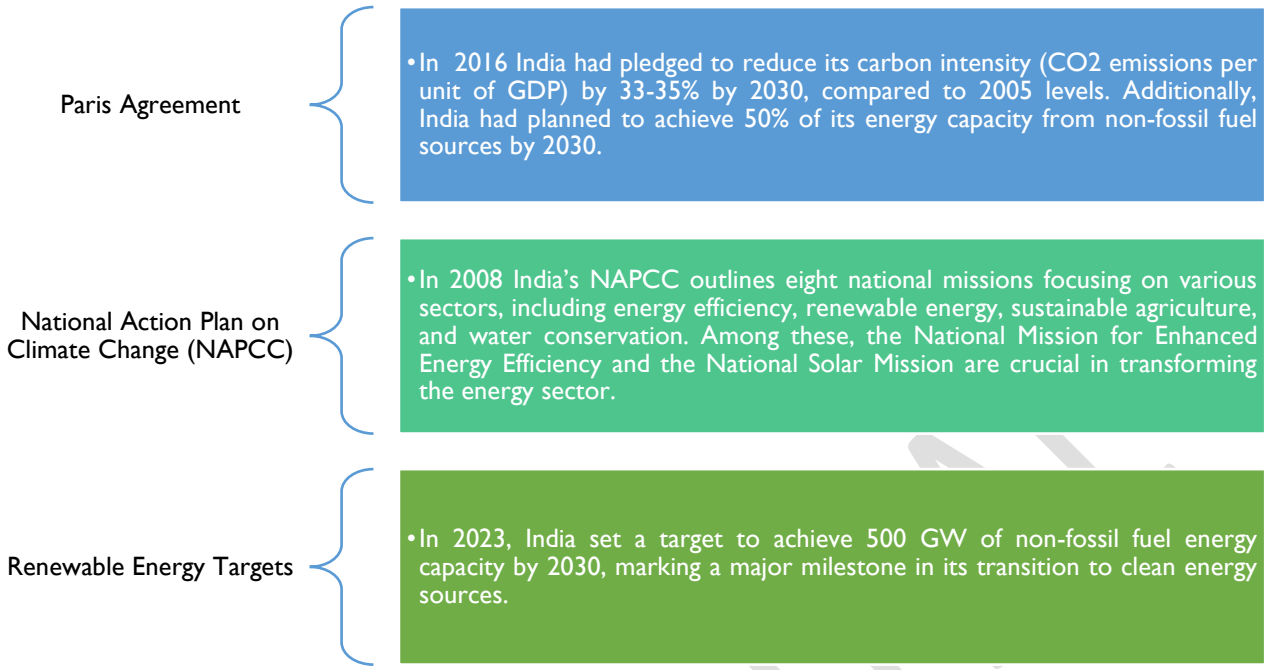
In India, the industrial sector leads electricity consumption at 41%, with iron and steel being highly energy intensive. The domestic sector follows with 26% and the highest growth rate, while agriculture accounts for 18%. Commercial use stands at 8.29%, railways at 1.51%, and other sectors like government and defence make up 5.6%. Key challenges include limited electricity access for about a quarter of the population, heavy reliance on energy imports, and stark urban-rural energy use disparities.

3.5 Climate Change Initiatives in India & its Impact on India's Energy Landscape

India's energy sector is at a crossroads, balancing the need for economic growth with environmental sustainability. The country's ambitious renewable energy targets and policy initiatives reflect a strong commitment to mitigating climate change. However, challenges such as continued reliance on fossil fuels and the need for workforce upskilling must be addressed to achieve a sustainable and inclusive energy transition. India's goal is to achieve net-zero carbon emissions by 2070.

India has been actively implementing climate change initiatives to transition towards a more sustainable energy future. These include expanding renewable energy capacity, particularly solar and wind power, aiming for 500 GW of non-fossil fuel energy by 2030. The country is also pushing for greater energy efficiency, promoting electric vehicles (EVs), and enhancing carbon capture technologies. These efforts are reshaping India's energy consumption patterns by reducing reliance on coal, promoting cleaner energy sources, and increasing the share of renewables in the energy mix. As a result, India's carbon emissions are expected to gradually decrease, though challenges remain due to growing energy demands and the need for technological advancements.

India's Commitment to Climate Change Mitigation:



Transition to Renewable Energy: The growing investment in renewable technologies and grid integration has made renewable energy more feasible and reliable in India, helping to reduce dependence on coal and other fossil fuels. With a focus on rural electrification, India is promoting decentralized renewable energy solutions like solar-powered microgrids, which are aiding in reducing energy poverty while advancing sustainable development goals.

Phasing Out Fossil Fuels: While coal remains a critical part of India's energy mix due to its affordability and availability; India has committed to phasing out inefficient and polluting coal plants. The country is also looking to increase the efficiency of existing coal plants through carbon capture and storage (CCS) technologies. India is exploring the use of carbon pricing mechanisms, such as carbon taxes or cap-and-trade systems, to reduce reliance on fossil fuels. Additionally, energy subsidies, particularly for coal, are being reformed to encourage more sustainable energy consumption patterns.

Insights on India-United States (US) Energy Trade Partnership 2025: Recent joint statement between Indian Prime Minister Narendra Modi and U.S. President Donald Trump signals a notable shift in the Indo-US energy partnership. This announcement follows a series of meetings and agreements aimed at bolstering bilateral relations, particularly within the energy sector. The renewed emphasis on fossil fuels marks a clear divergence from the "clean energy transition" initiatives that characterized Modi's meeting with ex-President Biden in 2024.

Expected changes in Energy Mix in India: India's energy sector is on a transformative path towards sustainability, driven by proactive government policies, growing foreign direct investment (FDI), and the country's commitment to climate goals under international frameworks. By 2030, India aims to achieve 500 GW of installed non-fossil fuel capacity, significantly altering its energy mix.

Renewable energy especially solar and wind is expected to play an increasingly dominant role, substantially reducing India's reliance on coal and oil. While coal will remain critical in the near term, particularly for industrial use and base-load power generation, its share in the overall mix is projected to decline. The intermittent nature of renewables is being addressed through large-scale investments in battery storage systems and grid modernization initiatives, ensuring stability and reliability in power supply. This shift not only represents a move toward cleaner energy but also highlights India's strategic approach to energy security, environmental sustainability, and economic growth.

3.5.1 Global Climate Change Initiative: COP 29

COP 29 represents the 29th Conference of the Parties (COP) under the United Nations Framework Convention on Climate Change (UNFCCC). This annual global climate summit brings together world leaders, policymakers, scientists, and activists to deliberate and negotiate strategies for addressing climate change and advancing global climate action.

The COP 29 Presidency has officially launched the COP 29 Energy Initiatives, inviting endorsements for key pledges, including the COP 29 Global Energy Storage and Grids Pledge, the COP 29 Green Energy Zones and Corridors Pledge, and the COP 29 Hydrogen Declaration. Additionally, the Presidency highlights the critical link between climate change, conflict, and humanitarian needs through the Baku Call on Climate Action for Peace, Relief, and Recovery and the establishment of the Baku Climate and Peace Action Hub.

During a High-Level Roundtable on Green Energy, Hydrogen, and Global Energy Storage and Grids, the COP 29 Presidency officially launched three key energy initiatives, urging endorsements from Party and non-Party stakeholders. These initiatives aim to build on the outcomes of the first GS on renewable energy and hydrogen. The initiatives include:

- **COP 29 Global Energy Storage and Grids Pledge** – Endorsers commit to a collective goal of deploying 1,500 GW of energy storage globally by 2030, which is over six times the capacity of 2022. Additionally, they pledge to add or refurbish 25 million kilometres of grids by 2030, acknowledging the need for an additional 65 million kilometres by 2040.
- **COP 29 Green Energy Pledge: Green Energy Zones and Corridors** – Endorsers commit to developing green energy zones and corridors that will connect high-generation green energy sources with the communities that need them most. This will involve building larger intraregional and interregional interconnected power grids to enable cost-effective and secure electricity transmission over long distances.
- **COP 29 Hydrogen Declaration** – Endorsers pledge to scale up renewable, clean/zero-emission, and low-carbon hydrogen production while accelerating the decarbonization of existing hydrogen production from unabated fossil fuels. The initiative aims to significantly increase green hydrogen production from its current level of one million tonnes per year while reducing the 96 Mt of hydrogen currently produced from unabated fossil fuels.

- **COP 29 CCUS Policies, Finance, and Technology**- At COP 29, discussions on Carbon Capture, Utilization, and Storage (CCUS) will focus on scaling up global commitments, financing, and technological advancements. Strengthening policies within Nationally Determined Contributions (NDCs), increasing financial support through climate funds and carbon credits, and expanding CCUS infrastructure, including CO_2 transport and storage networks, will be key priorities. Advancements in direct air capture (DAC), bioenergy with carbon capture (BECCS), and CO_2-based products will be explored to enhance efficiency and cost-effectiveness.
- **COP 29 CCUS for Developing Nations and Industrial Decarbonization -** Developing nations will receive attention for technology transfer, capacity-building, and financial aid to integrate CCUS into their sustainable development goals (SDGs). Regulatory frameworks ensuring safe CO_2 storage, monitoring, and legal clarity will be discussed, alongside public awareness initiatives to address concerns. Industry participation, particularly in high-emission sectors like cement, steel, and oil & gas, will be emphasized to align CCUS with corporate net-zero strategies and global decarbonization efforts.
- **COP 29 CCUS Waste to Energy -** At COP 29, discussions on Waste-to-Energy (WTE) focused on its role in reducing landfill waste, cutting methane emissions, and supporting clean energy transitions. Key areas included policy enhancements, technological advancements, and green financing to scale up WTE projects, particularly in developing nations. Challenges like air pollution, public acceptance, and regulatory frameworks were addressed to ensure sustainable implementation. Emphasis was placed on capacity-building, technology transfer, and industry collaboration to integrate WTE into Nationally Determined Contributions (NDCs) and global net-zero strategies.

Key opportunities for **COP 29** to showcase progress in energy transitions and contribute to limiting global temperature rise include:

- Expanding energy storage and electricity grids, with a target of achieving 1,500 GW of energy storage capacity by 2030, while accelerating the development and modernization of electricity grids.
- Enhancing clean energy investment in developing economies, which requires a threefold increase in annual concessional funding, reaching USD 115 billion by 2030.
- Aligning the next round of Nationally Determined Contributions (NDCs) with the Global Stocktake (GS) outcomes, ensuring climate action is data-driven and effective.
- The International Energy Agency (IEA) expects global clean energy investment to exceed USD 2 trillion for the first time in 2024.

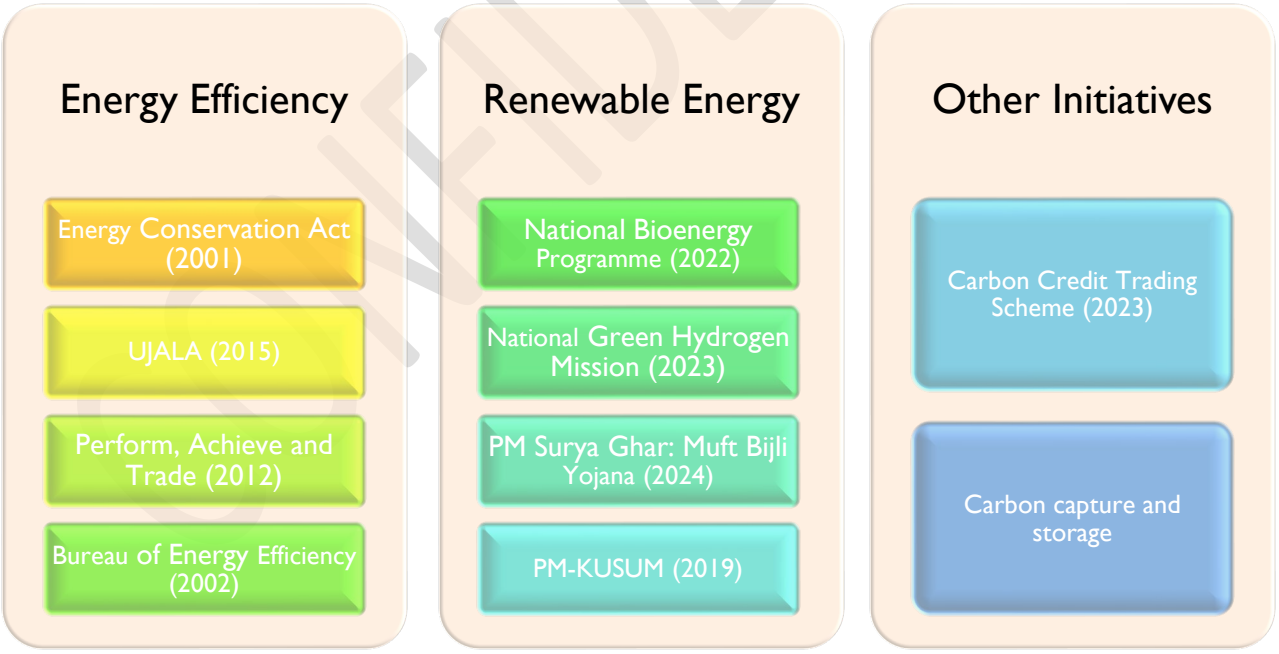
3.5.2 Regulatory Landscape: Clean Energy and Energy Generation

The Indian government has implemented several initiatives to promote clean energy and accelerate the transition towards a sustainable and low-carbon future. Programs like the National Solar Mission and PM-KUSUM aim to expand solar energy adoption, while the National Green Hydrogen Mission focuses on developing green hydrogen as an alternative fuel. The Renewable Energy Development Agency (IREDA) facilitates funding for clean energy projects, and the Production-Linked Incentive (PLI) scheme supports domestic manufacturing of solar PV modules and batteries.

Additionally, policies like the Energy Conservation Act and Perform, Achieve, and Trade (PAT) scheme drive energy efficiency across industries. To promote decentralized clean energy, the PM Surya Ghar: Muft Bijli Yojana aims to install rooftop solar panels in households. The government is also strengthening grid infrastructure through initiatives like the Green Energy Corridors, enabling seamless integration of renewable energy into the national grid. Furthermore, India is actively participating in global collaborations, such as the **International Solar Alliance** (ISA) and the **COP 29** Energy Initiatives, to scale up clean energy investments and innovation.

Climate Change Initiatives

India has implemented several climate change initiatives that have significantly influenced its energy consumption patterns and energy mix. These efforts aim to enhance energy efficiency, increase the share of renewable energy, and reduce greenhouse gas emissions.



Hence, India's energy initiatives focus on improving efficiency and expanding renewable energy. Key programs include the Energy Conservation Act, UJALA LED scheme, and PAT for energy efficiency, along with the National Bioenergy Programme, National Green Hydrogen Mission, and PM-KUSUM for renewable energy. Additionally, Carbon Credit Trading Scheme and Carbon Capture and Storage technology address emissions and climate change.

Renewable Energy Initiatives:

These initiatives aim to expand India's renewable energy capacity and transition toward cleaner energy sources.

- National Bioenergy Programme: Promotes bioenergy solutions like biogas and biomass power.
- National Green Hydrogen Mission: Supports the production and use of green hydrogen as an alternative fuel.
- PM Surya Ghar: Muft Bijli Yojana: A scheme to provide free electricity through solar power for households.
- PM-KUSUM: A program to encourage farmers to adopt solar-powered irrigation and reduce reliance on diesel.

Other Initiatives: These additional policies aim to mitigate climate change by regulating carbon emissions and adopting advanced technologies.

- Carbon Credit Trading Scheme: Establishes a carbon market to incentivize industries to reduce emissions.
- Carbon Capture and Storage (CCS): A technology-driven approach to capturing and storing CO_2 emissions from industries and power plants.

Impact on India's energy consumption pattern / energy mix

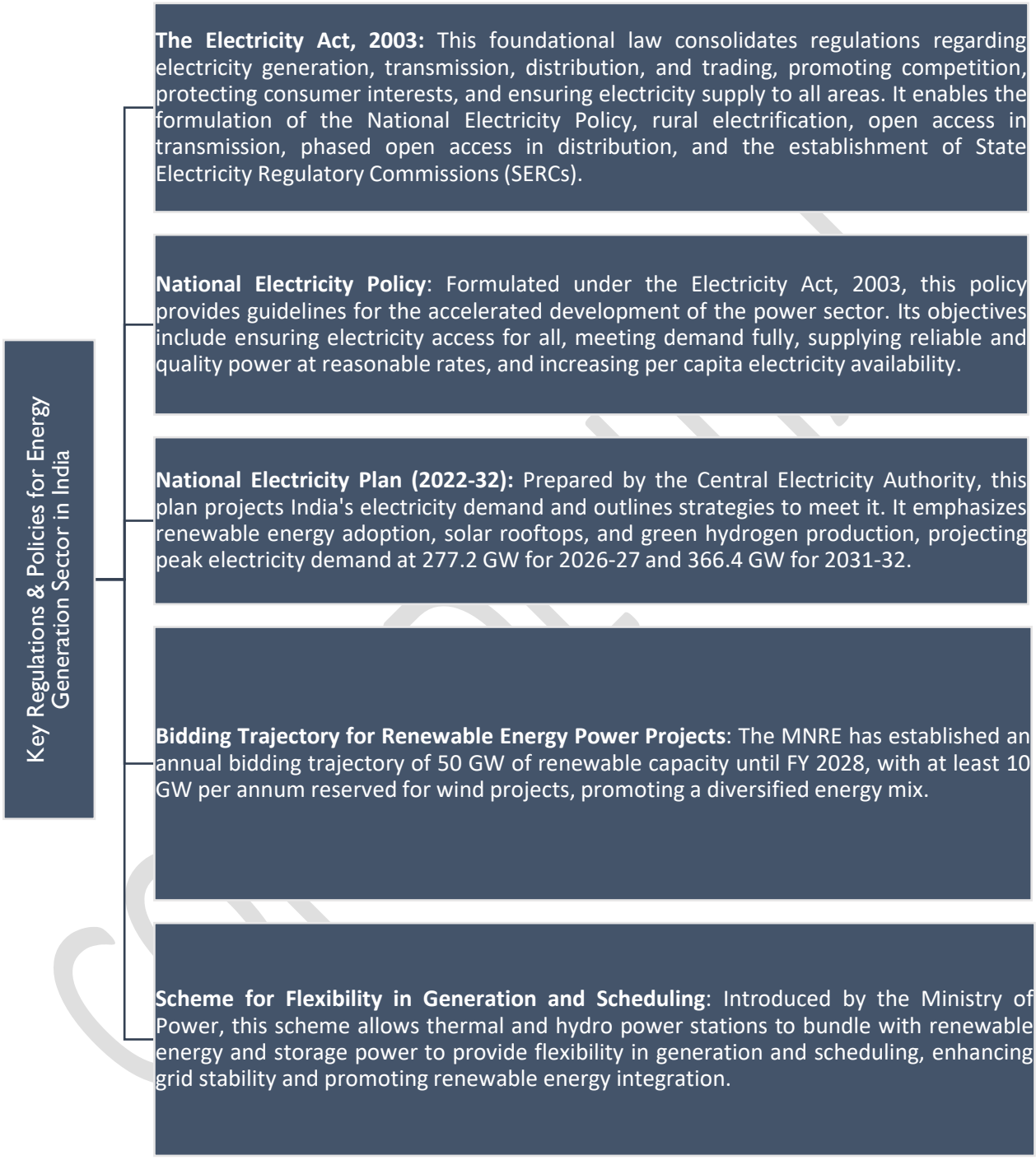
In 2021-22, energy efficiency initiatives in India led to substantial improvements, including energy savings of 44.43 million tonnes of oil equivalent (Mtoe) and a corresponding reduction of about 280.77 million tonnes of CO_2 emissions. India's renewable energy sector has also grown, with an installed capacity of approximately 209.44 GW as of August 2024 and plans to add 35 GW of solar and wind energy by March 2025.Additional context:

- **Energy Savings:** Energy savings from national schemes in FY 2023 resulted in 50.8 MTOE savings, equally divided between thermal and electrical savings. In the absence of energy efficiency measures, India's energy consumption in 2022-23 would have been 6.6% higher, equivalent to the energy demand of Tamil Nadu.
- **Economic Impact:** Energy efficiency initiatives have had a significant economic impact, with cost reductions of INR 1.84 lakh crore reported in FY 2023, about 1.1% of India's GDP.
- **Energy Intensity Reduction:** India's energy intensity decreased by 19.85% from 0.2801 Mega joules per rupee in FY 2013 to 0.2245 Mega Joules in FY 2022.
- **Renewable Energy Targets:** India is committed to reducing the emission intensity of its GDP by 45% by 2030 from 2005 levels and has increased its cumulative energy savings targets to 150 MTOE by 2030.

India's energy consumption landscape is undergoing a significant transformation, driven by both energy efficiency measures and the expansion of renewable energy sources. These efforts are not only leading to substantial energy savings and reduced carbon emissions but also contributing to economic growth and a decreased energy intensity. As India continues to pursue its ambitious renewable energy targets and implement energy-efficient practices, it is poised to achieve a more sustainable and secure energy future.

Key Regulations / Policies Impacting the Energy Generation Sector in India.

India's energy generation sector is governed by a framework of regulations and policies aimed at promoting sustainable development, enhancing energy security, and increasing the adoption of renewable energy source



Impact

- **Production-linked incentives (PLI):** PLI schemes for solar panel manufacturing and battery storage aim to boost domestic production and reduce reliance on imports.
- **Carbon pricing:** Carbon tax or cap-and-trade policies internalize the environmental damages caused by carbon dioxide emissions.

These policies collectively aim to transform India's energy landscape by promoting renewable energy adoption, ensuring efficient energy distribution, and meeting the country's growing energy demands sustainably. Other important aspects of India's energy policy include promoting the generation of renewable energy, enabling open access for consumers to choose their electricity supplier, and increasing penalties for non-compliance with regulations. The government is also focused on maximizing the production of green hydrogen and enhancing the cost-competitiveness of green hydrogen.

3.5.3 Expected Growth in Energy Demand in India (2030 Scenario)

India's energy demand is projected to grow significantly in the coming years, driven by rapid economic expansion and urbanization. The International Energy Agency (IEA) forecasts that India's natural gas demand will increase by nearly 60%, reaching approximately 103 billion cubic meters annually by 2030. To meet this rising demand, liquefied natural gas (LNG) imports are expected to double to around 65 billion cubic meters per year.

Electricity consumption is also set to rise, with an anticipated annual growth rate of over 6% until 2026, propelled by strong economic activity and increased adoption of air conditioning. In response, India is scaling up investments in renewable energy, aiming to achieve net-zero emissions by 2070. This ambitious goal requires an average annual investment of USD 160 billion across the energy sector through 2030, a threefold increase from current levels. These efforts underscore India's commitment to diversifying its energy mix and enhancing energy security.

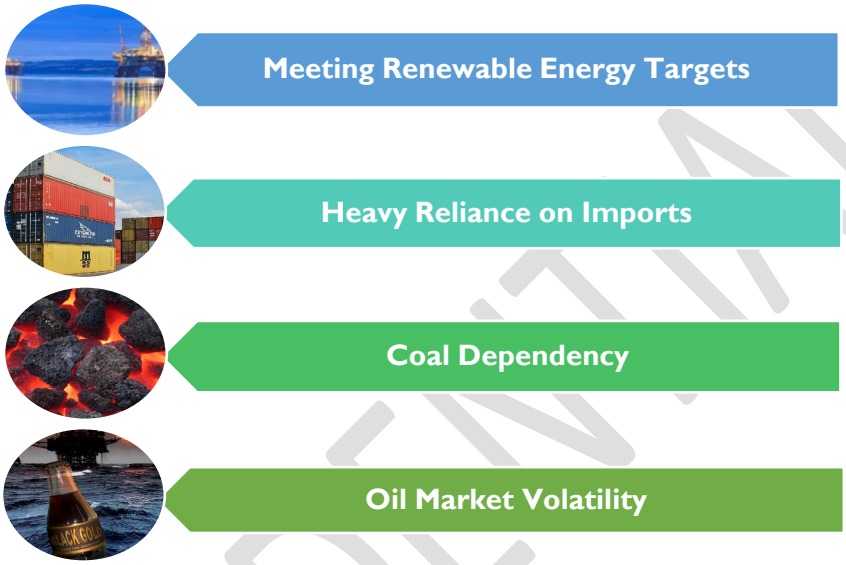
India's energy demand is projected to surpass domestic supply, accounting for 30% of global energy demand growth by 2035. Energy remains vital to India's development goals, including electrification and infrastructure expansion. While India will continue to rely on energy imports, particularly for fossil fuels, it also presents opportunities for energy efficiency solutions and renewable technologies.

In terms of key commodities, India will remain heavily dependent on oil and gas imports. Although it aims for long-term self-sufficiency in thermal coal, imports will be necessary in the medium term. India's ability to capitalize on these opportunities hinges on its reform trajectory. Balancing rapid energy transition, self-sufficiency, security, and climate commitments will be challenging, yet reflects its policy priorities. The political imperative to provide affordable electricity for all will significantly shape future reforms.

However, India's energy sector is marked by inefficient policies, supply constraints, and a lack of transparent pricing, which hinder investment. Distribution remains a major bottleneck, outweighing capacity issues. While political realities may result in gradual rather than sweeping reforms, India is actively working to address these challenges.

3.6 Key Threats & Challenges Facing Energy Sector.

In 2025, India's energy sector grapples with the dual challenge of meeting its rapidly growing demand while transitioning towards a more sustainable and cleaner energy future. The country continues to rely heavily on fossil fuels, particularly coal, which accounts for over 70% of its electricity generation, posing challenges to its net-zero commitments by 2070. Despite significant progress in renewable energy expansion, integrating variable power sources like solar and wind into the grid remains a technical and infrastructural challenge. Below are the major **Threats and Challenges faced by energy sector in India:**



Meeting Renewable Energy Targets

India is committed to its ambitious goal of 500 GW of renewable energy capacity by 2030. By March 2024, the country had installed approximately 209.4 GW of renewable energy capacity. Achieving the 2030 target requires an annual installation rate of around 50 GW, but in FY2024, India added just over 18 GW. To facilitate the integration of renewable energy, transmission schemes are being implemented in states like Rajasthan, Gujarat, Maharashtra, and Tamil Nadu. Initiatives such as the National Green Hydrogen Mission and PM-KUSUM aim to accelerate renewable energy capacity growth nationwide.

Heavy Reliance on Imports

India's energy sector is significantly challenged by its heavy reliance on crude oil imports, with over 80% of its crude oil sourced from foreign countries, making energy security a critical concern. In the first nine months of FY 2025, India's oil import dependency increased to 88.1%, compared to 87.5% in the same period the previous year. This reliance exposes India to the volatility of global oil prices, which can adversely affect its trade deficit, foreign exchange reserves, and inflation rate. In the first half of FY 2025, the crude oil import bill surged by 12%, reaching USD 71.3 billion. To mitigate this import dependence, the government is actively promoting domestic oil production, the use of biofuels and renewable energy sources, and improvements in energy efficiency. India's oil demand is projected to grow substantially in FY 2025. However, ample global oil supplies and slowing Chinese consumption may improve India's bargaining position with Gulf suppliers.

Coal Dependency [1]

Despite growing renewable energy initiatives, coal remains a critical component of India's energy mix, accounting for 55% of the country's energy needs. Coal's continued importance is due to the intermittent nature of renewable energy sources and the current lack of sufficient energy storage solutions. To meet the rising demand, the government has set a coal production target of 1,193.39 MT for the financial year 2025-26, a 10.5 percent increase from the FY 2025 target of 1,080 MT. Ministry of Coal data indicates that the country produced 988.32 MT of coal up to December 15th, compared to 918.02 MT during the same period last year, representing a 7.66 percent increase.

Oil Market Volatility

The oil market in 2025 is expected to remain volatile due to trade uncertainties, geopolitical risks, OPEC+ decisions, and global economic conditions. Supply is projected to exceed demand, driven by increased production from non-OPEC+ countries, while geopolitical tensions and sanctions could disrupt supply chains. Refinery challenges and rising global inventories may exert downward pressure on prices. Major banks forecast Brent crude to range between USD 60-USD 76 per barrel, with fluctuations throughout the year. Traders must adopt risk management strategies, monitor OPEC+ compliance, and analyse market trends to navigate price uncertainties effectively.

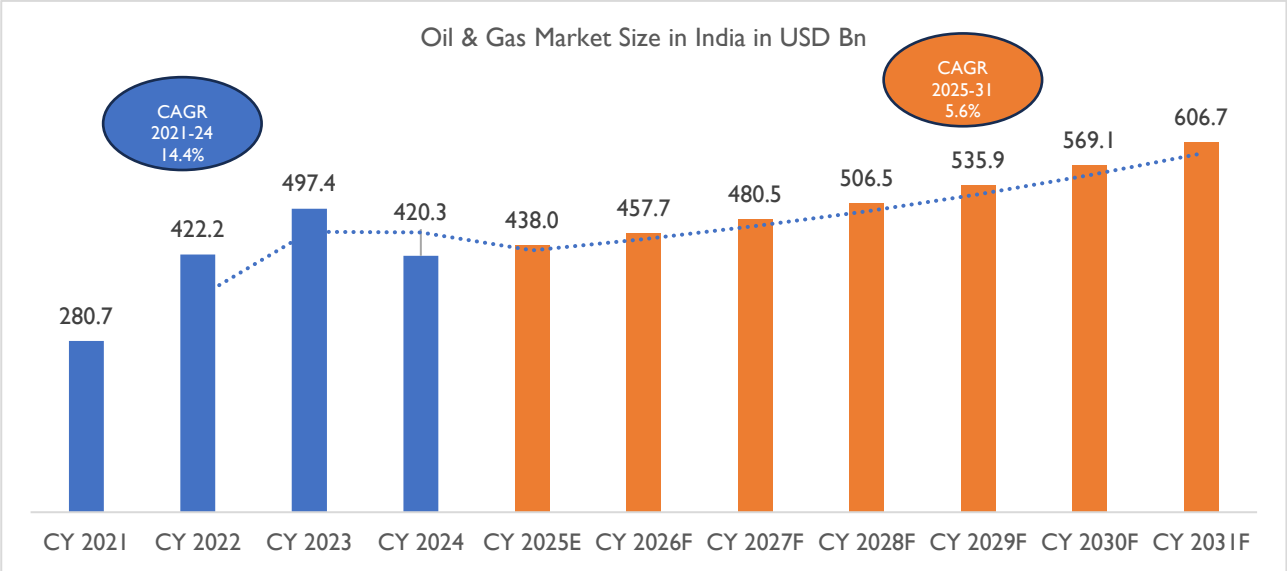
India's energy sector faces significant challenges, including supply-demand imbalances, dependence on fossil fuel imports, grid infrastructure limitations, and the need for massive investment in renewable energy. Additionally, regulatory hurdles, climate change risks, and technological gaps pose further obstacles. However, with strategic policy interventions, enhanced private sector participation, and a strong push for clean energy, India can overcome these challenges and achieve a more sustainable, resilient, and energy-secure future.

[1] https://coal.nic.in/en/major-statistics/coal-indian-energy-choice

4. Oil & Gas: India Scenario

The oil and gas sector are among the eight core industries in India and plays a major role in influencing the decision-making for all the other important sections of the economy. India's economic growth is closely related to its energy demand, therefore, the need for oil and gas is projected to increase, thereby making the sector quite conducive for investment. India retained its spot as the third-largest consumer of oil in the world as of 2023.

Oil & Gas Market in India: CY 2021- CY 2031F

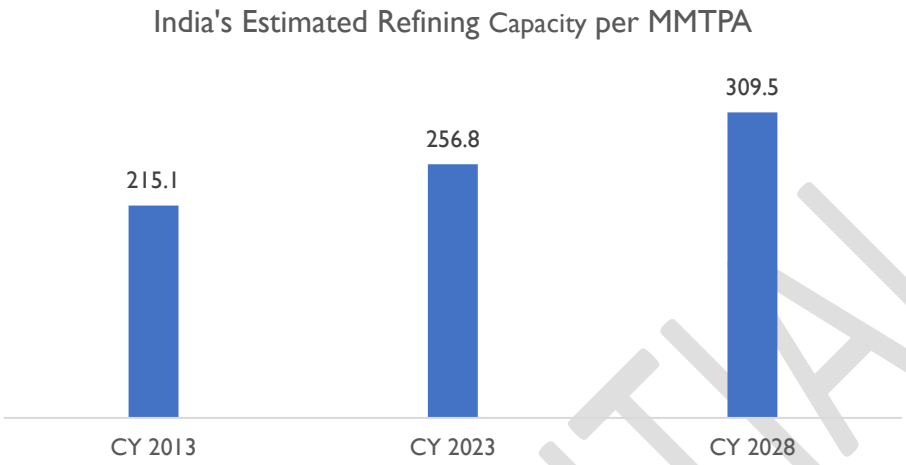


Source: Primary and Secondary Research

The Indian government has introduced several policies to address the growing demand for energy and to boost investment in the sector. These include allowing 100% Foreign Direct Investment (FDI) in key areas such as natural gas, petroleum products, and refineries. Additionally, the FDI cap for public sector refining operations has been raised to 49%, while ensuring that there is no disinvestment or dilution of domestic ownership in existing Public Sector Undertakings (PSUs).

As a result, India has become an attractive destination for both domestic and international investors, with prominent companies like Reliance Industries Ltd. (RIL) and Cairn India establishing a presence in the market. The exploration and production sectors alone are expected to draw around USD 25 billion in investment. India is already a significant refining hub, home to 23 operational refineries, and further development is planned to enhance export-oriented infrastructure, including product pipelines and export ports, to attract additional foreign investment.

According to the IEA (India Energy Outlook 2021), primary energy demand is predicted to nearly double to 1,123 million tonnes of oil equivalent as India's GDP rises to USD 8.6 trillion by 2040. In the last ten years, India's refining capacity has expanded from 215.1 million metric tons per year (MMTPA) to 256.8 MMTPA. It is expected to rise to 309.5 MMTPA by the year 2028.



Source: Ministry of Petroleum

Annual Oil & Gas Demand Pattern in India & Historical Growth Trend

India's oil and gas sector is expected to continue evolving with a balance between meeting growing demand, energy security, and sustainability goals. The government has placed substantial emphasis on energy transition while ensuring continued growth in both the upstream and downstream sectors of the oil and gas industry. India's oil demand is forecasted to experience a twofold increase, reaching 11 million barrels per day by CY 2045E. Additionally, diesel demand in the country is projected to double, reaching 163 million tons by CY 2030. By CY 2045, diesel and gasoline are expected to account for 58% of India's total oil demand.

Here is the demand pattern of oil & gas in India:

Details	Unit/ Base	2020-21	2021-22	2022-23	2023-24	2024-25 (P) (Apr-Nov)
Crude Oil Production in India	MMT	30.5	29.7	29.2	29.4	19.1
Consumption of Petroleum Products	MMT	194.3	204.2	223.0	234.3	157.5
Production of Petroleum Products	MMT	233.5	254.3	266.5	276.1	186.4
Gross Natural Gas Production	MMSCM	28,672	34,024	34,450	36,438	24,243
Natural Gas Consumption	MMSCM	60,815	63,907	59,979	67,512	48,682

Source: Ministry of Petroleum

Production of Petroleum Products:

- **Steady Growth in Production**: The production of petroleum products has consistently grown over the years, from 233.5 MMT in 2020-21 to 276.1 MMT in 2023-24, indicating an average annual growth rate of approximately 6.3%.
- **Growth Drivers**: This growth can be attributed to India's position as a refining hub, with 23 refineries currently in operation. India's refining capacity continues to expand, meeting the rising demand for petroleum products domestically and for export. Companies like Reliance Industries and Indian Oil Corporation are major contributors to this growth.
- **Surplus Production vs. Consumption**: The fact that production has consistently exceeded consumption (e.g., 266.5 MMT produced in 2022-23 vs. 223 MMT consumed) indicates that India is a net exporter of petroleum products, particularly to markets in Asia, Africa, and the Middle East.

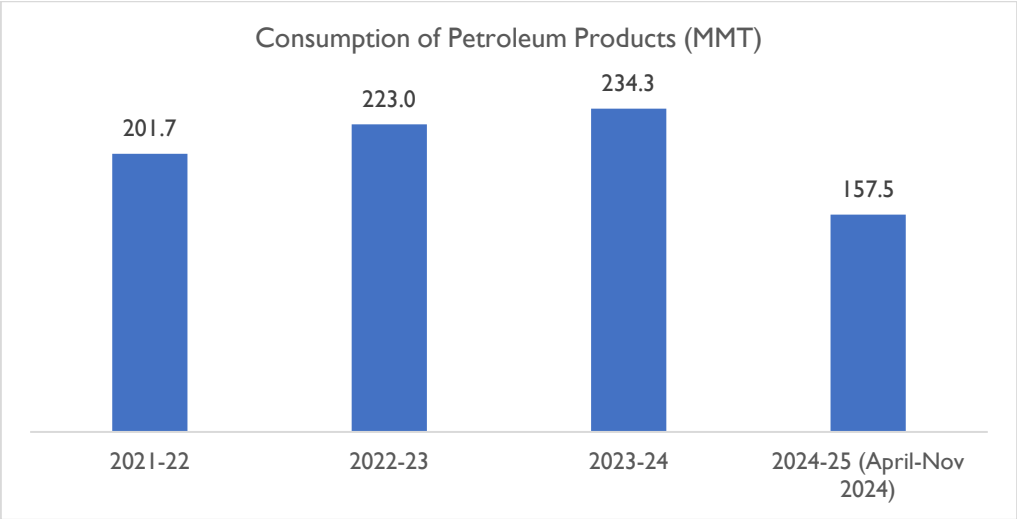
Gross Natural Gas Production:

- **Gradual Increase**: India's natural gas production has steadily increased over the years, from 28,672 MMSCM in 2020-21 to 36,438 MMSCM in 2023-24. This represents a growth of approximately 27% over the 4-year period.
- **Improved Domestic Production**: The increase in natural gas production is largely due to improvements in the exploration and production of domestic gas fields, such as the KG Basin (Krishna-Godavari Basin), and the focus on utilizing stranded gas reserves.
- **Shift Towards Gas**: India is shifting towards natural gas as a cleaner alternative to coal and oil, in line with its commitment to reducing carbon emissions and increasing the share of natural gas in its energy mix (aiming for 15% by 2030). The increase in production is part of this strategic push.

Consumption Pattern Petroleum Products in India

The production and consumption of petroleum products in India have shown significant trends in recent years, reflecting the country's growing energy demands and refining capabilities. India’s consumption of refined petroleum fuels and products is expected to reach a new peak in the financial year **2025-26 (FY26)**, driven by consistent growth in energy demand across various sectors of the economy.

The Petroleum Planning & Analysis Cell (PPAC) of the oil ministry has projected a **4.7% increase** in petroleum product consumption compared to the revised estimate for **FY 2025, totalling 252.93 million tonnes**. This growth reflects the rising demand for crude oil in the country.



Source: Ministry of Petroleum, MMT- Million Metric Tons

From 2021-22 to 2022-23, India's consumption of petroleum products increased by 10.6%. This growth reflects the post-pandemic recovery, where industries, transportation, and other sectors began to return to pre-pandemic levels of activity. However, from 2022-23 to 2023-24, the growth rate slowed down to 5.1%. This indicates that while demand for petroleum products continues to grow, the rate of growth is moderating. This could be attributed to

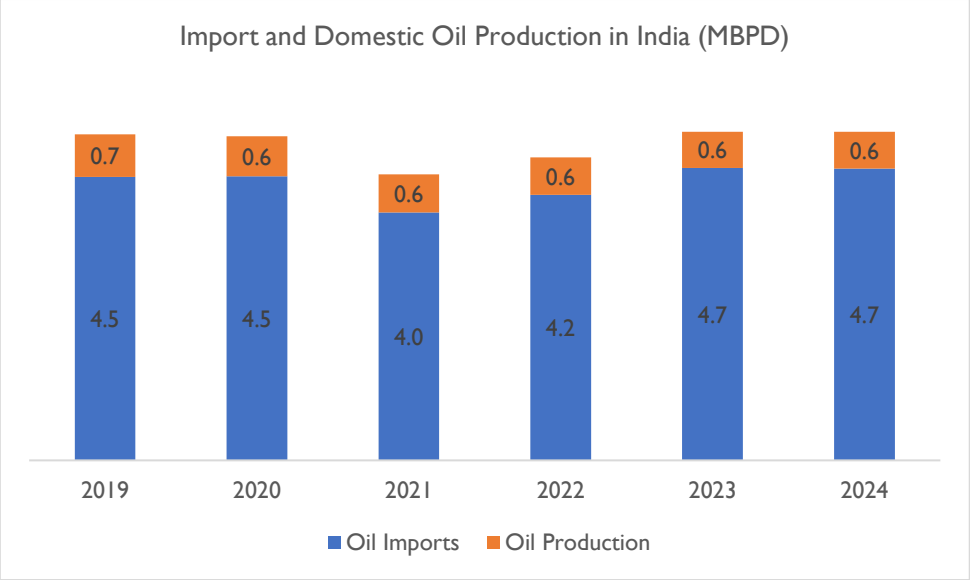
- **Maturity of the Recovery Phase**: The initial post-pandemic surge in demand has slowed down as the economy stabilized, and growth in industrial and transportation sectors becomes steadier.
- **Policy Shifts**: India's increased focus on promoting cleaner energy sources, energy efficiency, and alternative fuels (e.g., electric vehicles, biofuels) may be starting to affect the growth rate of traditional petroleum demand.
- **Economic Factors**: A potential slowdown in economic growth, inflationary pressures, or rising fuel prices could be impacting consumption patterns, especially in price-sensitive sectors like transportation.

Sectoral Consumption Variations:

Diesel consumption is expected to remain robust due to its extensive use in transportation (commercial vehicles) and power generation (particularly backup generation in urban and rural areas). Meanwhile gasoline demand is driven by the automobile sector, particularly in urban areas where personal car ownership is increasing.

4.1 Insight on Import Dependence of India

India's oil and gas import dependence is a critical aspect of its energy landscape, reflecting both the country's growing energy needs and the challenges associated with domestic production. India's oil import dependency continues to grow, while domestic oil production remains stagnant. The gap between imports and production has remained wide, with imports consistently outpacing domestic output. Despite efforts to increase domestic production, India will continue to rely heavily on oil imports to meet its growing energy needs. The government's focus on energy diversification and clean energy technologies will help reduce oil consumption over the long term, but oil imports are likely to remain a significant part of India's energy strategy for the foreseeable future.



Source: Ministry of Petroleum, MBPD- Million Barrels Per Day

From 2021 to 2022, oil imports rose by 7.1%, from 3.9 million tonnes to 4.2 million tonnes, driven by post-pandemic recovery and increased demand with economic reopening. Between 2022 and 2023, imports grew by 10.1%, reaching 4.6 million tonnes, reflecting ongoing economic growth and higher global oil prices. In 2023-2024, imports saw a slight decline of 0.2%, from 4.6 million tonnes to 4.6 million tonnes, indicating stable oil demand and the impact of government efforts to promote cleaner energy alternatives.

Comparison of Oil Imports and Oil Production:

Reliance on Imports: India continues to be heavily dependent on oil imports, as its domestic production is far from sufficient to meet its consumption needs. In 2024, India's oil imports (4.6 million tonnes) are significantly higher than its oil production (0.5 million tonnes), indicating that imports still make up the bulk of India's oil consumption.

Imports vs. Domestic Production Trend:

The gap between imports and domestic production has remained large, with imports consistently being more than 7 times the domestic production throughout the period from 2019 to 2024.While domestic production has declined slightly or remained stable, imports have shown a more varied trend, with periods of increase, especially as India's demand for petroleum products continues to rise post-pandemic.

Consumption Demand: India's consumption of petroleum products continues to outstrip its domestic production capacity. As India remains one of the world's largest oil consumers, its reliance on imports is unlikely to change drastically in the short term unless there are significant developments in domestic production or changes in the country's energy mix.

4.2 Geopolitical Changes and its Impact on India's Oil & Gas Demand Landscape

The geopolitical landscape significantly impacts India's oil and gas demand, particularly in light of recent events such as the Russia-Ukraine war and ongoing tensions in the Middle East. These developments have reshaped India's import strategies and influenced its energy security.

Impact of the Russia-Ukraine Conflict:

- **Shift in Import Sources**: The Russia-Ukraine conflict has led to a substantial reconfiguration of global oil flows, with India emerging as a key player in this new landscape, Russia was a minor supplier of crude oil to India, accounting for approximately 2% of India's annual crude imports in 2021. Prior to the war, Russia was ranked ninth among India's crude oil suppliers; however, by mid-2023, it had surged to become the second-largest supplier, Share rising to nearly 20% surpassing Saudi Arabia.

- **Economic Advantages**: India capitalized on discounted Russian crude, which was offered at prices lower than those from other suppliers. This strategy not only diversified India's oil import sources but also provided economic benefits amid global price volatility.

- **Challenges Due to Sanctions**: The imposition of U.S. sanctions targeting Russia's oil supply chain in January 2025 led to increased shipping costs and complexities in procuring Russian oil. Consequently, Indian refiners faced difficulties in securing Russian crude for March deliveries, prompting a search for alternative sources.

Impact of Middle East Tensions:

- **Supply Security Concerns**: The Middle East has historically been a significant source of crude oil for India, with countries like Iraq and Saudi Arabia being major suppliers. However, ongoing conflicts and instability in this region pose risks to supply continuity and pricing stability. As India reduces its dependence on Middle Eastern oil, it faces challenges in maintaining relationships with these traditional suppliers while balancing its need for affordable energy. Despite India's rising oil imports from Russia, it still depends significantly on oil and gas imports from the Middle East.

- The share of Russian oil in India's August imports declined to about 36% after rising for five straight months, the data showed. In July 2024, Russian oil accounted for about 44% of India's oil imports. The share of Middle Eastern oil in India's August crude imports rose to 44.6% from 40.3% in July. During April-August, the region's share had declined to about 44% from about 46% a year ago. Iraq, Saudi Arabia, the UAE and Kuwait are main Middle Eastern suppliers of oil to India.

- Diversification Efforts: Due to ongoing conflict in middle east. In response to these tensions, India has intensified efforts to diversify its crude oil sources. Notably, there has been an uptick in crude oil imports from Brazil, reflecting India's strategy to mitigate risks associated with over-reliance on Middle Eastern supplies.

- Recent geopolitical events have significantly influenced India's oil and gas demand landscape. The shift towards Russian crude amidst the backdrop of the Russia-Ukraine war has altered traditional import patterns and highlighted vulnerabilities associated with dependence on Middle Eastern suppliers. As India navigates these challenges, it must continue to diversify its energy sources while enhancing domestic production capabilities and strategic reserves to ensure long-term energy security in an increasingly volatile global environment.

4.3 Key Demand Drivers: Oil & Gas

Economic Growth and Industrialization

- As India's economy continues to grow, the demand for energy, including oil and gas, increases due to higher industrial activity, transportation, and infrastructure development. A growing GDP drives demand across sectors such as manufacturing, construction, and heavy industries.

Transportation and Mobility

- India's rapidly expanding transportation sector is a major contributor to oil demand. The growth in passenger vehicles, commercial transportation, and the rise of logistics services significantly boosts the need for petrol, diesel, and aviation fuel

Urbanization and Infrastructure Development

- With urbanization increasing in India, demand for energy, particularly oil and gas, rises due to the construction of new residential, commercial, and industrial infrastructure. This includes the demand for diesel for construction equipment, machinery, and heating fuel for homes.

Energy Security and Policy Initiatives

- Government policies, including the push for energy security and strategic petroleum reserves (SPR), influence the demand for oil and gas. India's efforts to balance energy import dependence with domestic production, and the expansion of its renewable energy portfolio, also play a role.

Technological Advancements and Shifts in Consumption

- Innovations in fuel efficiency, the rise of electric vehicles, and the increasing adoption of cleaner technologies may moderate the demand for traditional fossil fuels, influencing long-term consumption trends.

Government Subsidies and Regulatory Framework

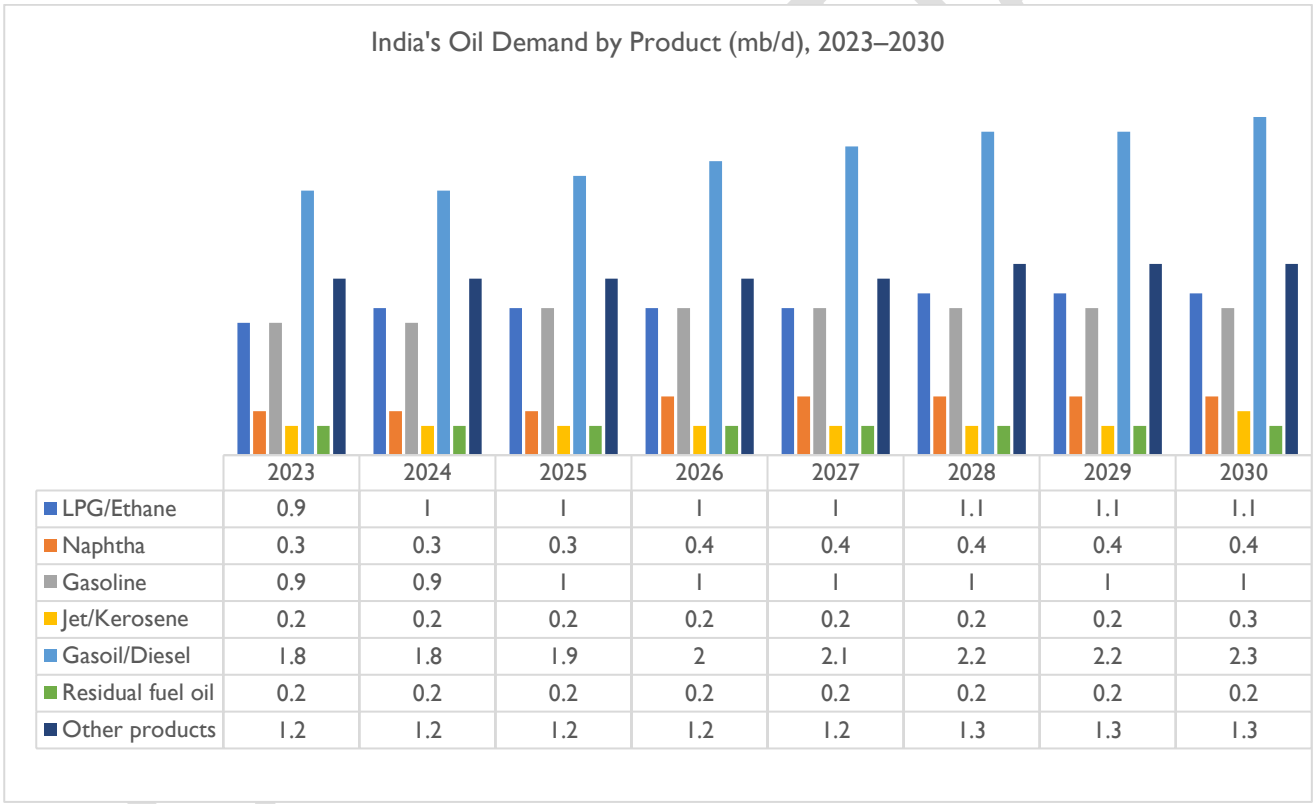
- Government subsidies on fuels, such as LPG, petrol, and diesel, directly affect domestic consumption. Regulatory changes, including taxation policies and emission standards, also influence the demand for different types of fuel.

4.4 Expected Growth in India's Oil & Gas Demand

India is projected to be the largest driver of global oil demand growth from 2023 to 2030, surpassing China. Fuelled by robust economic and demographic growth, India's oil demand is expected to increase by nearly 1.2 mb/d, contributing to more than one-third of the global rise of 3.2 mb/d. Unlike other major economies, India's demand growth will be more diverse, with only 18% of its increase directed towards petrochemical feedstocks, compared to over 90% globally.

The country's demand surge will be primarily driven by sectors like manufacturing, commerce, transport, and agriculture, resulting in a significant rise in diesel consumption. India's economic expansion, averaging 6.8% annually in the past decade, is projected to continue at 6.5% from 2024-2030, making it the fastest-growing major economy and a key contributor to global economic growth.

India's Oil Demand by Product (mb/d), 2023–2030:[2]



	2023	2024	2025	2026	2027	2028	2029	2030
LPG/Ethane	0.9	1	1	1	1	1.1	1.1	1.1
Naphtha	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4
Gasoline	0.9	0.9	1	1	1	1	1	1
Jet/Kerosene	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3
Gasoil/Diesel	1.8	1.8	1.9	2	2.1	2.2	2.2	2.3
Residual fuel oil	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Other products	1.2	1.2	1.2	1.2	1.2	1.3	1.3	1.3

Source: International Energy Agency, (mb/d)- Million Barrels Per Day

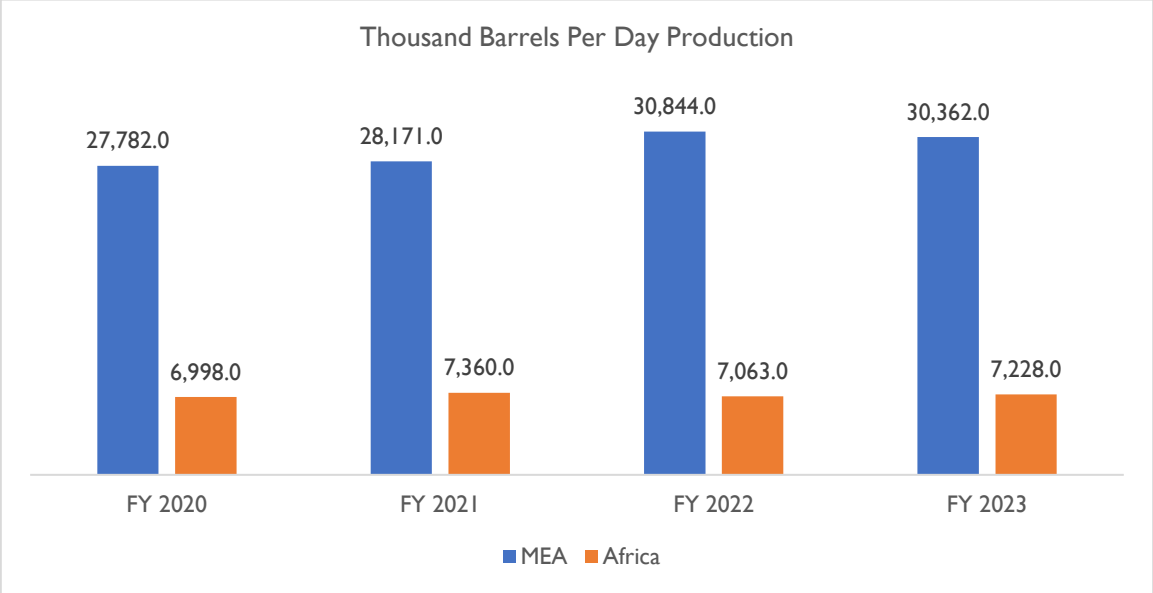
Gas Demand and Growth in India till 2030: India's natural gas consumption is projected to increase by 60% from 2023 to 2030, driving a significant rise in liquefied natural gas (LNG) imports. Domestic production is expected to grow only 8%, reaching 38 bcm annually by 2030, while demand could soar to 103 bcm, or potentially 120 BCM with additional government support. This gap will make India, the world's fourth-largest LNG importer, double its LNG imports to 65 bcm by 2030, aligning with its current import terminal capacity of 47.7 million metric tons per year.

[2] https://www.iea.org/reports/india-gas-market-report

4.5 Oil & Gas Exploration & Production Scenario in MENA Region[3]

Energy is widely recognized as a crucial factor in the economic development of any nation. The MENA (Middle East and North Africa) region has been a key player in the global energy sector for decades, supporting industrialization and economic progress in countries worldwide. The region is home to approximately 40% of the world's proven oil reserves and 41% of its natural gas resources, thanks to its favourable geological conditions for the generation and accumulation of these resources.

Total production of Oil in Middle East in past few years:[4]



Source: Organization of the Petroleum Exporting Countries, and all figures are derived from the latest available data

Key Takeaways:

- In FY 2023, oil production reached 30,362 thousand barrels per day, accounting for 31.5% of the global market signifying major influence over global oil supply and pricing.
- From FY 2020 to FY 2023, oil production rose by 3.3%, showing modest growth amid global demand shifts and geopolitical factors.
- A separate producer held a 7.5% market share in FY 2023, indicating a moderate yet impactful role in global supply dynamics.
- MENA is home to major oil and gas fields, including Ghawar (Saudi Arabia), Burgan (Kuwait), Rumaila (Iraq), and South Pars/North Dome (Iran-Qatar).
- In North Africa, leading oil and gas producers include Algeria, Libya, and Egypt.

[3] https://www.oilfieldtechnology.com/digital-oilfield/21122022/the-latest-developments-in-the-mena-region/

4.5.1 Key Players Brief Insight on Production Scenario & Reserves

The Middle East and North Africa (MENA) region is a cornerstone of the global oil and gas industry, holding nearly half of the world's oil reserves and a significant share of natural gas. Key producers like Saudi Arabia, Iran, Iraq, and the UAE play a critical role in shaping global energy prices and supply. Oil and gas exports are vital to MENA economies, contributing 40% of GDP in Saudi Arabia, 42% in Iraq, and 25% in Iran. The region is heavily investing in upstream projects and expanding production capacity, while National Oil Companies are increasingly exploring low-carbon and renewable ventures. In line with global energy transition goals, countries like Saudi Arabia and the UAE are diversifying into renewables, nuclear, and emerging hydrogen markets. MENA's strategic location and energy dominance make it a key player in global energy security and geopolitics.

Company	Country	Production Capacity (BPD)
Saudi Aramco	Saudi Arabia	11 million
National Iranian Oil Company (NIOC)	Iran	3.8 million
Iraq National Oil Company (INOC)	Iraq	4.5 million
Abu Dhabi National Oil Company (ADNOC)	United Arab Emirates (UAE)	3.7 million
Kuwait Petroleum Corporation (KPC)	Kuwait	2.8 million
Sonatrach	Algeria	0.45 million
Equinor	Algeria	2 million

Source: Organization of the Petroleum Exporting Countries

*BPD- Barrels Per day

4.5.2 Key Production Hubs / Countries

Table 1 Below are the Major Oil Producing Countries in Middle East and Africa Region: (Thousand Barrels Per Day) [5]

Country	2020	2021	2022	2023	Growth % (2020-23)	Contribution to GDP in %
MEA						
Saudi Arabia	11,039	10,954	12,191	11,389	+3.2%	22.8%
Iran	3,230	3,766	3,945	4,662	+44.2%	16.2%
Iraq	4,114	4,102	4,520	4,355	+5.9%	42%
United Arab Emirates	3,679	3,640	4,020	3,922	+6.6%	23.5%
Africa						
Algeria	1,332	1,353	1,443	1,408	+5.7%	14%
Libya	420	1,286	1,143	1,271	+202.6%	68%
Egypt	632	608	613	610	-3.5%	9%

Source: Organization of the Petroleum Exporting Countries, IEA, Note: Note: All figures are derived from the latest available data

Key Takeaways: MEA

- Saudi Arabia: Moderate growth of 3.2% (2020–2023), with a dip in 2021 and 2023; remains the world's top oil exporter, led by Saudi Aramco.
- Iran: Strong 44.2% growth, recovering from sanctions; holds large reserves but faces foreign investment and tech access limitations.
- Iraq: Grew 5.9%, despite volatility; increasing capacity in southern fields like Rumaila.
- UAE: Stable 6.6% growth; ADNOC drives expansion, especially in offshore fields like Zakum.

Key Takeaways: North Africa

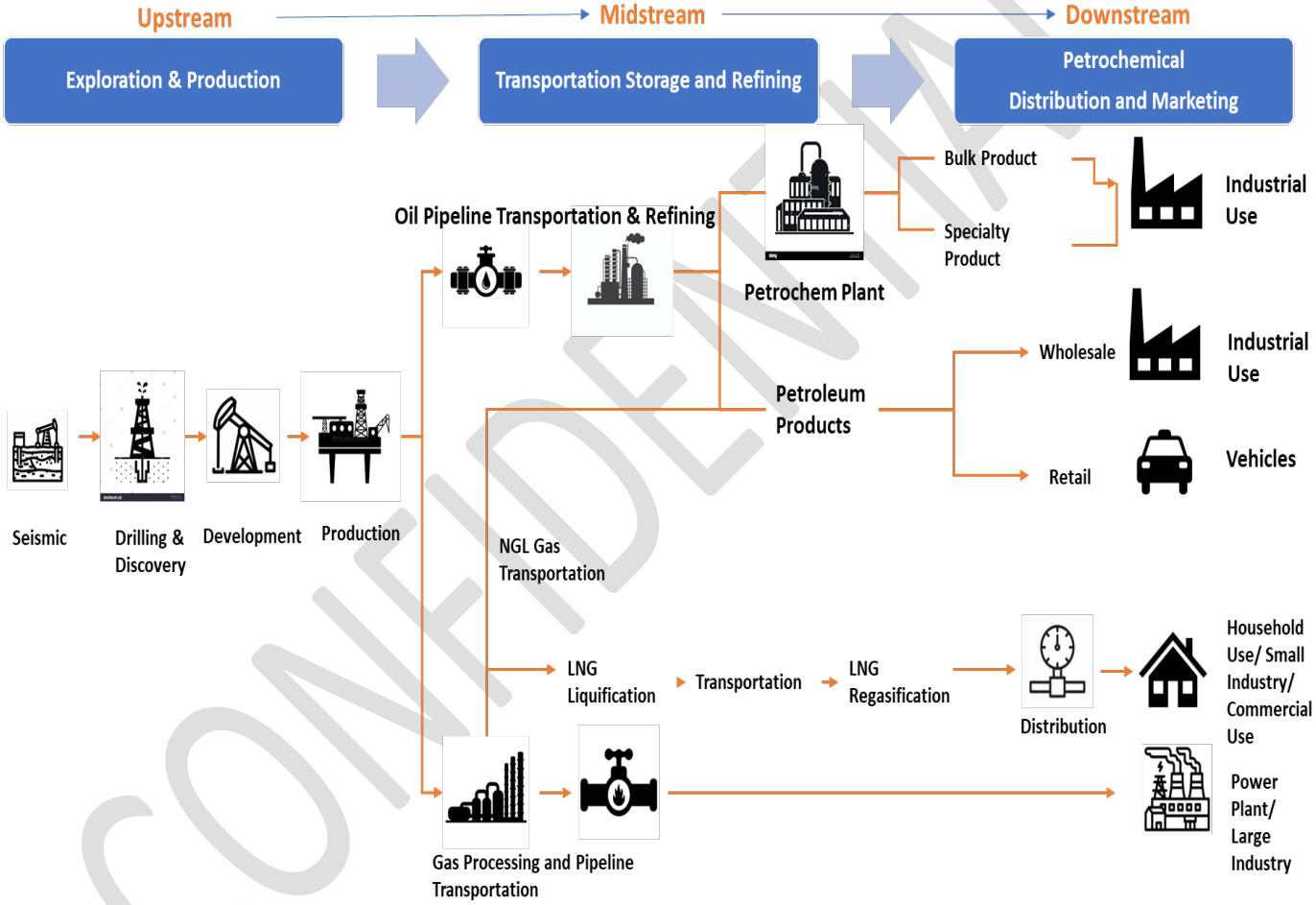
- Libya: Impressive 202.6% growth, rebounding from political unrest and restoring capacity.
- Algeria: Steady 5.7% growth, but pace slowing; consistent production improvements.
- Egypt: Declined 3.5%, possibly due to aging fields and a shift toward natural gas.

[5] https://s3.pplstatics.com/lasprovincias/www/multimedia/2024/10/02/productor-petroleo

5. Mapping the Oil & Gas Value Chain in India

India's energy sector value chain is complex, with distinct yet interdependent segments in oil & gas, coal, and renewable energy. While coal and oil & gas continue to dominate in terms of total energy production, the renewable energy sector is expanding rapidly, spurred by technological advancements, government policies, and global environmental commitments. Each of these sectors requires continuous investment in infrastructure, technology, and sustainability practices to meet India's future energy demands while transitioning to a low-carbon economy.

Oil & Gas Industry Value Chain:



Upstream

Oil & Gas Exploration: Involves searching for crude oil reservesthrough geological surveys, seismic studies, and exploration drilling. Key players include ONGC (Oil and Natural Gas Corporation) and Oil India Ltd. Similar to oil exploration, natural gas exploration includes offshore and onshore drilling to locate gas reserves

Drilling is a crucial phase in oil and gas exploration and production. Exploratory drilling involves drilling wells to confirm the presence and assess the quantity and quality of hydrocarbons. Once reserves are confirmed, development drilling takes place to maximize extraction from the field by drilling additional wells.

Production involves extracting hydrocarbons from the ground. This phase includes well completion, which prepares the well for production after drilling. To maximize recovery rates throughout the well's life, various production optimization techniques are employed, including enhanced oil recovery methods.

Midstream

Transportation: Midstream companies are responsible for transporting crude oil and natural gas from production sites to refineries or processing plants. Pipelines are the most common mode for long-distance transportation due to their efficiency and cost-effectiveness. Rail and trucking are used for shorter distances or where pipeline infrastructure is limited, while barges and tanker ships are employed for transportation across waterways.

Storage: Midstream operations include the construction and management of storage facilities such as tanks and terminals.

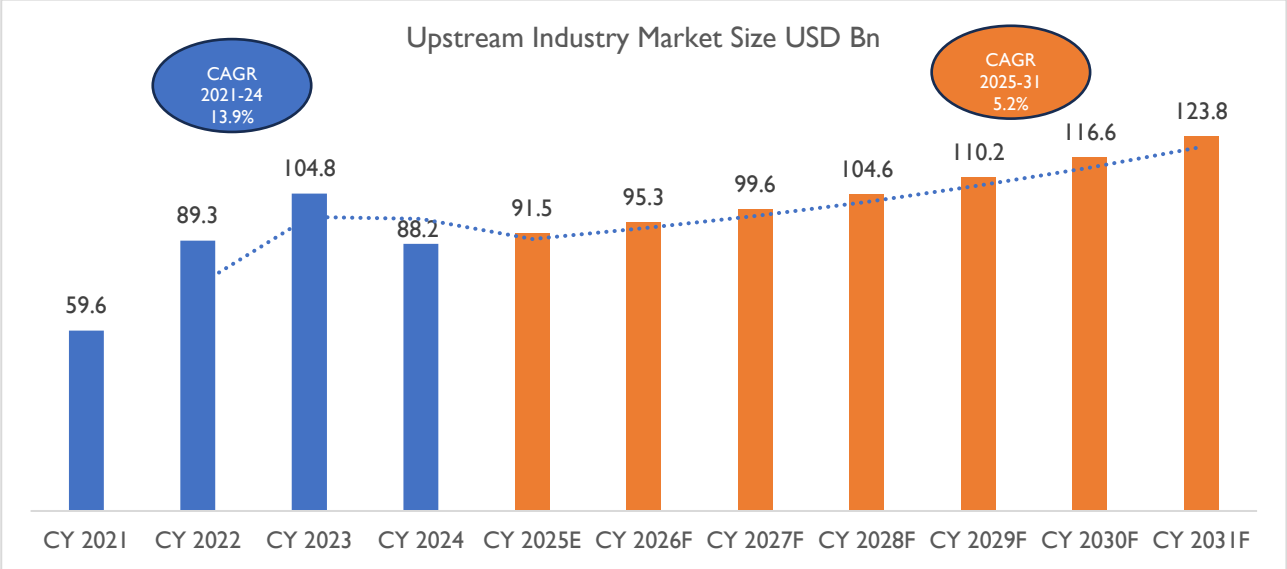
Downstream

The downstream sector encompasses all activities following the extraction of crude oil and natural gas. Key activities include refining crude oil into various products, transporting them to storage and retail outlets, and finally, marketing these products to consumers through diverse channels.

5.1 Upstream Oil & Gas Infrastructure in India: Exploration and Production Scenario

The upstream oil and gas infrastructure in India is vast and continuously developing, with significant investments in both offshore and onshore exploration and production. While there are several challenges, including technological advancements required for deep-water exploration and expansion of pipeline networks, the growth in India's upstream sector is essential for meeting the country's growing energy demands. The government's ongoing reforms and investments in infrastructure will further strengthen India's position in the global energy landscape.

Upstream Industry Market: Historical Trend and Forecasted Market Growth



Source: Primary and Secondary Research

The India Oil & Gas Upstream Market has experienced strong growth from USD 59.6 billion in 2021 to USD 88.2 billion in 2024, reflecting a compound annual growth rate (CAGR) of 13.9% over this period. This growth has been driven by several factors, including increased domestic production, the expansion of exploration activities, and rising demand for energy as India's economy continues to grow. The upstream market, which includes exploration and production (E&P) of oil and gas, has been a major focus for the government and private players alike, given the country's reliance on energy imports and the need to boost domestic production.

In the forecast period, growth in the upstream market is expected to slow somewhat. From USD 88.2 billion in 2024, the market is projected to reach USD 123.8 billion by 2031, representing a CAGR of 5.2% between 2025 and 2031. This slowdown can be attributed to two factors – maturity of projects (Many of the large exploration projects initiated in the past decade are expected to reach a more stable phase of production, which may reduce the pace of expansion) and price stabilization (Global oil prices, which have a significant influence on upstream activities, are expected to stabilize, leading to more moderate revenue growth),

Despite the slower growth forecast after 2025, the **India Oil & Gas Upstream Market** will remain an integral part of the energy landscape, driven by **long-term energy security goals**, **energy demand**, and

investment in domestic exploration. Energy demand will increase as the country's social and economic growth progresses. The country relies on imports for approximately 83% of its crude oil requirements and 47% for natural gas. To close the energy supply and demand gap, MoPNG intends to boost exploration and production efforts in the country.

Oil and gas exploration and production (E&P) is the upstream segment of the energy industry, focused on locating and extracting crude oil and natural gas from the Earth. This critical stage involves identifying potential reserves, drilling exploratory wells, and developing infrastructure to extract, process, and transport hydrocarbons. Globally, the oil and gas exploration and production (E&P) sector was estimated to have a market size of USD 3 trillion USD in 2019 (as per a secondary report) and employed over 4.5 million people, highlighting its role as a key pillar of the global energy supply chain.

Oil & Gas Exploration & Production Infrastructure:

Table 2 State-Wise Production of Crude Oil

State	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25
Onshore						
Assam	4093	3902	3991	4166	4361	4454
Arunachal Pradesh	56	53	48	47	52	50
Andhra Pradesh	243	195	202	236	250	284
Gujarat	4707	4651	4626	4849	4950	5135
Rajasthan	6653	5891	5885	5074	4421	3428
Tamil Nadu	415	410	367	324	294	263
West Bengal	0	0.13	0.05	0.01	0	0
A. Onshore Total Production	16167	15103	15120	14697	14329	13616
Offshore						
Eastern Offshore	557	744	626	550	1463	2437
Western Offshore	14857	14236	13604	13552	13239	12471
Gujarat Offshore	589	411	338	379	326	181
B. Offshore Total Production	16003	15391	14569	14482	15027	15088
Total Production (A+B)	32170	30494	29688	29179	29356	28704

Condensate receipt at Uran & Hazira included in Western Offshore Basin of Maharashtra

Source: Oil & Natural Gas Corporation Ltd., Oil India Ltd. and DGH

Table 3 Basin-wise Production of Gas

State/Region	2020-21	2021-22	2022-23	2023-24	2024-25(P)
Andhra Pradesh	827	809	710	722	758
Assam & Arunachal Pradesh	3051	3429	3611	3529	3597
Gujarat	1138	1017	923	926	1053
Rajasthan	2040	2619	2340	2199	1785
Tamil Nadu	911	1067	1109	1016	1013
Tripura	1634	1531	1675	1525	1224
Jharkhand (CBM)	2	4	10	5	47
Madhya Pradesh (CBM)	334	389	264	234	294
West Bengal (CBM)	307	290	399	411	415
Onshore Total	10243	11155	11042	10567	10186
Mumbai High + Eastern Offshore	17086	15943	15325	14979	14701
Private / JVCs	1343	6926	8084	10892	1126
Offshore Total	18429	22869	23409	25871	25928
Grand Total	28672	34024	34450	36438	36113

5.1.1 Major Oil & Gas Fields in India:

India's reliance on domestic oil production is significant but not enough to meet the entire demand. These oil fields contribute to reducing India's dependence on oil imports and support the country's energy requirements, transportation, and industrial uses. However, India still imports a large portion of its oil needs, which makes the development and enhancement of domestic oil exploration crucial.

Onshore Oil Fields:

Region	Onshore Oil Field Name	Capacity	Products Manufactured	Operator
Assam	Digboi Oil Field (Brahmaputra Valley)	Over 1,000 wells drilled; 0.65 MMTPA Capacity	LPG, Motor Spirit, Mineral Turpentine Oil, SKO, HSD, LDO, Furnace Oil, Bitumen, Raw Petroleum Coke, Paraffin Wax	Indian Oil Corporation Ltd (IOC)
	Naharkatiya Oil Field	2.5 million tonnes of oil and 1 million cubic meters of natural gas annually	LPG, Kerosene	Oil India Limited (OIL)
Gujarat	Ankleshwar Oil Field	Originally 2.8 million tonnes per annum; 6.72 million bbl/y oil and 1163.74 million m^3/y gas (2017)	Gasoline, Kerosene	Oil and Natural Gas Corporation (ONGC)
	Cambay-Luni (Khambhat) Oil Field	1.5 million tonnes oil and 0.8–1 million cubic meters of gas annually	Light Oil, Gas, Hydrocarbon	Synergia Energy Ltd
	Ahmedabad-Kalol Oil Field	1.5 million tonnes oil, 0.8-1 million m^3 gas annually	Oil	Gujarat State

Rajasthan	Mangala Oil Field	1.5 million tonnes oil and 0.8–1 million cubic meters of gas annually; total reserves ~3 crore tonnes	Crude Oil	Cairn India (Vedanta Group)

Offshore Oil Fields

Region	Onshore Oil Field Name	Capacity	Operator	Products Manufactured
Western Coast	Mumbai Oil Field	1,659Mt total reserves; 134,000 barrels/day in 2024; 527 million barrels of oil and 221 billion m³ gas produced	Oil and Natural Gas Corporation (ONGC)	Crude Oil, Gas
	Bassein Oil Field	Cumulative gas production 248,000 million m³; Gas production 10,857.58 million m³/y; Oil production 19.88 million bbl/y	Oil and Natural Gas Corporation (ONGC)	Crude Oil, Gas
Eastern Coast	Krishna Godavari (KG) Basin	19,190 barrels of crude oil/day; 9.8 million metric standard cubic meters of gas/day; Pipeline capacity 16 MMSCMD, 877.86 km long	Oil and Natural Gas Corporation (ONGC)	Crude Oil, LNG, Natural Gas
	Cauvery Delta Basin: Narimanam Oil Field	1300 m³ capacity with 12 wells	Oil and Natural Gas Corporation (ONGC)	Crude Oil, LNG, Natural Gas

The E&P process is divided into four major phases:

Exploration & Surveying

- The first stage involves extensive research and geophysical surveys to locate underground or underwater reserves of hydrocarbons. Techniques such as seismic, magnetic, and gravimetric surveys help identify potential oil and gas deposits. Data is collected to assess the feasibility of extraction, estimate reservoir size, and evaluate environmental and logistical risks. Advanced remote sensing technologies and artificial intelligence (AI)-driven predictive modelling are increasingly enhancing the accuracy of exploration efforts.

Well Development & Drilling

- Once a viable site is identified, exploratory wells are drilled to confirm the presence of hydrocarbons. Depending on the location, wells can be onshore or offshore. Offshore drilling often involves floating or fixed platforms, requiring significant infrastructure investment. International standards such as ISO 16901:2015 and ISO 19900:2019 provide guidelines for safety and risk assessment in both onshore liquefied natural gas (LNG) facilities and offshore structures.
- Technological advancements in directional drilling and horizontal drilling have improved access to reserves while minimizing environmental disruption. The ability to drill multiple wells from a single site has increased efficiency and reduced costs.

Extraction & Production

- Once drilling confirms a viable reserve, extraction begins. Crude oil and natural gas are extracted, separated, and processed to remove water, sand, and other impurities. While natural gas can often be processed on-site, crude oil must be transported to refineries for further refinement.
- The ISO 20815:2018 standard plays a crucial role in ensuring production efficiency and reliability in petroleum, petrochemical, and natural gas industries. Subsea production systems, governed by ISO 13628, have revolutionized deepwater extraction by allowing remotely operated equipment to function in extreme environments.

Well Abandonment & Site Restoration

- As reserves are depleted or become economically unviable, wells must be safely sealed and abandoned to prevent environmental hazards. Proper decommissioning involves plugging the wellbore, restoring the site, and mitigating potential leaks. Regulatory frameworks ensure that companies follow strict environmental protection measures when shutting down operations.

Currently, approximately **13% of oil** and **53% of natural gas** are produced domestically by E&P companies, reducing the nation's reliance on imports. In 2023-24, crude oil production reached 29.36 million metric tons (MMT), with a provisional output of 14.4 MMT recorded for 2024-25. According to the International Energy Agency (IEA), India's projected oil demand by 2030 is expected to reach 6.6 million barrels per day (mb/d), while petrol demand is forecasted at 1.0 mb/d.

The Role of Standards in Oil & Gas Infrastructure

The oil and gas industry operates in harsh and high-risk environments, requiring robust infrastructure, specialized equipment, and strict safety protocols. International standards provide guidelines for designing, constructing, and maintaining oil rigs, pipelines, storage facilities, and refineries. Notable standards include:

- **ISO 19905-3:2017** – Site-specific assessment for mobile floating units.
- **ISO 13628** – Design requirements for subsea production systems.
- **ISO 20815:2018** – Production assurance in petroleum and gas industries.

5.1.2 Insight on Oil & Gas Drilling Infrastructure in India

India's oil and gas drilling infrastructure is crucial to the exploration, extraction, and production of crude oil and natural gas, which play a significant role in the country's energy supply. This infrastructure includes the equipment, technology, and systems used in both offshore and onshore drilling operations.

Types of Drilling Rigs and Platforms:

I. **Onshore Drilling Rigs**:
   - **Land-based Drilling Rigs**: These rigs are used for drilling onshore oil and gas fields across India. Onshore rigs include both conventional drilling rigs and mobile drilling units that can be moved to different locations for exploration and production activities. India has a significant number of these rigs, especially in areas like Assam, Rajasthan, and Gujarat.
   - **Coiled Tubing Units**: These are used for operations like well interventions, workover operations, and maintaining oil wells, especially when there's a need to boost the well's production rate. They are especially used in maturing fields.

II. **Offshore Drilling Rigs**:
   - **Jack-up Rigs**: These are mobile drilling units that are placed on the seabed and are used to drill in shallow water regions, typically in depths of up to 500 meters. They are used extensively in the Mumbai High and other offshore fields in the Arabian Sea.
   - **Semi-Submersible Rigs**: These rigs are used in deeper waters, beyond the capabilities of jack-up rigs. They are designed to float on the surface of the water but are anchored to the seabed. India uses semi-submersible rigs for drilling in deeper parts of the Krishna-Godavari Basin and other offshore fields.
   - **Floating Production Storage and Offloading (FPSO)**: These are specialized offshore platforms used in deepwater drilling and production. They have the capability to process and store crude oil before it is transported to shore. ONGC and other private players use FPSOs in fields like KG-D6 in the Krishna-Godavari Basin.

Key Infrastructure Developments:

Government Initiatives: The government is actively promoting exploration and production (E&P) activities through policies like the Open Acreage Licensing Policy (OALP), with ONGC, Oil India Limited (OIL), Sun Petro Chemicals Private Limited, and a consortium of Reliance Industries Limited and BP Exploration winning contracts for exploration and development. The government is also looking to enhance LNG import capacity by developing new terminals and augmenting existing capacities.

Investment: The government is investing in developing the 2650-km Pradhan Mantri Urja Ganga project and the 1565-km North-eastern Region Gas Grid project. Capital support of about Rs. 10,676 crores have been extended to these projects.

Refinery Expansion: Projects are underway to expand the Digboi Refinery from 0.65 MMTPA to 1 MMTPA with a project cost of Rs 768 Cr. The centre laid foundation stones for the expansion of the Guwahati Refinery and augmentation of the Betkutchi (Guwahati) Terminal Project in March 2024.

Pipeline Projects: Several pipeline projects are under construction to enhance transportation infrastructure. These include:

Mundra Panipat Crude Oil Pipeline

- A 1,033 km long pipeline with a capacity of 17.5 MMTPA from Churwa in Gujarat to Panipat in Haryana. The project cost is Rs. 9,028 Cr.

Ennore – Thiruvallur – Bengaluru – Puducherry – Nagapattinam – Madurai – Tuticorin Natural Gas Pipeline

- A 1,444 km pipeline with a capacity of 35 MMSCMD to supply natural gas to Tamil Nadu, Andhra Pradesh, and Karnataka. The project cost is Rs. 6025 Cr.

Paradip Hyderabad Pipeline Project

- A 1,212 Km pipeline for transporting petroleum products from Paradip to Hyderabad. The project cost is Rs. 3,338 Cr.

Augmentation of Salaya-Mathura Crude Oil Pipeline System

- This augmentation project involves augmenting pumping facilities at 5 locations storage facilities, and delivery facilities at Koyali refinery, all in Gujarat. The project cost is Rs 1614 Cr.

- **City Gas Distribution (CGD) Networks:** Five firms won licenses for developing CGD networks in eight geographical areas (GAs) under Rounds 12 and 12A of CGD bidding, with anticipated investment around Rs 410 billion.
- **Power Infrastructure**: IOCL has decided to develop infrastructure for importing bulk grid power at refineries to import grid power, with the installation & commissioning of 220 KV transmission line.

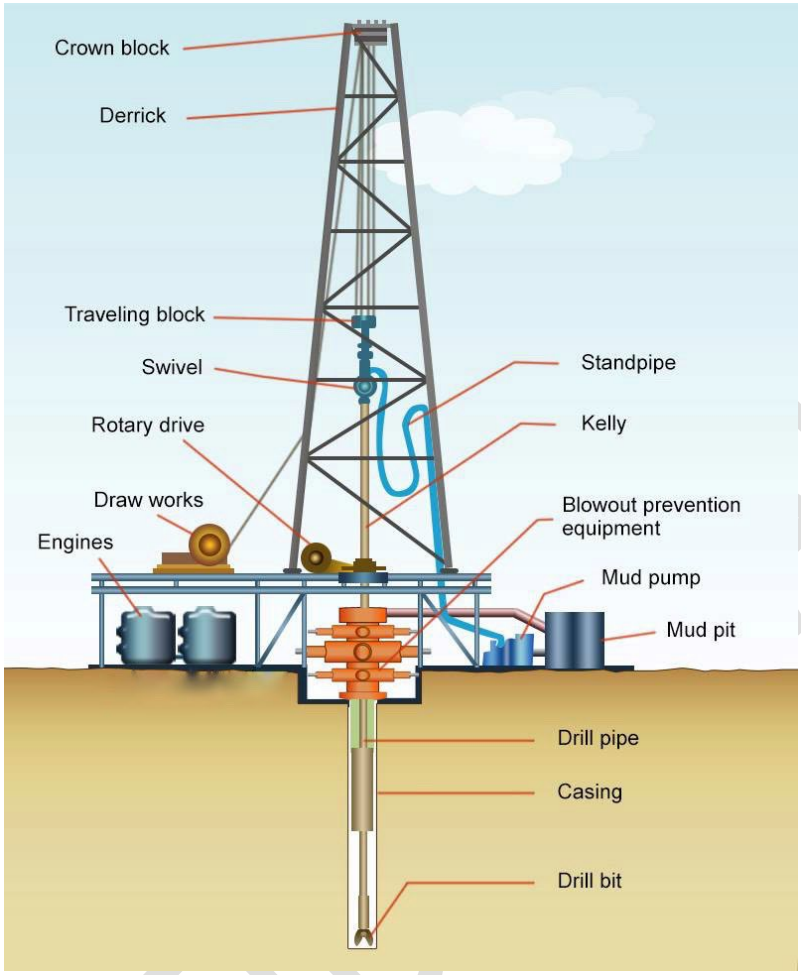
- **Drivers**: The oil and gas drilling infrastructure in India is being driven by a combination of rising energy demand, favourable government policies, technological innovations, foreign investments, and a strategic focus on reducing import dependency. These drivers, together with increasing environmental concerns and global market dynamics, are shaping the future of the oil and gas sector in India.
- **Increasing Energy Demand**: As India's population and economy grow, the demand for energy, particularly petroleum products and natural gas, continues to rise. This growing demand for energy fuels the need for expanded oil and gas exploration, drilling, and infrastructure development. The energy consumption is projected to keep increasing due to urbanization, industrialization, and a higher standard of living, creating a strong incentive for improving drilling infrastructure.
- **Government Policies and Initiatives**: The Indian government has rolled out various policies and initiatives to enhance oil and gas exploration and production, such as the Hydrocarbon Exploration and Licensing Policy (HELP) and the National Policy on Biofuels. The Make in India initiative also encourages local manufacturing of drilling equipment, components, and services, boosting domestic infrastructure development in the oil and gas sector. The government's focus on enhancing energy security and reducing dependency on imports has also led to the development of oil and gas infrastructure.
- **Technological Advancements**: The adoption of new technologies, such as seismic imaging, horizontal drilling, and hydraulic fracturing (fracking), has significantly improved the efficiency and cost-effectiveness of drilling operations.
- **Exploration of Untapped Reserves**: India has several unexplored and under-explored oil and gas reserves, especially in the offshore and deepwater regions. This provides a significant growth opportunity for drilling infrastructure, which is crucial for tapping into these resources. Shale gas reserves in India are also becoming an area of interest for drilling and infrastructure development.

5.1.3 Overview on Key Components in Drilling Infrastructure

Oil drilling activities are critical in the production of petroleum, which is a valuable energy source. Oil drilling entails drilling through the earth's surface to reach the reservoir. India's drilling infrastructure for oil and gas consists of several key components, including onshore and offshore drilling rigs, advanced drilling technologies, and safety measures. Onshore rigs are primarily used in fields in Assam, Rajasthan, and Gujarat, with mobile and conventional rigs supporting exploration and production. Offshore fields, such as those in the Mumbai High and Krishna-Godavari Basin, rely on specialized rigs like jack-up rigs, semi-submersible platforms, and FPSOs for deepwater drilling.

Modern technologies like directional and horizontal drilling, hydraulic fracturing, and well control systems are employed to enhance efficiency and access difficult-to-reach reserves. Additionally, safety systems like blowout preventers (BOPs) and environmental protection protocols are critical for managing risks, especially in offshore operations. Key players in India's drilling infrastructure include state-owned ONGC and OIL, alongside private companies like Reliance Industries. Despite challenges like aging fields and deepwater drilling complexities, ongoing advancements in technology and infrastructure are positioning India's oil and gas sector for future growth.

Drilling Rig Components:

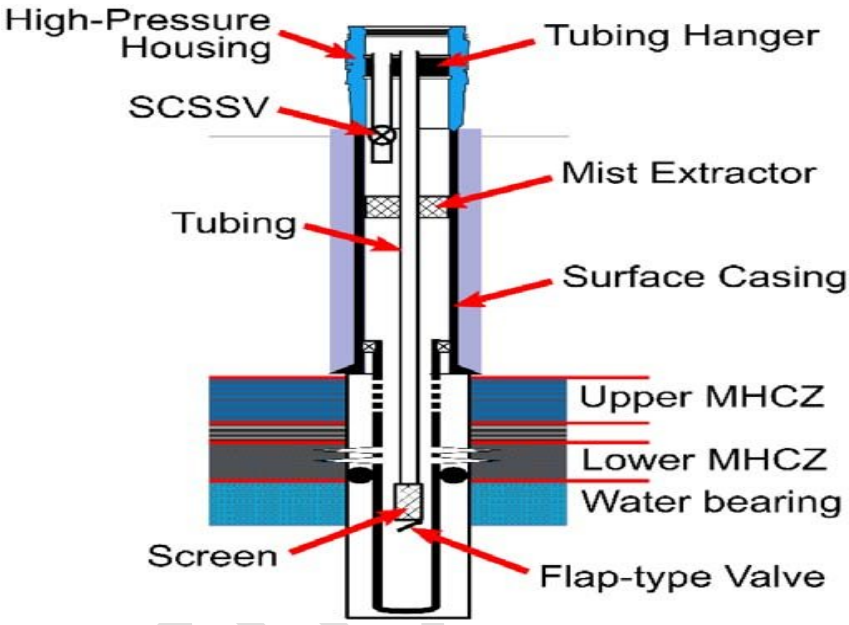


- **Derrick**: A tower-like support framework that houses the drilling equipment. It's tall enough to allow new pipe sections to be added during drilling. Derricks come in various types like single, double, triple, and Quadri.
- **Drill Bits, Pipes, and Collars**: Drill bits are used to break apart the rock4. Drill pipes, connected pipes, transport mud during drilling2. Drilling collars collect core samples to evaluate reservoir properties.
- **Drilling Line**: A collection of twisted wires that lowers and lifts the drilling rigging.
- **Mud Pump and Mud Tank**: The mud pump circulates drilling mud to cool the drill bit and carry rock cuttings to the surface. Mud tanks store the drilling mud.
- **Blowout Preventer (BOP)**: A critical safety device used to prevent uncontrolled release of crude oil or natural gas from the well. Types include annular, pipe ram, and blind ram.
- **Top Drive**: A motor suspended from the derrick that drives the drill into the ground2. It allows for drilling longer sections of pipe at once, improving efficiency.
- **Drill Floor**: The main area on the rig where tools are located for connecting drill pipe, bottom hole assembly, tools, and the drill bit.
- **Draw works**: The mechanical section that reels in/out the drill line to raise/lower the traveling block.
- **Traveling Block**: Used to raise and lower the drill string.

- **Crown Block**: A set of pulleys located at the top of the derrick, used in conjunction with the traveling block to raise and lower the drill string.
- **Swivel**: Connects the top of the drill string to the drilling line and allows the drill string to rotate.

List of other items: Shale shakers, Suction line (mud pump), Motor or power source, Hose, Standpipe, Kelly hose, Gooseneck, Racking Board, Stand, Setback (floor), Kelly drive, Rotary table, Bell nipple, Drill string, Casing head or Wellhead, Flow line.

Well Completion and Production Equipment:



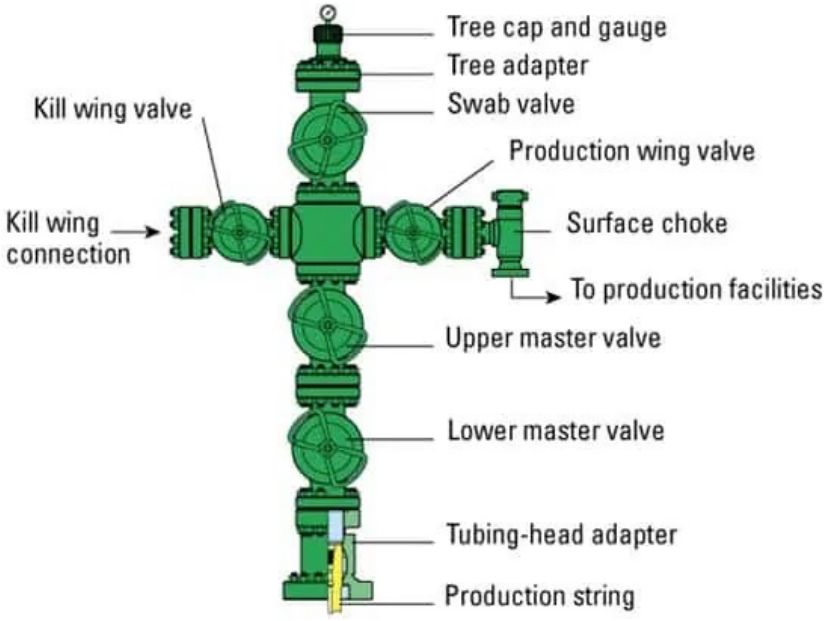
- **Well Completion**: The process of making a well ready for production (or injection) after drilling operations. Well completions ensure that the well is ready for production or injection as per the well placement and well depth.
- **High-Pressure, High-Temperature (HPHT) Considerations**: HPHT wells require specialized tools.
- **Wellhead with Situation Control**: This is the pressure-containing equipment at the surface of the well where casing strings are suspended and the Blow Out Preventer (BOP) or Christmas tree is connected.
- **Tubing Hanger**: This component sits in the upper portion of the wellhead, within the tubing head flange and serves as the main support for the production tubing1. The tubing hanger may be manufactured with rubber or polymer sealing rings to isolate the tubing from the annulus. It is secured within the tubing head flange with lag bolts that apply a downward pressure on the tubing hanger to compress the sealing gaskets and to prevent the tubing from being hydrostatically or mechanically ejected from the annulus.
- **Tubing**: Transports fluids from the wellbore to the surface. Production tubing is the main conduit for transporting hydrocarbons from the reservoir to the surface (or injection material the other way). It runs from the tubing hanger at the top of the wellhead down to a point generally just above the top of the production zone.

- Production tubing is available in various diameters, typically ranging from 2 inches to 4.5 inches. It may be manufactured using various grades of alloys to achieve specific hardness, corrosion resistance or tensile strength requirements. Tubing may be internally coated with various rubber or plastic coatings to enhance corrosion and/or erosion resistance.
- **Surface Casing**: The search results mention casing, but not specifically "surface casing." Casing generally refers to steel pipes placed into the wellbore to stabilize it. The search results also mention that Casing is set above the producing zone, the zone is drilled, and the liner casing is cemented in place.
- **Screens (Sand Control Screens)**: Prevent sand migration into the wellbore. Sand control screens prevent the ingress of sand into the wellbore, maintaining production rates and protecting equipment. An uncemented screen and liner assembly can be installed across the pay section to minimize formation damage and gives the ability to control sand.

Flap Type Valve: There was no mention of this specific component in the provided search results.

Mix Extractor: There was no mention of this specific component in the provided search results.

Christmas Tree:

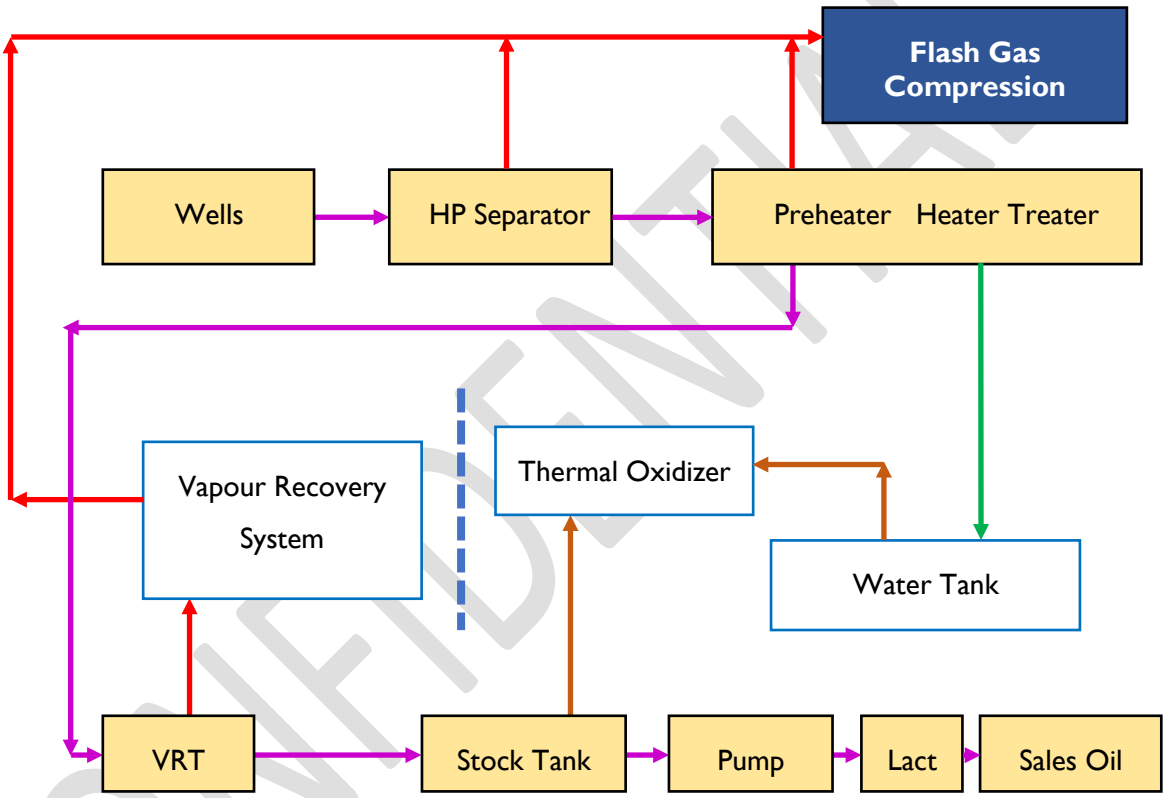


- **Production String:** The production string is the series of pipes that runs through the well from the surface to the reservoir. It carries oil or gas from the well to the surface facilities. In Christmas Tree it serves as the conduit for the oil or gas from the well into the production system. The Christmas Tree is attached to the production string and controls the flow.
- **Tubing Head Adapter:** The tubing head adapter (THA) is a connection point that connects the production tubing to the wellhead. It helps to support the tubing string and allows fluid from the well to be channelled to the surface. In Christmas Tree it provides a secure point for attaching the Christmas Tree to the wellbore and acts as an interface for connecting the tubing string to the surface equipment.

- **Lower Master Valve (LMV): T**he Lower Master Valve is a primary valve on the Christmas Tree that controls the flow of oil or gas from the well. It is typically used to isolate the well during well maintenance or emergencies. In Christmas Tree it provides the most significant level of safety by shutting off the flow of hydrocarbons from the well, preventing uncontrolled releases.
- **Upper Master Valve (UMV):** The Upper Master Valve is another key valve located above the Lower Master Valve. It works in conjunction with the LMV to control the flow of fluids. In Christmas Tree it provides an additional layer of control for the well, used for shutting in the well, when necessary, such as during maintenance or to control well pressures.
- **Choke:** The choke is a device that regulates the flow rate of oil or gas from the well. It is typically adjustable and helps manage pressure levels to prevent overproduction. In Christmas Tree the choke reduces the pressure in the production system, controlling the flow rate of the hydrocarbons and ensuring safe and efficient operation.
- **Production Wing Valve:** The production wing valve is a valve used to control the flow of production fluids from the well. It is positioned near the choke and allows the operator to manage the production flow. In Christmas Tree it is used for the isolation of the production flow and to direct it to the pipeline or storage system.
- **Swab Valve:** The swab valve is typically used for testing or well intervention. It allows fluids to be injected or withdrawn from the well during swabbing operations, which are done to clean or test the well. In Christmas Tree it facilitates wellbore cleaning and allows for pressure and flow testing to evaluate the condition of the well.
- **Tree Adapter:** The tree adapter connects the Christmas Tree to the wellhead and tubing system, allowing the rest of the Christmas Tree components to function properly. In Christmas Tree it ensures a secure connection to the wellbore and ensures proper alignment of the equipment.
- **Tree Cap & Gauge:** The tree cap is typically a cover that is placed on the Christmas Tree for protection when the well is not in production. The gauge is used to monitor the pressure in the wellbore. In Christmas Tree the cap protects the equipment from environmental damage when not in use, and the gauge provides critical data on well pressure, helping operators make informed decisions about production and safety.
- **Kill Wing Valve: T**he kill wing valve is a valve that is part of the blowout prevention system. It allows for the injection of kill fluids (e.g., heavy mud) into the well to control pressure and prevent blowouts. In Christmas Tree it plays a critical role in well control, particularly in emergencies when the well experiences uncontrolled pressure. It helps prevent dangerous situations such as blowouts by enabling operators to inject pressure-controlling fluids.
- **Kill Wing Connection:** This is the connection point for the kill wing valve. It provides a secure link for injecting kill fluids into the wellbore during an emergency. In Christmas Treee kill wing connection is used to supply kill fluids during emergency situations, like a blowout or uncontrolled release of hydrocarbons, to control well pressure and stop the flow.

5.1.4 Surface facility development: Overview of Surface Facility Development Process

Surface facility development in oil and gas exploration and production (E&P) involves designing, constructing, and integrating essential infrastructure to process, store, and transport hydrocarbons efficiently. These facilities play a crucial role in ensuring the safe handling of extracted crude oil and natural gas by incorporating wellhead platforms, flowlines, separators, storage tanks, and supporting systems. The development process focuses on optimizing production efficiency, maintaining safety standards, and minimizing environmental impact while ensuring seamless operations from extraction to transportation.



This Block diagram represents a **typical unconventional surface facility** used in oil and gas production, outlining key processes involved in handling extracted hydrocarbons. The process begins at the **wells**, where crude oil, natural gas, and water are brought to the surface. The extracted fluids pass through a **high-pressure (HP) separator**, which separates gas, oil, and water. The separated oil then moves through a **preheater and heater treater**, where it is heated to remove water and impurities.

Any excess gas from the separation process is captured by the **flash gas compression** system for further utilization or sale. Meanwhile, the separated water is directed to a **water tank** for disposal or treatment. The treated oil is then stored in a **stock tank** before being transferred for sale. A **vapor recovery system (VRT)** captures vaporized hydrocarbons, reducing emissions and improving efficiency, while a **thermal oxidizer** burns excess hydrocarbons to ensure environmental compliance.

Finally, the oil is pumped through a **Lease Automatic Custody Transfer (LACT) unit**, ensuring accurate measurement before it enters the sales pipeline. This system optimizes hydrocarbon recovery, enhances

operational efficiency, and minimizes environmental impact. Oil and gas surface facilities are an integrated system designed to extract, process, store, and transport hydrocarbons from the wellhead to refineries or distribution points. These facilities ensure efficient handling of crude oil and natural gas while maintaining safety and environmental standards.

The major components of surface production equipment include:

1) **Wellhead Systems** – Controls extraction and provides pressure containment.
2) **Flowlines** – Transport hydrocarbons from wells to processing facilities.
3) **Separators and Heater Treaters** – Separate oil, gas, and water for further processing.
4) **Tank Batteries and Metering Facilities** – Store and measure hydrocarbons before transportation.

Production engineers typically design all equipment within the lease area, while **pipeline and facilities engineers** manage transportation infrastructure beyond the lease boundary.

Key Components of Surface Facilities in Brief:

1) **Wellhead Systems:** The wellhead is a critical interface between the underground reservoir and surface facilities. It provides mechanical support, pressure control, and flow regulation.

- **Casing and Tubing Heads:** Provide structural support and pressure sealing.
- **Christmas Tree:** A system of valves and chokes that controls production flow.
- **Artificial Lift Equipment:** Used in wells that do not have enough natural pressure (e.g., sucker rod pumps, gas lift systems).
- **Pressure Monitoring and Safety Systems:** Includes pressure gauges and emergency shutoff mechanisms.

2) **Flowlines:** Flowlines are small-diameter pipelines that transport hydrocarbons from the wellhead to separation and processing facilities. They play a crucial role in gathering production and ensuring a continuous flow to the next stage. The development of pipelines in oil and gas surface facilities is a multi-step process that ensures the safe and efficient transportation of hydrocarbons from production sites to refineries or end-users. Each phase- from design to maintenance, it plays a crucial role in ensuring reliability, safety, and regulatory compliance. Flowlines connect wellheads to separators, ensuring that production moves efficiently through the facility.

- **Pipeline Design:** The initial stage involves determining the diameter, material, and layout of the pipeline system. Design considerations include oil and gas volume, pressure, terrain characteristics, and environmental factors. Proper planning helps optimize flow efficiency while minimizing operational risks.

- **Pipeline Construction:** Once the design is finalized, construction begins with excavation and trenching for pipeline installation. Pipes are laid, welded, and joined, followed by the integration of valves, fittings, and corrosion protection systems. Each step ensures structural integrity and long-term durability.
- **Pipeline Testing:** Before commissioning, pipelines undergo rigorous testing to verify integrity and safety. Hydrostatic testing (filling pipelines with pressurized water) is conducted to detect leaks, alongside additional structural and regulatory compliance checks.
- **Pipeline Commissioning:** After successful testing, the pipeline is connected to existing infrastructure and gradually introduced into service. Commissioning involves performance monitoring, system calibration, and safety validation to ensure seamless operation.
- **Pipeline Maintenance:** Regular maintenance is essential for continued pipeline reliability. This includes periodic inspections, repairs, and component replacements as needed. Advanced monitoring systems help detect pressure variations, corrosion, and blockages to prevent failures and optimize performance.

The pipeline development process in oil and gas facilities demands careful engineering, quality control, and proactive maintenance to guarantee safe, efficient, and uninterrupted hydrocarbon transportation across the network.

3) **Separation Systems:** Once hydrocarbons reach the surface, they need to be separated into their primary components: oil, gas, and water.

- **Separators**: Vessels that separate fluids based on density and gravity settling.
  - Gun Barrel, Free Water Knockout (FWKO), and Scrubbers are common separator types.
  - Gas Separation: Removes entrained liquids to prevent damage to downstream equipment.
  - Oil-Water Separation: Achieved using settling tanks and electrostatic coalescers.
- **Heater Treaters**: A special type of separator that uses heat to accelerate oil-water separation.
  - Heating reduces oil viscosity, helping water separate more efficiently.
  - Fuel Source: Typically powered by gas produced from the well itself.

Separation efficiency depends on factors such as fluid properties, temperature, and flow conditions.

4) **Tank Batteries and Metering Facilities:** After separation, hydrocarbons are stored and measured before transport.

- **Storage Tanks:** Hold oil and water before shipment or disposal -Typically, at least two tanks are used: one for filling and another for shipping.

➢ **Metering Systems:** Measure hydrocarbon flow rates and composition.

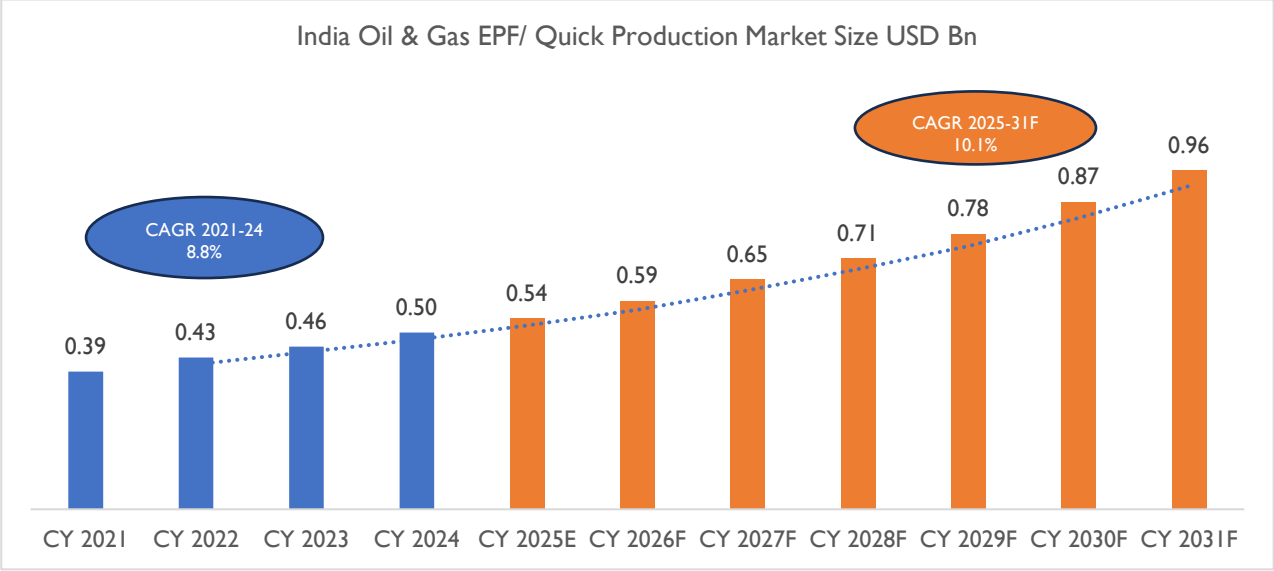
- Lease Automatic Custody Transfer (LACT) Units: Automatically measure oil volume, gravity, temperature, and water content.
- Orifice Meters: Used for gas flow measurement, with pressure and temperature sensors providing real-time data.

Custody Transfer: Oil and gas are transferred to pipelines, tankers, or other transportation systems under strict measurement standards to ensure accurate sales accounting.

5.1.5 Quick Production Facility/ Early Production Facility

An Early Production Facility (EPF) in the oil and gas industry is a modular and adaptable system designed to rapidly initiate production from newly discovered oil and gas fields. EPFs significantly shorten the time between discovery and the first production of oil or gas. Their modular nature allows for easy transportation, installation, and seamless integration into existing production setups. EPFs are instrumental in early monetization by enabling the extraction from drilled wells while exploration and full field development continue. They are particularly useful for monetizing small, isolated reserves (often referred to as "pimple fields") or temporarily enhancing production systems during the life cycle of a field.

India Oil & Gas Early Production Facilities (EPF)/ Quick Production Facilities Market:



Source: D&B Research

The India Oil & Gas Early Production Facilities (EPF)/Quick Production Facilities market has experienced steady growth from USD 0.39 billion in CY 2021 to USD 0.50 billion in CY 2024, reflecting a CAGR of 8.8%. This growth is driven by the increasing demand for quicker and more efficient oil and gas production solutions, which EPFs provide by enabling faster project execution and early revenue generation in emerging fields.

Looking forward, the market is projected to accelerate, reaching USD 0.96 billion by CY 2031, with a higher CAGR of 10.1% from CY 2025 to CY 2031. This growth is expected to be fuelled by continued investments in exploration and production, particularly in marginal and underdeveloped fields, where EPFs play a key role in maximizing production early in the project lifecycle. The trend toward faster time-to-market for oil and gas production, along with technological advancements in EPF design and efficiency, will further drive the market's expansion.

EPF Benefits in Field Development & Production Planning:

Early Revenue Generation: One of the key advantages of Early Production Facilities (EPFs) is their ability to generate revenue early in the project lifecycle. Designed for rapid deployment, EPFs can be quickly assembled and installed, often bringing production online in just a few months. Their modular design allows for seamless integration into existing infrastructure, reducing setup time and minimizing on-site construction. By enabling early production, EPFs facilitate faster monetization of oil and gas reserves, which can significantly enhance project financing and overall project economics. This quick start to production is especially valuable in reducing the time from discovery to revenue generation, benefiting both operating companies and investors.

Cost Efficiency: EPFs offer a cost-effective solution, especially for marginal fields, smaller reserves, or temporary production increases. By using modular, often prefabricated components, they reduce the initial capital expenditure typically required for full-scale production facilities. The minimal on-site construction needed further lowers costs, making EPFs an ideal choice for projects were larger, more permanent installations may not be economically justified. This efficiency allows operators to achieve early production without incurring the high costs associated with building a full-scale facility, improving the financial feasibility of smaller or less-developed reserves.

Flexibility, Scalability, and Upgradability: The modular nature of EPFs provides operators with significant flexibility and scalability, making them adaptable to evolving production needs. These facilities can be easily scaled up or down based on production requirements and market conditions, offering operators the ability to respond quickly to changing circumstances. EPFs can also be transported, installed, and upgraded with minimal effort, making it possible to modify the facility as the field develops. This adaptability ensures that operators can customize the EPF to meet specific field requirements and continue to enhance its capabilities over time as production increases or market conditions shift.

EPFs are typically deployed during the early stages of field development when production rates are lower, and the infrastructure needs to be quickly established to start generating revenue.

Infrastructure Involved:

1. **Modular Process Skids:** EPFs utilize modular process skids for various processing operations. These skids are compact, prefabricated, and easily deployable, allowing for rapid installation and integration into the EPF layout.
2. **Well Testing Skids:** Used for initial well testing and evaluation, these skids incorporate equipment such as chokes, separators, and metering systems to control flow and separate well fluids.
3. **Separation Skids:** These skids include two-phase or three-phase separators to separate the well stream into gas, oil/condensate, and water phases.
4. **Stabilization Skids:** Used to condition the produced oil or condensate by removing light hydrocarbon components and meeting transportation specifications.
5. **Dehydration Skids:** These skids remove water vapor from the gas stream, preventing hydrate formation and corrosion issues.
6. **Metering and Custody Transfer Skids (LACT Skids):** Used for accurate measurement and custody transfer of produced liquids, these skids incorporate components like flow meters and samplers.
7. **Produced Water Treatment Skids:** Designed to treat and manage the produced water stream, removing contaminants such as oil, solids, and dissolved salts.

Flare and Vent Skids: Used for safe disposal of excess gases or relief during upset conditions, ensuring compliance with environmental regulations.

5.1.6 Analysis Of Investments / Projects in India's Upstream Oil & Gas Sector

India's petroleum industry is a diverse sector that spans the exploration, production, refining, distribution, and marketing of petroleum products. It covers upstream activities, such as the extraction of crude oil and natural gas; midstream operations, which involve the transportation and storage of these resources; and downstream processes, including the refining and distribution of fuels like petrol, diesel, LPG, and kerosene.

India's oil and gas sector is experiencing a surge in investments driven by increasing energy demand and the government's proactive measures to bolster domestic production and reduce import reliance. This has made the sector highly attractive for investment. The government's initiatives, such as allowing foreign investment in significant parts of the sector, including natural gas and petroleum products, and permitting foreign investors to own up to 49% of public sector projects without reducing the government's share, have sparked considerable interest from both domestic and international companies.

Recent updates in India's petroleum industry:

- India is set to expand its exploration acreage to **1 million square kilometres by 2030**, with a **16%** growth anticipated in 2025. The price of a domestic LPG cylinder in India remains among the lowest globally, priced at **INR 803 for a 14.2 kg cylinder**. For households under the PMUY scheme, the effective price drops to **INR 503 per cylinder** after a targeted subsidy of **INR 300.**
- The approval process for exploration and production activities has been streamlined, cutting **down from 37 to just 18 approval steps,** with nine of them now eligible for self-certification.
- The introduction of the Oilfields (Regulation and Development) Amendment Bill in 2024 ensures greater policy stability for oil and gas producers and facilitates a single license for all hydrocarbons. The bill was recently approved by the Rajya Sabha on December 3, 2024.

Investments in Upstream Sector:

- Minister of Petroleum & Natural Gas, Mr. Hardeep Singh Puri, stated that the Exploration and Production (E&P) sector presents investment prospects totalling USD 100 billion by 2030.
- India's oil demand in 2024 is projected to increase by 220,000 barrels per day, reaching a total of 5.57 million barrels per day, reflecting a 4.19% rise compared to 2023, according to OPEC estimates.
- In February 2023, Oil India Limited launched its project for India's first exploratory oil well in the Mahanadi Onshore Basin in Odisha, under the OALP initiative.
- Additionally, in May 2022, ONGC revealed plans to invest USUSD 4 billion between FY 2022-25 to boost its exploration activities within India.

Future Prospects: India's petroleum industry is heading toward a transformative future, influenced by global shifts in energy and growing domestic demand. The sector's growth will be driven by higher investments in exploration, expanding refining capabilities, and integrating renewable energy solutions. Efforts such as the development of green hydrogen and carbon capture technologies underscore the industry's flexibility. With an emphasis on sustainability and energy efficiency, India is positioned to retain its leadership in the global energy arena while fulfilling its climate goals.

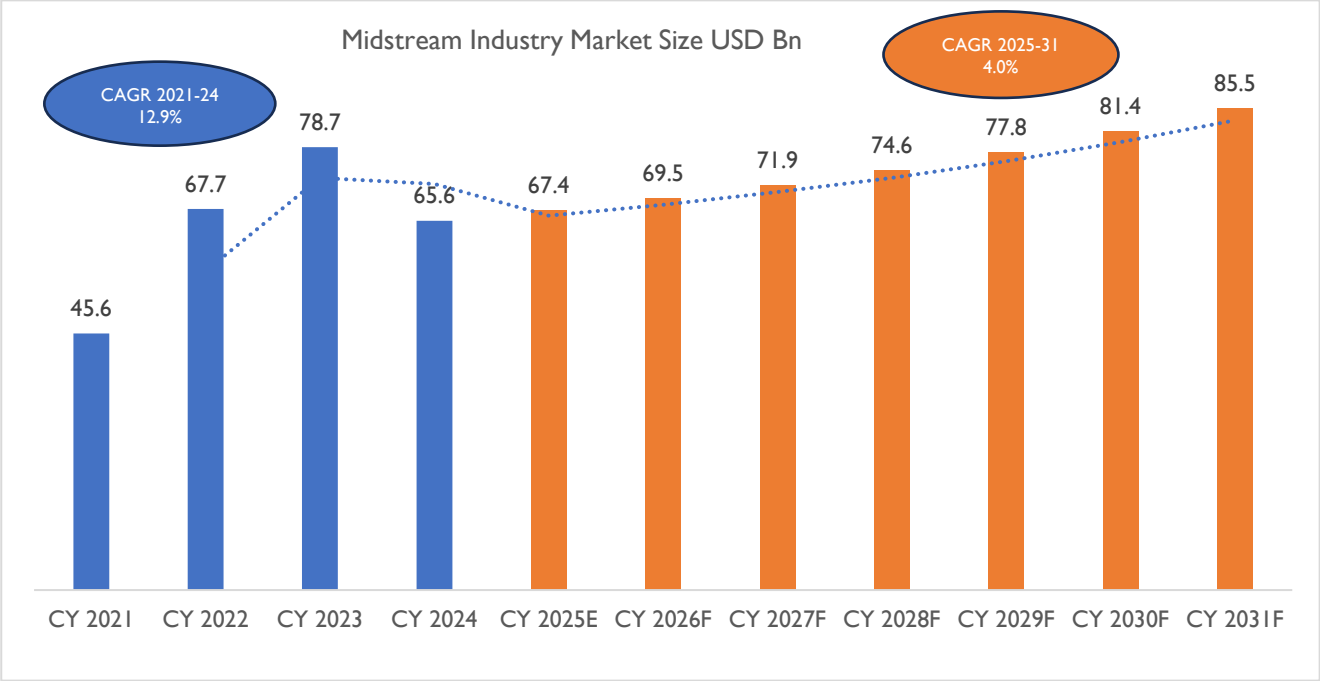
Future targets of the country:

Key Area	Future Target
Refining Capacity	309.5 MMTPA by 2030
Ethanol Blending	20% by 2025-26
Green Hydrogen Production	5 MMTPA by 2030
Exploration Acreage	1 million sq. kms. by 2030

Source: PIB.Gov

5.2 Midstream Infrastructure: Transportation, Storage & Processing

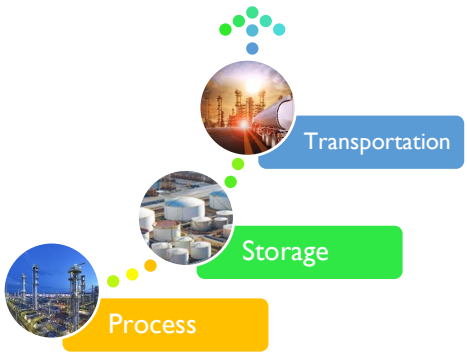
Midstream Industry Market: Historical Trend and Forecasted Market Growth

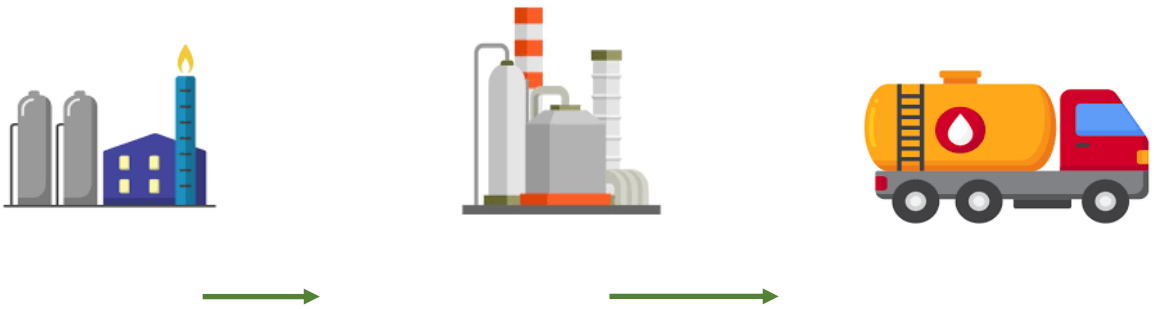


Source: Primary and Secondary Research

Midstream operations in the oil and gas industry act as a crucial link between upstream extraction and downstream distribution. This stage focuses on transporting, storing, and processing the crude oil and natural gas to ensure they are ready for further end use. Key midstream activities include moving extracted resources via pipelines, ships, or other transport systems, storing them at designated facilities, and processing them. These steps ensure that oil and gas meet quality standards before being delivered for commercial and industrial.

Essentially, midstream operations form the logistical backbone applications of the industry, enabling a seamless transition of resources from extraction sites to refineries and, ultimately, to end-users. The midstream sector of the oil and gas industry consists of three primary segments: transportation, storage, and processing. Each of these plays a vital role in ensuring the smooth movement, handling, and refinement of crude oil and natural gas before they reach end-users.





Processing: Processing is the initial stage of midstream activities, where raw natural gas is purified, and valuable natural gas liquids (NGLs) are extracted. Natural gas processing plants play a crucial role in removing impurities such as water, carbon dioxide, and sulphur, ensuring the gas meets quality standards before further use. Additionally, these plants separate NGLs like ethane, propane, and butane, which have significant industrial applications. Fractionation facilities further refine these NGLs by using a distillation process to isolate individual components, enabling their sale for various commercial and industrial purposes. This stage ensures that natural gas and its byproducts are properly treated and prepared for efficient utilization.

Storage: Storage serves as the intermediary phase, balancing supply and demand fluctuations while ensuring a steady supply of oil and gas. Crude oil is stored in large tanks or underground caverns near production sites and refineries, allowing for future processing and use. Natural gas, on the other hand, is stored in underground facilities such as depleted reservoirs, salt caverns, and aquifers to manage seasonal demand shifts. Similarly, refined petroleum products like gasoline, diesel, and jet fuel are kept in storage tanks at refineries, distribution terminals, and fuel depots, ensuring they are readily available for efficient distribution when needed.

Transportation: Transportation is the final stage of midstream operations, responsible for moving crude oil, natural gas, and refined products from storage facilities to processing plants and end-users. Pipelines are the most cost-effective and secure method for transporting hydrocarbons over long distances. They are categorized into crude oil pipelines, which transfer unrefined oil to refineries, natural gas pipelines that move gas from extraction sites to processing plants, and product pipelines that distribute refined fuels such as gasoline and diesel. Additionally, tankers play a crucial role in international trade, transporting bulk quantities of crude oil and liquefied natural gas (LNG) across oceans. These vessels include crude oil tankers, LNG carriers, and product tankers that handle refined petroleum. For shorter distances, trucks provide flexibility by delivering oil and gas to areas not serviced by pipelines or rail, ensuring last-mile connectivity in the supply chain.

Overall, midstream operations ensure the seamless transition of oil and gas from extraction to final distribution by integrating efficient transportation, storage, and processing systems. These activities form the backbone of the energy supply chain, enabling the reliable and secure delivery of fuel resources worldwide.

Transportation, Storage & Processing Drivers for Oil & Gas Industry:

Infrastructure Development and Investments

- The Indian government has been investing heavily in building and upgrading oil and gas infrastructure, including pipelines, storage facilities, and terminals to ensure efficient transportation and processing of oil and gas.
- Example: The Indian Strategic Petroleum Reserve (ISPR) has been established to store crude oil at strategic locations, ensuring energy security during emergencies.
- Additionally, IOCL (Indian Oil Corporation Limited) has developed multi-product pipelines that transport petroleum products efficiently across regions.

Privatization and Public-Private Partnerships (PPP)

- The oil and gas sector in India has seen increased participation from private players, leading to more investment in infrastructure. PPP models have enabled faster and more efficient project execution, ensuring the timely construction of pipelines, storage facilities, and processing plants.
- Example: The GAIL India Ltd. has expanded its gas pipeline network under a PPP model, improving transportation efficiency and enabling the delivery of natural gas to various industries.

Energy Security Concerns

- With growing geopolitical uncertainties and the risk of energy supply disruptions, India has focused on enhancing its storage and processing capabilities to ensure energy security.
- Example: The Strategic Petroleum Reserves (SPR) in locations such as Mangalore, Visakhapatnam, and Padur help store emergency supplies of crude oil, ensuring India's ability to manage supply disruptions.

Logistics and Distribution Network Enhancement

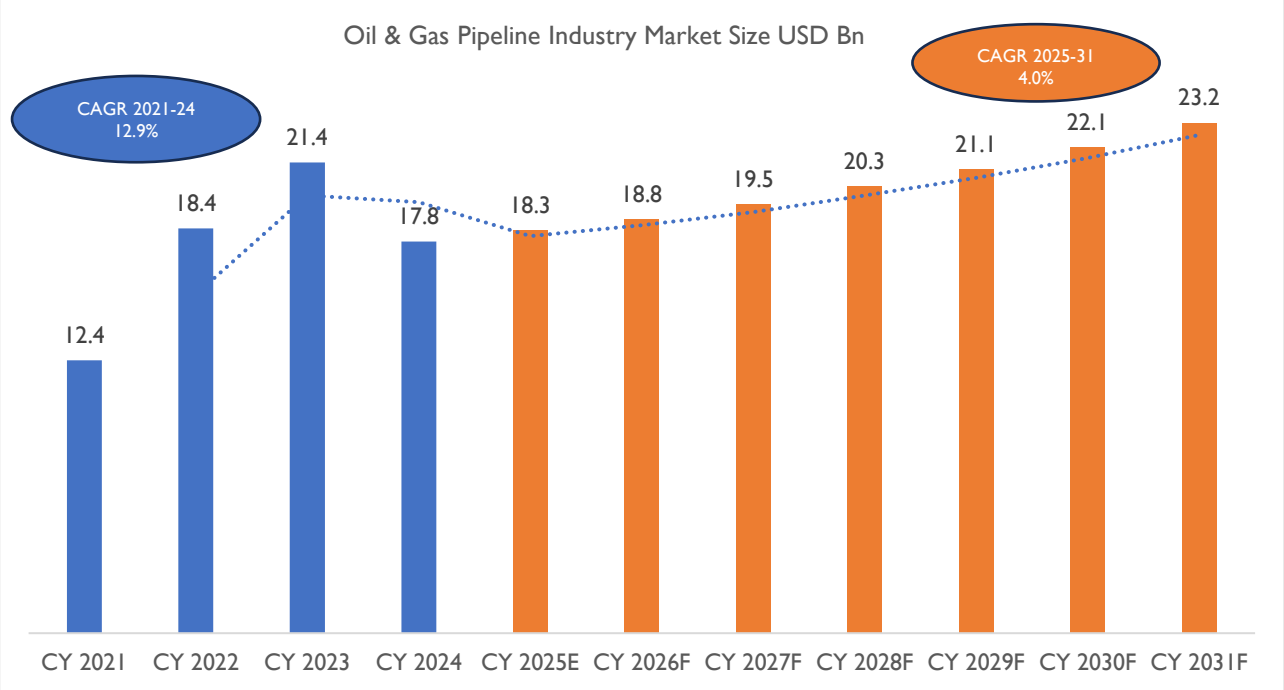
- The growth of logistics networks, including rail, road, and sea transportation, plays a significant role in the efficient movement of oil and gas products. Investment in ports and infrastructure has enabled better distribution and processing.
- Example: The JNPT (Jawaharlal Nehru Port Trust) in Mumbai has become a vital hub for the import and export of crude oil and refined petroleum products, driving the transportation needs of the oil and gas sector.

5.2.1 Oil & Gas Pipeline Infrastructure in India

India's Oil & Gas Pipeline Infrastructure is a vital component of the country's energy transportation system, facilitating the movement of crude oil, natural gas, and refined products across vast distances. The pipeline network spans over 16,000 kilometres, connecting major production centres, refineries, and consumption hubs, and plays a crucial role in ensuring the efficient, safe, and cost-effective delivery of energy resources.

Key pipelines include crude oil pipelines, natural gas transmission lines, and product pipelines, which support both domestic needs and regional exports. India is also expanding its pipeline infrastructure with significant projects such as the Pradhan Mantri Urja Ganga Project, aimed at increasing natural gas accessibility, and the National Gas Grid, intended to integrate gas supply across states. The government's focus on improving pipeline infrastructure is helping reduce reliance on road and rail transport, reducing costs, enhancing energy security, and minimizing environmental impact. Additionally, with increasing demand for cleaner energy sources, there is a growing emphasis on LNG (Liquefied Natural Gas) pipelines, strengthening India's position as a key player in the global energy market.

Oil & Gas Pipeline Industry Market: Historical Trend and Forecasted Market Growth (CY 2021-CY 2031):



Source: Primary and Secondary Research

Table 4 Existing Major Crude Oil Pipelines in India- As on 31.03.2023 by Ministry of Petroleum and Natural Gas Latest Annual Report:

Type of Pipeline/ Owner/ Name of Pipeline	Length (Km)	Capacity (MMT)	Throughput (MMT)		Capacity Utilization in 2022-23 (%)
			2021-22	2022-23	
IOCL					
Salaya Mathura Pipeline	2646	25.0	25.9	28.5	114.2
Mundra Panipat Pipeline	1194	8.4	7.0	5.8	69.2
Paradip Haldia Barauni pipeline	1355	15.2	15.6	19.0	125.2
Salaya Mathura Pipeline	14	-	-	-	-
Paradip Haldia Barauni pipeline	92	-	-	-	-
A. Total IOCL	5301	48.6	48.5	53.4	109.8
ONGC					
CTF Kalol to CTF Nawagam - New	63	3.1	1.1	1.0	33.2
Nawagam-Koyali (18" New)	80	5.4	3.6	3.7	68.9
Nawagam-Koyali (14" Old)	78	3.3	0.0	0.0	0.0
Mehsana-Nawagam trunk line - New	77	2.3	2.1	2.1	93.4
CTF, Ankleshwar to Koyali pipeline	95	2.2	0.6	0.5	24.2

CTF, Ankleshwar to CPF, Gandhar	44	0.4	0.0	0.0	0.0
CPF, Gandhar to Saraswani 'T' point	57	1.8	0.5	0.4	23.4
Akholjuni- Koyali oil pipe line	66	0.5	0.4	0.4	82.5
Lakwa-Moran oil line (New)	15	1.5	0.5	0.5	34.0
Lakwa-Moran oil line (Old)	18	1.5	0.0	0.0	0.0
Geleki-Jorhat oil line (old)	49	1.5	0.0	0.0	0.0
Geleki-Jorhat oil line (new)	48	1.5	0.3	0.3	18.7
Borholla- Jorhat (old)	43	0.6	0.0	0.0	0.0
Borholla- Jorhat (New)	43	0.6	0.2	0.2	34.8
NRM (Narimanam) to CPCL	5	0.7	0.4	0.3	41.9
KSP-WGGS to TPK Refinery	14	0.1	0.1	0.1	74.4
GMAA EPT	4	0.1	0.0	0.0	36.2
Mumbai High - Uran Trunk Pipeline	204	15.6	6.4	3.6	23.2
Heera-Uran Trunk Pipeline	81	11.5	4.4	6.0	52.4

Bombay-Uran Trunk 30" Pipeline	203	6.4	0.0	0.5	7.4
B. Total ONGC	1284	60.6	20.6	19.8	32.6
OIL					
Duliajan-Digboi-BarauniBongaigaon Pipeline	1193	9.0	6.2	6.8	76.0
HMPL					
Mundra - Bhatinda Pipeline	1017	11.3	13.1	12.8	113.8
BPCL					
Vadinar - Bina Pipeline	937	7.8	7.4	7.8	100.2
CAIRN					
Mangala- Bhogat Pipeline	660	8.7	5.9	5.1	58.6
Bhogat- Marine	28	2.0	1.4	2.1	105.0
C. Total CAIRN	688	10.7	7.3	7.2	67.2
D. Total Crude Oil Pipeline	10420	147.9	103.1	107.8	72.8

Source: MoPNG

India's natural gas pipeline infrastructure plays a crucial role in the economical and safe transportation of natural gas. The network has evolved significantly over the past two decades, and recent developments have further expanded its reach. As of September 2024, 33,475 km of natural gas pipelines have been authorised, with 24,945 km operational and over 10,000 km still under construction. Over the last four to five years alone, nearly 7,500 km of operational pipelines have been added to the network. India also maintains a robust crude oil pipeline network, which spans 10,938 km and has a total capacity of 153.1 million metric tonnes per annum (mmtpa), complementing the country's growing energy infrastructure and supporting its increasing demand for energy.

Historically, GAIL (India) Limited and Gujarat State Petronet Limited (GSPL) dominated the natural gas pipeline network in India before 2007. The formation of the Petroleum and Natural Gas Regulatory Board (PNGRB) in 2006 introduced new regulations and tariff structures, which revealed regional imbalances in the pipeline infrastructure. Between 2007 and 2020, the network expanded from 7,200 km to about 17,000 km, owned by multiple entities, each implementing its own tariff system. This concentration of pipelines in select regions led to imbalances in the national network.

To address these issues, a number of reforms were implemented between 2020 and 2023, including measures to extend gas accessibility to remote areas and the discontinuation of the additive tariff regime. A key initiative in this transformation is the "One Nation One Gas Grid" project, which connects 22 trunk and regional pipelines, aiming to create a unified, efficient national gas network. Starting in April 2023, the PNGRB introduced a unified tariff system for interconnected pipelines, creating three tariff zones rather than two.

Despite the expansion, capacity utilisation remains relatively low for most pipelines, with major networks operating at 40-50% capacity. For instance, GAIL's integrated pipeline network operates at 48% capacity, and Indian Oil Corporation's Dadri-Panipat pipeline at 52%. GSPL's network is an exception, operating at 71% capacity. To boost capacity utilisation, further expansion of the pipeline network, particularly in remote areas, is essential.

Pipeline Infrastructure Limited (PIL) is a key player in this expansion. It operates a 1,480 km pipeline from Kakinada in Andhra Pradesh to Bharuch in Gujarat, which is India's first bi-directional natural gas pipeline. This pipeline connects important supply hubs on the east coast to key demand centres in the west. The network is supported by 10 compressor stations and has an installed power capacity exceeding 900 MW. Currently, PIL's capacity utilisation stands at about 40%, and it transports roughly 30% of the country's domestic gas. In the past five years, the volume transported by PIL has nearly doubled, driven by an increased supply of domestic gas from the east coast. The entire pipeline is remotely operated from two control stations, one in Mumbai and the other in Hyderabad.

PIL serves various sectors, including refineries, fertilisers, petrochemicals, power plants, and city gas distribution (CGD), making it an integral part of India's national gas grid and the unified tariff regime. To assess its operational efficiency, benchmarking exercises are conducted against global pipelines. In 2022, a total of 41 pipelines, including six gas pipelines, were evaluated. The study revealed that while Indian pipelines excel in several areas, such as operational practices, energy efficiency remains an area for improvement. Additionally, expenditure on maintenance and integrity management is lower than global standards, potentially affecting long-term pipeline safety and reliability. Although pipeline utilisation has shown improvement, there is still considerable potential for further growth.

Table 5 List of fully operational common carrier natural gas pipelines: [6]

Natural Gas Pipelines	State(s)	Length (KM) (Operating)	Ownership
Assam Regional Network	Assam	8	GAIL
Cauvery Basin Network	Puducherry and Tamil Nadu	242	GAIL
Hazira-Vijaypur-Jagdishpur - GREP (Gas Rehabilitation and Expansion Project)-Dahej-Vijaypur HVJ/VDPL	Uttar Pradesh, Madhya Pradesh, Rajasthan and Gujarat, Haryana, Delhi, and Uttarakhand	6,732	GAIL
Dahej-Vijaypur (DVPL)-Vijaypur-Dadri (GREP) Upgradation DVPL 2 & VDPL	Uttar Pradesh, Madhya Pradesh, Rajasthan and Gujarat, Haryana, Delhi, and Uttarakhand	6,732	GAIL
Kakinada-Hyderabad-Uran-Ahmedabad (East West Pipeline)	Andhra Pradesh, Gujarat, Maharashtra, Telangana and Karnataka	1,483	PIL
Dahej-Uran-Panvel-Dabhol	Gujarat, Maharashtra, UT of Dadra & Nagar Haveli and Daman & Diu	943	GAIL
KG Basin Network	Andhra Pradesh	867	GAIL
Gujarat Regional Network	Gujarat	585	GAIL
Agartala Regional Network	Tripura	65	GAIL
Dadri-Panipat	Haryana and Uttar Pradesh	143	IOCL
Mumbai Regional Network	Maharashtra	125	GAIL
Uran-Trombay	Maharashtra	24	ONGC
High Pressure Gujarat Gas Grid	Gujarat	2758	GSPL

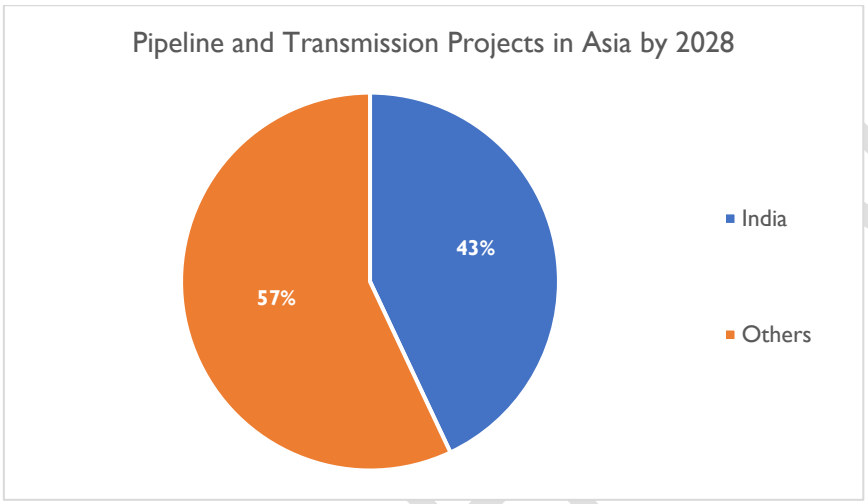
[6] Government of India

Hazira-Ankleshwar (HAPI)	Gujarat	73	GGL
Low Pressure Gujarat Gas Grid	Gujarat	57	GSPL
Shahdol-Phulpur	Madhya Pradesh and Uttar Pradesh	304	RGPL
Assam Regional Network	Assam	107	AGCL
Dukli – Maharajganj	Agartala (Tripura)	0 (5.2 Auth.)	GAIL
Uran-Taloja	Maharashtra	42	DFPCL
Vijaipur-Auraiya-Phulpur spur line	Madhya Pradesh, Uttar Pradesh	667	GAIL
Chainsa-Jhajjar-Hissar	Haryana, Rajasthan	444	GAIL
Dadri-Bawana-Nangal	Punjab, Haryana, Uttar Pradesh, Uttarakhand, Delhi, Himachal Pradesh	983	GAIL

Source: MoPNG

5.2.2 Expansion Plans: Upcoming Pipeline Networks

On January 7, 2025, India's Ministry of Petroleum and Natural Gas announced plans to expand the country's natural gas pipeline network by an additional 10,805 kilometres (6,714 miles). This expansion builds on the existing network, which spanned 24,945 kilometres (15,499 miles) as of September 10, 2024. Compared to the 15,340 kilometres (9,532 miles) in operation in 2014, this reflects a 62.6% increase in pipeline infrastructure.[7]



Source: D&B Research

Out of the 62 pipeline projects set to commence operations in India by 2028, gas pipelines are anticipated to make up 48.4%, followed by product pipelines at 40.3% and oil pipelines at 11.3%. Gas pipelines are projected to dominate in terms of length, accounting for 57% of total pipeline expansions. Key upcoming gas pipeline projects include the **Jagdishpur–Haldia Phase II pipeline**, spanning 1,900 km and operated by **GAIL (India) Ltd**, expected to begin operations in 2024. Another major development is the **Mehsana–Bhatinda pipeline**, stretching 1,834 km, operated by **GSPL India Gasnet Ltd**, and also slated for completion in 2024.

Product pipelines will contribute around 30% of total transmission pipeline length additions. Among these, the **Kandla–Gorakhpur product pipeline**, covering 2,809 km, is one of the most significant projects. This pipeline is currently under construction and expected to commence operations in 2024, with IHB Ltd serving as the operator. This rapid expansion aligns with India's broader strategy to strengthen its oil and gas infrastructure, improve accessibility, and support its growing energy consumption needs.

[7]https://www.pipeline-journal.net/news/india-expand-natural-gas-pipeline-network-nearly-11000-km#:~:text=India%20plans%20to%20expand%20its,announced%20on%20January%207%2C%202025.

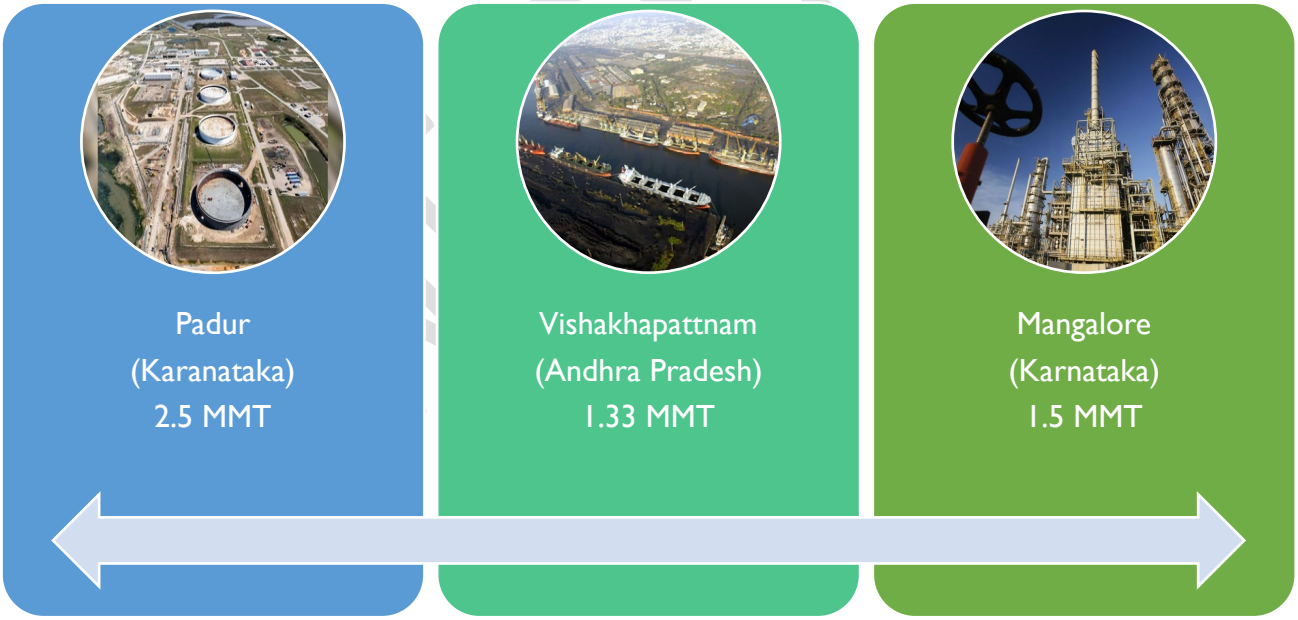
Pipeline Project Name	Length (km)	Expected Completion Date & Estimated Project Cost	Description
Jagdishpur-Haldia-Bokaro-Dhamra Natural Gas Pipeline (Urja Ganga Project)	3,306	Mar-25 (Estimated Project Cost: 12,940 Crore)	Aimed at connecting the eastern part of India with the National Gas Grid, this pipeline will ensure the availability of natural gas in Uttar Pradesh, Bihar, Jharkhand, Odisha, and West Bengal. It also plans to connect to the North-East Grid, serving eight North-Eastern states in phases. The project has faced delays due to right-of-use (RoU) availability issues but is now slated for completion by March 2025.
National Gas Grid Expansion	10,805	Ongoing (Estimated Project Cost: 12,940 Crore)	The Ministry of Petroleum and Natural Gas has announced plans to expand the national gas grid by 10,805 km. This expansion aims to connect all major demand and supply centres across India, ensuring uniform availability of natural gas and supporting economic and social progress.
Mehsana–Bhatinda Natural Gas Pipeline	1,834	2025 (Estimated Project Cost: 4,500 Crore)	Operated by GSPL India Gasnet Ltd, this pipeline aims to transport natural gas from Mehsana in Gujarat to Bhatinda in Punjab, enhancing gas connectivity in northern India.
Mumbai–Nagpur–Jharsuguda Natural Gas Pipeline	1,755	2025 (Estimated Project Cost: Rs 2660 crore)	Managed by GAIL (India) Ltd, this pipeline will connect Mumbai in Maharashtra to Jharsuguda in Odisha via Nagpur, facilitating gas distribution across central and eastern regions.
Kandla–Gorakhpur LPG Pipeline	2,809	2025 (Estimated Project Cost: 10,923 Crore)	Operated by IHB Pvt Ltd, this pipeline is set to be the longest upcoming pipeline, aiming to meet the growing liquefied petroleum gas demand in the western parts of Gujarat, Madhya Pradesh, and Uttar Pradesh.
North-East Natural Gas Pipeline Grid Project	1,656	2025 (Estimated Project Cost: Rs 9265 Crore)	This project involves constructing a natural gas pipeline grid branching from Guwahati to Imphal, Agartala, and Itanagar, aiming to enhance gas connectivity in northeastern India.
Turkmenistan–Afghanistan–Pakistan–India (TAPI) Pipeline	1,814	Ongoing (Investment: Rs 65,360 Crore)	The TAPI pipeline aims to transport natural gas from Turkmenistan through Afghanistan and Pakistan into India, enhancing regional energy cooperation. The Turkmenistan section was completed in 2024, with ongoing developments in Afghanistan.

5.2.3 Strategic Petroleum Reserve Program in India

In a move to enhance the country's energy security, the Government of India approved the construction of Strategic Petroleum Reserves (SPRs) on January 7, 2004. To implement and manage these reserves, a Special Purpose Vehicle (SPV) was established. In 2006, the ownership of Indian Strategic Petroleum Reserve Limited (ISPRL) was transferred to the Oil Industry Development Board (OIDB) following a decision by the Cabinet Committee on Economic Affairs (CCEA). The SPRs are funded through OIDB resources. Currently, ISPRL operates as a wholly owned subsidiary of the Oil Industry Development Board, a corporate body.

Under Phase-I of the SPR program, ISPRL developed underground rock caverns with a total storage capacity of 5.33 million Metric Tonnes (MMT) at three locations: Visakhapatnam (1.33 MMT) in Andhra Pradesh, and Mangalore (1.5 MMT) and Padur (2.5 MMT) in Karnataka. These reserves serve as a safeguard against supply disruptions, ensuring strategic availability of crude oil during emergencies.

Collectively, the three SPRs can sustain approximately 9.5 days of national demand and were officially dedicated to the nation by the Hon'ble Prime Minister on February 10, 2019. The Government of India has allocated substantial funds to develop and maintain the SPRs. In the 12th Five-Year Plan, ₹4,948 crore was approved to fund the development of Visakhapatnam cavern and partially fund the Mangalore and Padur facilities.



The Abu Dhabi National Oil Company (ADNOC) has participated in Phase-I by storing 5.86 million barrels of Abu Dhabi National Oil Company crude in Cavern-A of the Mangalore SPR. To optimize utilization, the Union Cabinet approved the commercialization of Phase-I SPRs on July 8, 2021. This initiative allows ISPRL to lease up to 30% of the storage capacity to Indian or foreign companies, while ensuring that the Government of India retains priority rights over the stored crude in case of exigencies. Additionally, up to 20% of the storage capacity can be traded by Indian companies.

Expanding on the initiative, the government approved Phase-II of the SPR program, which includes an additional 6.5 MMT of storage capacity at Chandikhol (4 MMT) in Odisha and Padur (2.5 MMT) in Karnataka. These facilities, developed under the Public-Private Partnership (PPP) model, will also include two dedicated Single Point Moorings (SPMs) and associated pipelines.

Taking advantage of low crude oil prices in April-May 2020, India filled its SPRs to full capacity, leading to notional savings of approximately INR 5,000 crore. To attract global participation in Phase-II, two roadshows were conducted, drawing interest from major global trading firms such as Trafigura, BP, PetroChina, Glencore, Shell, Vitol, and others. The entire SPR infrastructure, including the caverns, SPMs, and pipelines, will remain under the ownership of the Government of India. At the end of the 60-year concession period, the facilities will be transferred back to the government.

Advantages and Application Area for Oswal Energies:

The Strategic Petroleum Reserve Program can benefit various equipment from Oswal Energies, particularly those used in oil and gas storage, processing, and transportation. Examples include:

- **Storage Tanks**: These are crucial for storing large quantities of petroleum and other chemicals, which are essential in maintaining strategic reserves.
- **Pressure Vessels**: Used for storing and processing pressurized liquids and gases, including petroleum products that are part of the reserve infrastructure.
- **Heat Exchangers**: Employed in refinery processes for transferring heat between different fluid systems, helping maintain optimal temperatures for oil storage and processing.
- **Pig Launcher & Receiver**: Essential for maintaining pipeline integrity, which is vital for the transportation and storage of crude oil in reserve facilities.

5.2.4 Future Plans in Establishing Strategic Petroleum Reserves

India's future strategic petroleum reserve (SPR) plans centre on significantly expanding its storage capacity to enhance energy security. The approved Phase II expansion involves establishing two new commercial-cum-strategic facilities, adding a total of 6.5 million Metric Tonnes (MMT) to the nation's reserves. These new reserves will be strategically located at Chandikhol in Odisha, with a capacity of 4 MMT, and an expansion of the existing facility at Padur in Karnataka, adding 2.5 MMT.

This expansion is being pursued under a Public-Private Partnership (PPP) model, leveraging private sector expertise and investment. The goal is to not only increase storage capacity but also to create commercial opportunities within the SPR framework. To that end, Budget 2025-26 has allocated ₹5,597 crore for oil purchases for the SPRs, ₹180 crore for operations and maintenance, and ₹335 crore for land acquisition and construction of new caverns.

The entire SPR facility will remain under the ownership of the Government of India. The agreement with the private partner stipulates that at the end of the 60-year concession period, the strategic petroleum reserve, including associated infrastructure like the Single Point Mooring (SPM) and pipelines (both onshore and offshore), will be transferred back to the Government.

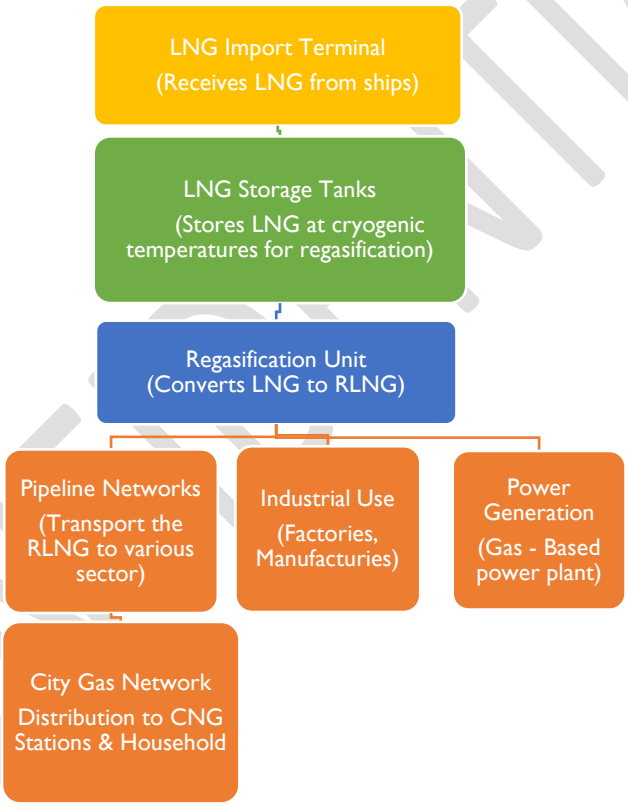
A critical aspect of these future plans is ensuring India's priority access to the stored crude oil. The Government of India will retain the first right to utilize the crude oil stored in these facilities in the event of an oil shortage or supply disruption.

Feature	Existing (Phase I)	Future (Phase II)
Capacity	5.33 MMT	6.5 MMT
Locations	Visakhapatnam (AP), Mangaluru & Padur (Karnataka)	Chandikhol (Odisha), Padur Expansion (Karnataka)
Mode	Government-owned	Public-Private Partnership (PPP)
Commercial Use	Partial	Fully commercial; operator can trade all stored oil
Government First Right	Yes, in case of oil shortage	Yes, in case of oil shortage
Completion	Completed	Target 2029-30 (for first SPR with private company)

5.2.5 RLNG Terminal Infrastructure in India

Regasified Liquefied Natural Gas (RLNG) is natural gas that has been cooled to approximately -160°C, transforming it into Liquefied Natural Gas (LNG) for easier storage and transportation. Upon reaching import terminals, LNG is regasified, converting it back into its gaseous state, and then distributed via pipelines to various sectors, including industry, power generation, and city gas distribution networks. This cleaner alternative to conventional fossil fuels is used in electricity generation, industrial heating, transportation, and residential applications. Terminal infrastructure for RLNG involves specialized facilities designed for importing, storing, processing, and distributing LNG. These include receiving docks, cryogenic storage tanks, regasification units, and pipeline connections, ensuring safe and efficient handling of LNG at every stage of the process to meet the growing energy demands of the country.

Existing RLNG Infrastructure in India



LNG Import Terminals:

India has developed several LNG import terminals along its coastline to meet its growing energy needs. Notable terminals include:

- **Dahej LNG Terminal (Gujarat):** Operated by Petronet LNG, with a capacity of 17.5 million tonnes per annum (MTPA). The project cost is estimated at Rs.2,800 crore.
- **Kochi LNG Terminal (Kerala):** Also managed by Petronet LNG, with a capacity of 5 MTPA. And the project is expected to cost around Rs.2,300 crore.

- **Chhara LNG Terminal (Gujarat):** Developed by Hindustan Petroleum Corporation Limited (HPCL), expected to commence operations by the end of 2024 or early 2025, with a capacity of 5 MTPA with an investment of approximately Rs 4,750 crore
- **Gopalpur Port (Odisha):** Petronet LNG plans to set up a floating LNG receipt facility here, with a capacity of about 4 MTPA. The enterprise value of GPL is projected to be Rs 3,080 crore, subject to closing adjustments, with a total consideration for the stake of Rs 1,349 crore.

LNG Storage Tanks: Upon unloading, LNG is stored in cryogenic tanks designed to maintain temperatures around -160°C, ensuring it remains in liquid form until regasification.

Regasification Units: Stored LNG is converted back to its gaseous state using heat exchangers, often utilizing seawater or other heat sources.

Distribution Network: Post-regasification, natural gas is distributed through pipelines to various end-users:

- **Industrial Use:** Factories and manufacturing units utilize natural gas for processes requiring consistent and efficient energy sources.
- **Power Generation:** Gas-based power plants use natural gas to generate electricity, contributing to the national grid.
- **City Gas Distribution (CGD):** Urban areas receive natural gas for residential cooking, heating, and fueling Compressed Natural Gas (CNG) stations for vehicles.

Advantages and Applications for Oswal Energy: Oswal Energy's heavy engineering division can contribute significantly to the RLNG infrastructure through:

- **Storage Tanks:** Designing high-pressure, cryogenic storage tanks for LNG.
- **Pressure Vessels:** Manufacturing vessels to handle natural gas under pressure during storage and transport.
- **Heat Exchangers:** Providing high-efficiency heat exchangers crucial for the regasification process.
- **Piping Systems:** Supplying heavy-duty piping systems for safe and efficient RLNG transportation.
- **Flow Control Equipment:** Offering valves, flow meters, and control systems to manage RLNG flow and pressure.

These contributions align with India's strategic push toward enhancing energy security and promoting cleaner fuel alternatives.

5.2.6 Small Scale LNG (SSLNG) Terminals in India

SSLNG terminals play a crucial role in ensuring energy security by acting as a backup supply in case of disruptions in pipeline-based gas distribution. During natural disasters, maintenance shutdowns, or geopolitical disturbances affecting LNG imports, SSLNG can provide an immediate and decentralized alternative to maintain energy continuity for critical industries, power plants, and essential services. SSLNG can complement renewable energy sources like solar and wind by providing a stable and dispatchable power source during periods of low renewable generation. Hybrid energy systems using SSLNG can enhance grid stability, especially in remote and island regions where energy storage options like batteries might be insufficient.

Role Played by SSLNG in India

- **Enhancing Energy Access in Remote Areas:** SSLNG (Small Scale Liquefied Natural Gas) serves as a decentralized energy solution, making gas distribution feasible in regions where pipeline expansion is either economically unviable or technically challenging. This enables industries and commercial establishments in remote areas to benefit from a reliable and cleaner energy source, thus improving energy access and sustainability.
- **Reducing Dependence on Diesel and Other Fuels:** SSLNG supports the decarbonization of industries and transport sectors by replacing diesel, furnace oil, and other high-emission fuels. Its use in heavy-duty vehicles, railways, and shipping aligns with India's carbon reduction commitments, contributing to a significant reduction in greenhouse gas emissions and promoting cleaner energy alternatives.
- **Supporting City Gas Distribution (CGD) Networks:** Many Cities Gas Distribution (CGD) companies rely on SSLNG supplies for gas distribution in urban and semi-urban areas where pipeline infrastructure is still developing. SSLNG helps bridge the gap, ensuring a continuous and efficient supply of natural gas to these areas, thus supporting the expansion and reliability of CGD networks.
- **Boosting Industrial and Commercial Consumption:** Small and medium enterprises (SMEs), power generation units, and the manufacturing sector benefit from SSLNG's cost-effective and environmentally friendly energy supply. The availability of SSLNG helps these industries reduce their operational costs while minimizing their environmental impact, thereby enhancing their overall efficiency and competitiveness.
- **Enhancing India's LNG Market and Trading Opportunities:** The introduction of SSLNG contracts on the India Gas Exchange (IGX) has facilitated new trading opportunities, improving market accessibility for LNG buyers and sellers. This development has boosted the LNG market in India, allowing for more flexible and transparent trading practices, and encouraging greater participation from domestic and international players.

These points highlight the significant role that SSLNG plays in enhancing energy access, reducing emissions, supporting city gas networks, boosting industrial consumption, and enhancing India's LNG market and trading opportunities. Together, these contributions help drive India's transition towards a more sustainable and efficient energy future.

- **Current Scenario of SSLNG in India (2024-25):** As of 2024-25, India's Small-Scale Liquefied Natural Gas (SSLNG) sector is witnessing significant developments aimed at enhancing energy accessibility and promoting cleaner fuel alternatives. The Indian government aims to increase the share of natural gas in the country's energy mix from the current 6.2% to 15% by 2030.
- **Indian Gas Exchange (IGX) Initiatives**: In April 2024, the Indian Gas Exchange (IGX) introduced SSLNG contracts at the Dahej and Hazira LNG terminals after receiving approval from the Petroleum and Natural Gas Regulatory Board (PNGRB). These contracts are designed for industries and City Gas Distribution (CGD) companies that lack pipeline connectivity, offering flexible options on a daily, fortnightly, and monthly basis. IGX also plans to expand these services to additional terminals, including Dhamra, Mundra, Ennore, Kochi, and on-land SSLNG stations at Vijaipur. This initiative seeks to address the growing demand for natural gas in off-grid regions while supporting the government's efforts to promote LNG-fuelled vehicles and establish retail stations along highways.
- **Public Sector Undertakings (PSUs) Engagement:** Public sector companies are actively investing in SSLNG infrastructure. In March 2024, GAIL (India) Ltd commissioned the first SSLNG unit in the country at its Vijaipur complex in Madhya Pradesh, with a daily capacity of 36 tonnes. In June 2024, Oil and Natural Gas Corporation (ONGC) and Indian Oil Corporation (Indian Oil) entered into a partnership to establish an SSLNG plant near ONGC's Hatta Gas Field in Madhya Pradesh. This plant is expected to produce 32 to 35 tonnes of LNG per day, utilizing around 45,000 standard cubic meters per day (SCMD) of gas. The project focuses on converting stranded gas fields into LNG for distribution via road tankers.

Market Expansion and Future Outlook:

The SSLNG sector is poised for significant growth, driven by increasing demand for natural gas in areas without pipeline infrastructure. In the fiscal year 2023-24, India recorded LNG imports of 85 million cubic meters per day, up from 72 million cubic meters per day in the previous fiscal year. This upward trend is expected to continue, supported by declining prices and rising demand. Projections indicate that demand for road-transported LNG could reach around 5 million cubic meters per day within the next five years. The government's plan to introduce over 500 LNG dispensing stations nationwide further underscores the anticipated expansion of the SSLNG segment.

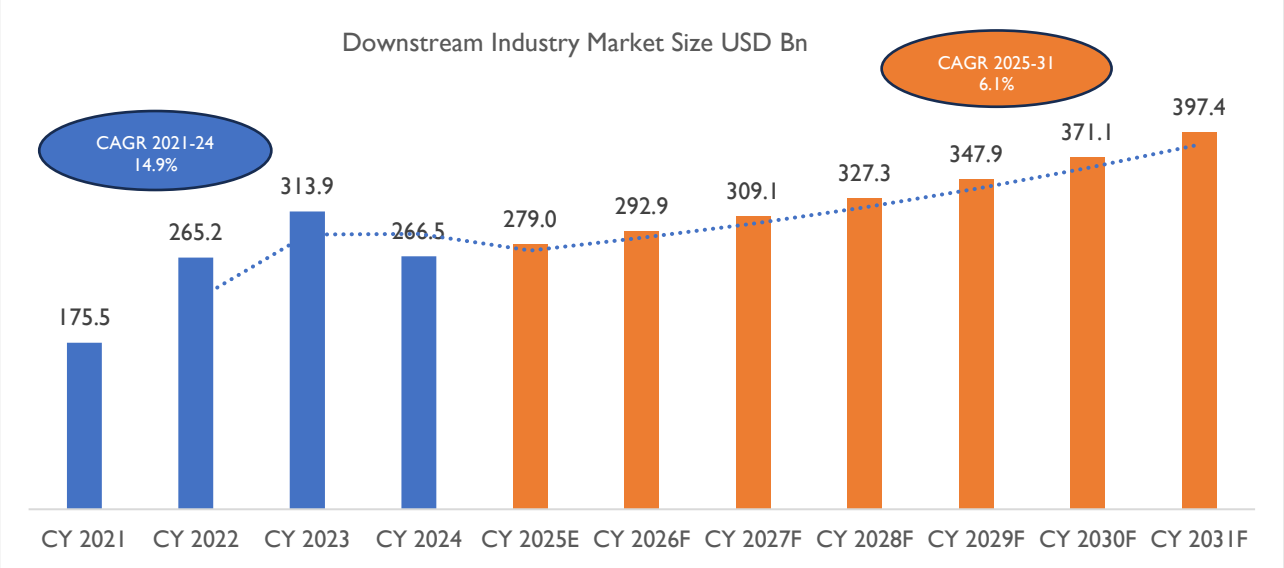
The growth of Small-Scale Liquefied Natural Gas (SSLNG) in India is improving natural gas accessibility, especially in areas without pipeline networks. Increased investments and government initiatives for LNG-based fuelling infrastructure are driving its expansion. SSLNG is expected to support industries, transportation, and energy security while contributing to a cleaner energy mix.

Advantages and Application Area for the Company:

- **Cryogenic Storage Tanks** – These are used to store LNG at very low temperatures. The SSLNG terminal infrastructure would require such tanks to store and transport the LNG safely.
- **Regasification Units** – These are crucial for converting LNG back into gas form. Oswal Energies equipment for this purpose could be used in the terminal's regasification process.
- **Pipeline and Distribution Systems** – The installation and maintenance of pipelines for the transportation of regasified LNG to end users could involve the use of Oswal Energies high-performance pipeline infrastructure and related equipment.
- **Pumps & Compressors** – For efficient transfer and pumping of LNG and its regasified form, Oswal Energies advanced pumping and compression systems would play a key role in facilitating LNG flow through the terminal.

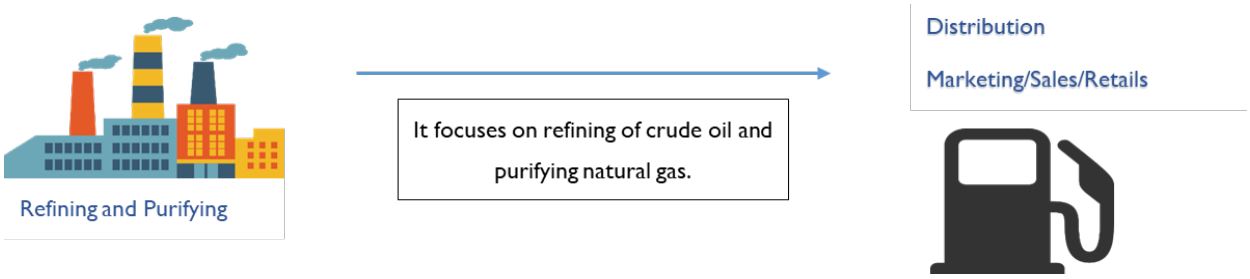
5.3 Downstream Infrastructure: Distribution, Refining & Purifying

Downstream Industry Market: Historical Trend and Forecasted Market Growth (CY 2021-CY 2031):



Source: Primary and Secondary Research

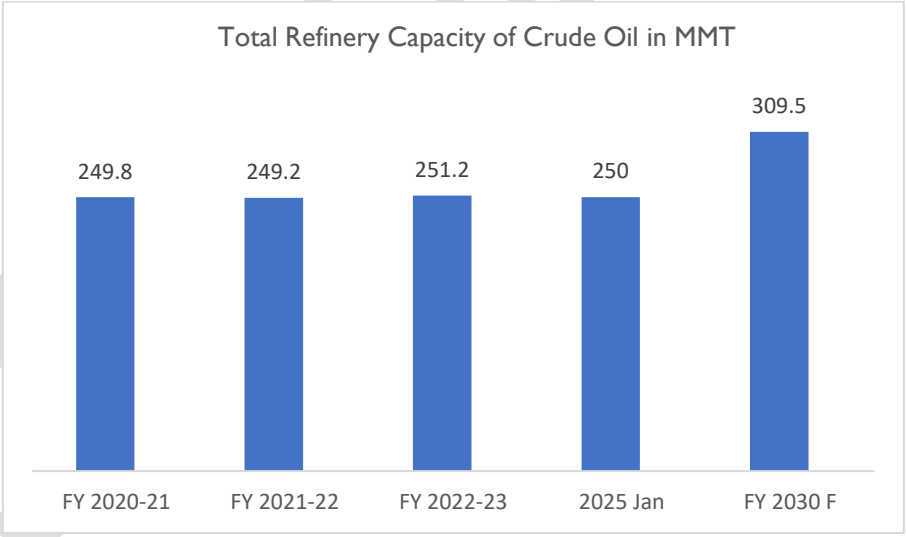
In the downstream infrastructure, crude oil is sent to refineries, where it undergoes processes such as distillation, cracking, and reforming to produce fuels like gasoline, diesel, jet fuel, and liquefied petroleum gas (LPG). Similarly, natural gas is processed to remove impurities and can be converted into liquefied natural gas (LNG) or compressed natural gas (CNG) for transportation and power generation. Additionally, hydrocarbons are used in petrochemical plants to create essential industrial materials such as plastics, fertilizers, and synthetic fibres. These refined products are then distributed through pipelines, storage terminals, and retail networks before reaching end consumers, ensuring a continuous supply of energy and raw materials for various industries and households.



The downstream sector of the oil and gas industry focuses on post-production activities, ensuring that oil and gas products reach consumers. This includes refining crude oil, processing and purifying raw natural gas, as well as marketing and distributing derived products. As the segment closest to end-users, it delivers essential products such as gasoline, diesel, jet fuel, heating oil, lubricants, and petrochemicals.

5.3.1 Crude Oil Refining Capacity in India

India has emerged as a major refining hub in the global oil and gas industry. As of April 2024, the nation's total refining capacity is around **256.82 million metric tonnes per annum (MMTPA**), making it the fourth largest in the world, behind the United States, China, and Russia. **Indian Oil Corporation Limited (IOCL)** plays a significant role in India's refining capacity, managing multiple refineries across the country. Key facilities include the Digboi Refinery in Assam with a capacity of **0.65 MMTPA**, the Koyali Refinery in Gujarat at **13.7 MMTPA**, and the Panipat Refinery in Haryana at **15 MMTPA**.



Source: PNG Annual Report 2022-23, PIB, Petroleum Planning & Analysis Cell (PPAC)

The total crude oil processed across refineries from **2020-21**, the impact of the **COVID-19 pandemic** led to a significant drop in crude processing to **221.8 MMT** as of previous year with utilization falling to **88.8%**, reflecting lower fuel demand and industrial slowdowns. As economic activity resumed, **2021-22** showed an increase in crude processing to **241.7 MMT**, with utilization improving to **97.0%**. By **2022-23**, the sector fully rebounded, processing **255.2 MMT** and achieving a **101.6% utilization rate**, showcasing strong recovery and demand. The data highlights the refining sector's resilience and ability to adapt to global economic challenges.

Impact on Equipment manufacturers and services providers:

- **Upgrades and Expansion Projects in Refineries**: India's refineries have seen periodic upgrades to expand capacity, driving demand for EPC contractors to manage large-scale projects, including installing new machinery and re-engineering systems. As refineries adopt advanced technologies like digitalization, automation, and cleaner solutions, EPC companies are playing a key role in retrofitting infrastructure with updated process units, safety systems, and emission controls. Future expansion, fuelled by government incentives, will further increase investments in new and upgraded refineries, requiring EPC contractors to design, procure, and construct these projects, while equipment manufacturers provide advanced, cutting-edge solutions.
- **Integration with Crude Oil Supply Chain**: The refining process requires constant crude oil supply, and any increase in refining capacity will lead to a surge in crude oil processing needs. This directly impacts the demand for oil and gas-related equipment, which is where Oswal Energies can supply solutions for oil pumping stations, compressors, and storage facilities. With India's projected increase in crude oil imports and refining capacity, Oswal Energies may benefit by becoming a key player in supplying technologically advanced systems to enhance oil processing, transportation, and storage.
- **Environmental Standards and Green Technology**: As refining capacity grows, there will likely be stricter environmental standards that refineries must meet. The company like Oswal Energies could benefit by providing eco-friendly solutions such as clean energy technologies, wastewater treatment systems, and low-emission equipment for refineries. Given the global trend towards sustainability, India's refining sector will likely prioritize green technologies. This shift could offer Oswal Energies the opportunity to design and implement innovative solutions that reduce emissions, conserve energy, and improve refinery efficiency.

5.3.2 Snapshot of Key Refineries

The country has a well-established network of refineries operated by Public Sector Undertakings (PSUs) and private companies, playing a crucial role in meeting domestic fuel demands and exporting refined petroleum products. India's oil refining sector is dominated by **Central Public Sector Enterprises (CPSEs)**, which are government-owned companies operating large refineries across the country. These refineries play a critical role in ensuring energy security, catering to domestic fuel demands, and supporting industrial growth. The major CPSEs in the refining sector include

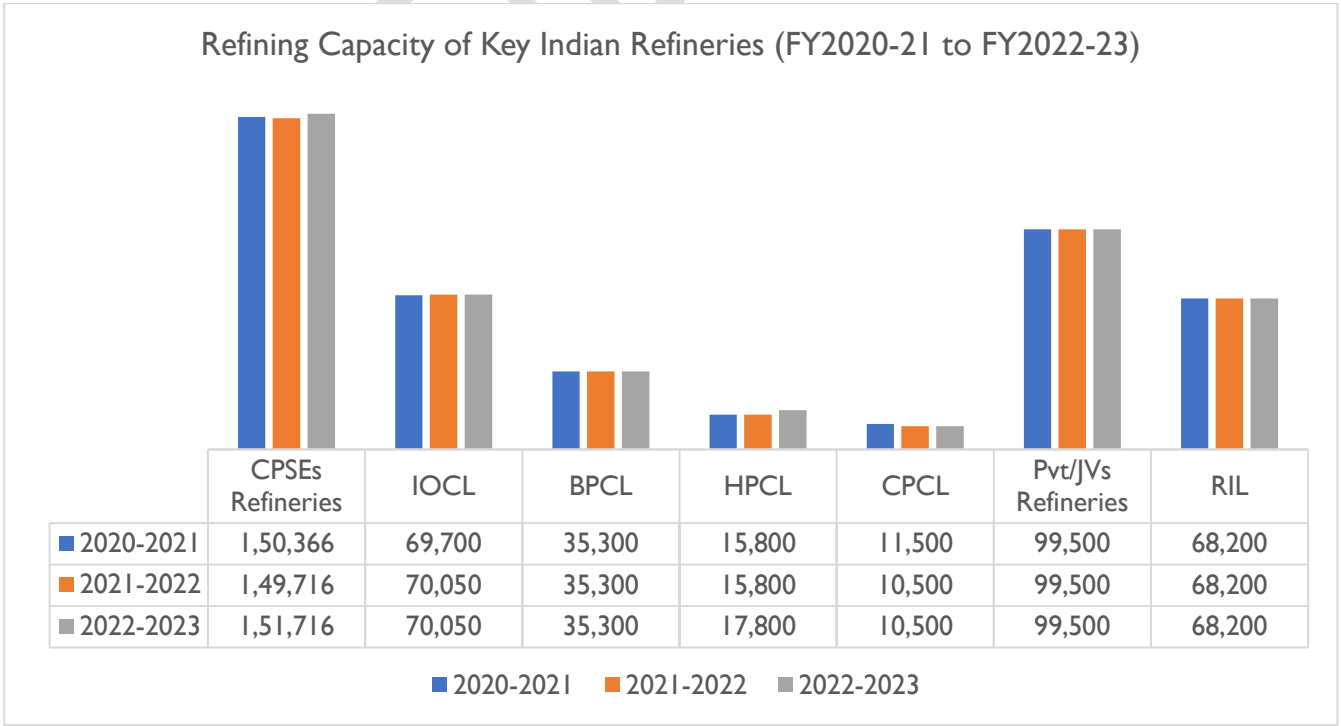
As of **2023**, the total refining capacity of CPSEs in India stands at approximately **151.7 million metric tonnes per annum (MTPA)**, accounting for more than **60% of India's total refining capacity**

- **Bharat Petroleum Corporation Limited (BPCL**) is a leading public sector refining company in India, operating four major refineries with a total capacity of 35.3 million metric tonnes per annum (MTPA). The Mumbai Refinery (12 MTPA) is one of the country's oldest and most efficient refineries, serving western India. The Kochi Refinery (15.5 MTPA) in Kerala is BPCL's largest facility, integrated with a petrochemical complex for high-value product manufacturing. The Bina Refinery (7.8 MTPA) in Madhya

Pradesh, managed by Bharat Oman Refineries Limited (BORL), plays a key role in meeting central India's fuel needs. BPCL also had a stake in the Numaligarh Refinery (3 MTPA) in Assam, which is being expanded to 9 MTPA to enhance fuel supply in the northeast. Known for its advanced technology and commitment to sustainability, BPCL produces BS-VI compliant fuels, ensuring cleaner and more efficient energy solutions for the country.

- **HPCL** (Hindustan Petroleum Corporation Limited) – Operates two major refineries in Mumbai and Visakhapatnam, with a total capacity of 17.8 MTPA, specializing in high-quality fuel production.
- **CPCL** (Chennai Petroleum Corporation Limited) – A subsidiary of IOCL, managing two refineries in Tamil Nadu with a refining capacity of 10.5 MTPA, primarily serving southern India.
- **Pvt/JVs Refineries** (Private and Joint Venture Refineries) – These refineries are privately owned or joint ventures, catering to both domestic fuel needs and exports.
- **RIL (Reliance Industries Limited**) – Operates the world's largest refining complex in Jamnagar, Gujarat, with a total capacity of 62 MTPA, producing high-quality fuels and petrochemical products.
- **Indian Oil Corporation Limited (IOCL),** India's top refiner, operated 11 refineries with a total capacity of 70.05 MTPA in 2022-23. Key refineries include the Panipat Refinery (Haryana, 15 MTPA, expanding to 25 MTPA), the Mathura Refinery (Uttar Pradesh, 8 MTPA, serving Delhi-NCR and neighbouring states with green technologies), the Haldia Refinery (West Bengal, 8 MTPA, supplying eastern and northeastern India), and the modern Paradip Refinery (Odisha, 15 MTPA). These refineries underpin IOCL's leading role in India's fuel supply.

Key Refineries with Refining Capacity in TPA:



	CPSEs Refineries	IOCL	BPCL	HPCL	CPCL	Pvt/JVs Refineries	RIL
2020-2021	1,50,366	69,700	35,300	15,800	11,500	99,500	68,200
2021-2022	1,49,716	70,050	35,300	15,800	10,500	99,500	68,200
2022-2023	1,51,716	70,050	35,300	17,800	10,500	99,500	68,200

Source: D&B Research

The refining capacity data from 2020-21 to 2022-23 indicates a relatively stable refining infrastructure in India, with minor fluctuations in CPSEs Refineries and no changes in Private/Joint Venture (Pvt/JVs) Refineries. The total CPSEs refining capacity remained around 150-151 MTPA, with IOCL (70.05 MTPA) and BPCL (35.3 MTPA) maintaining steady output. However, HPCL expanded its capacity from 15.8 MTPA to 17.8 MTPA in 2022-23, likely due to the Visakhapatnam Refinery upgrade. Meanwhile, CPCL's capacity decreased from 11.5 MTPA in 2020-21 to 10.5 MTPA in 2021-22, possibly due to restructuring or partial shutdowns.

In contrast, Pvt/JVs Refineries maintained a constant 99.5 MTPA, with Reliance Industries Limited (RIL) holding the largest share at 68.2 MTPA. The absence of expansion in private refineries suggests a focus on efficiency, exports, and product diversification rather than capacity growth. Overall, the data reflects a steady refining sector, with public refineries driving future expansions while private players maintain stability, prioritizing technological advancements and operational efficiency.

Capacity Expansion Plans in Refinery Sector

India's refinery sector is witnessing significant expansion to meet rising domestic fuel demand and enhance export capacity. With the government's target of achieving **450 million metric tonnes per annum (MTPA) refining capacity by 2040**, major **public sector (CPSEs) and private refiners** have announced expansion plans, focusing on **capacity enhancement, petrochemical integration, and green energy solutions.**

Detailed information about an expansion in refining capacity for each refinery is given below:

1. **Indian Oil Corporation Limited (IOCL)**:

- Panipat Refinery (Haryana): IOCL plans to expand the Panipat refinery's capacity from 15 million metric tonnes per annum (MMTPA) to 25 MMTPA by June 2026.
- Barauni Refinery (Bihar): The expansion aims to increase capacity from **6 MMTPA to 9 MMTPA**, with completion targeted by December 2025.
- Gujarat Refinery: Plans are underway to expand capacity from **13.7 MMTPA to 18 MMTPA**, integrating lube and petrochemical production units, expected to be completed by December 2025.

2. **Bharat Petroleum Corporation Limited (BPCL)**:

- Bina Refinery (Madhya Pradesh): BPCL is expanding the Bina refinery's capacity from **7.8 MMTPA to 11 MMTPA**, primarily to cater to the feed requirements of new petrochemical plants.
- New Refinery and Petrochemical Complex (Andhra Pradesh): BPCL plans to invest USD 11 billion in a new refinery and petrochemical complex in Andhra Pradesh, featuring a 9 MMTPA refinery integrated with an ethylene cracker unit, aiming for 35% petrochemical intensity.

3. **Hindustan Petroleum Corporation Limited (HPCL)**:

- Visakhapatnam Refinery (Andhra Pradesh): HPCL is enhancing its refining margins by utilizing more Russian oil and upgrading production facilities at the Vizag refinery.

4. **Numaligarh Refinery Limited (NRL)**:

- Numaligarh Refinery (Assam): NRL plans to expand its refining capacity from **3 MMTPA to 9 MMTPA** by March 2027. This includes laying a crude oil pipeline connecting the refinery to Paradip Port in Odisha, expected to be completed by December 2025.

5**. Mangalore Refinery and Petrochemicals Limited (MRPL)**:

- Mangalore Refinery (Karnataka): MRPL is planning a phased expansion to increase its capacity from **15 MMTPA to 18 MMTPA**, with investments in petrochemical production and advanced refining technologies.

6. **Chennai Petroleum Corporation Limited (CPCL):**

- Nagapattinam Refinery (Tamil Nadu): CPCL is expanding the Nagapattinam refinery's capacity from **1.0 MMTPA to 9.0 MMTPA**, aiming to make it a major refining hub in southern India.

7**. Private Sector Initiatives**:

- Reliance Industries Limited (RIL): While not expanding crude refining capacity, RIL is focusing on advanced petrochemicals, biofuels, and hydrogen production, investing in renewable energy-driven refining processes.
- Nayara Energy (Vadinar Refinery): Nayara Energy is investing in a Petrochemical Expansion Project to diversify its product mix beyond fuels and plans for a Green Hydrogen Initiative to support sustainability goals.

India's refining sector is on a strong growth trajectory, with significant capacity expansions planned by 2027. Public sector refineries, led by IOCL, BPCL, HPCL, and MRPL, are at the forefront of this expansion, increasing their refining capacities to meet the rising domestic demand for petroleum products. Meanwhile, private refiners like Reliance Industries and Nayara Energy are shifting their focus towards high-value petrochemicals, biofuels, and green hydrogen production, rather than expanding crude refining capacity.

The industry is also undergoing a transformation with greater emphasis on green energy, integrating low-carbon technologies, renewable energy solutions, and sustainable refining processes. These developments align with India's broader goal of achieving fuel self-sufficiency, reducing dependence on crude oil imports, and strengthening energy security, positioning the country as a global refining and petrochemical hub in the coming years.

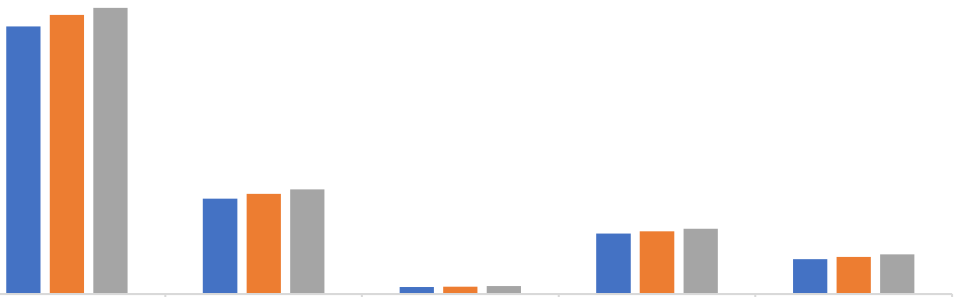
5.3.3 Petrochemical Production Scenario in India

India, as the sixth-largest chemicals producer globally and the third-largest in Asia, plays a significant role in the international chemical trade, exporting to over 175 countries. The sector contributes approximately 15% of India's total exports, showcasing its strong global presence. Union Minister Shri Hardeep Singh Puri highlighted that chemicals and petrochemicals will be key drivers of global oil demand growth, with India's petrochemical industry closely linked to its expanding refining capacity.

To support this growth, the Indian government, along with public sector undertakings (PSUs) like ONGC and BPCL and private sector leaders such as Haldia Petrochemicals, is making substantial investments in the petrochemical sector. Currently, USD 45 billion worth of petrochemical projects are in progress, with an additional USD 100 billion expected to be invested in the coming years to cater to the rising domestic and international demand. These investments align with India's long-term strategy to transition towards a lower-carbon economy, ensuring sustainable and energy-efficient petrochemical production.

The Minister also emphasized that India's petrochemical capacity is set to rise significantly, increasing from approximately 29.62 million tonnes to 46 million tonnes by 2030. This expansion will enhance domestic production capabilities, reduce dependency on imports, and solidify India's position as a leading global petrochemical hub. India's petrochemical industry has exhibited notable production volumes over the past three fiscal years. Below is a table summarizing the production of key petrochemical products.

Production of key petrochemical products



	Polymers	Synthetic Fibers	Elastomers	Synthetic Detergents	Performance Plastics
2020-2021 (MMT)	11.5	4.1	0.3	2.6	1.5
2021-2022 (MMT)	12	4.3	0.32	2.7	1.6
2022-2023 (MMT)	12.3	4.5	0.35	2.8	1.7

Note: As per the latest annual report MoPNG

Polymers: Leading Petrochemical Segment. Polymers remain the most produced petrochemical product, with output rising from 11.5 MMT in 2020-21 to 12.3 MMT in 2022-23, marking a 6.96% growth. This increase is primarily fuelled by expanding packaging, automotive, and consumer goods industries, where materials like polyethylene (PE), polypropylene (PP), and polyvinyl chloride (PVC) play a crucial role. The surge in urbanization and the growing consumption of plastic-based products has further supported this consistent rise in production.

Synthetic Fibers: Sustained Growth in the Textile Industry. Synthetic fibre production increased by 9.75% over three years, growing from 4.1 MMT to 4.5 MMT. The textile sector, particularly polyester, nylon, and acrylic fibre segments, has been a major driver of this demand. India's booming apparel and home furnishing markets, along with rising demand for athleisure and performance wear, are contributing significantly to this upward trend.

Elastomers: Fastest Growing Segment (+16.67%). Elastomers, including synthetic rubber, exhibited the highest percentage growth, rising from 0.3 MMT to 0.35 MMT (+16.67%) over three years. The automobile and tire industries, which rely heavily on synthetic rubber, have been key consumers. Additionally, government policies promoting electric vehicle (EV) manufacturing and automotive sector expansion are expected to further drive demand for elastomers in the coming years.

Synthetic Detergents: Steady Growth in FMCG Industry. The production of synthetic detergents increased by 7.69%, from 2.6 MMT to 2.8 MMT. This growth is driven by rising consumer spending on household cleaning products, increased hygiene awareness post-pandemic, and expansion in rural markets. The continued expansion of the Fast-Moving Consumer Goods (FMCG) sector is expected to sustain demand for detergent-based formulations.

Performance Plastics: 13.33% Growth Due to High-Performance Applications. Performance plastics grew from 1.5 MMT to 1.7 MMT (+13.33%), fuelled by technological advancements and increased adoption of lightweight materials. These plastics are extensively used in medical devices, aerospace, high-end electronics, and automotive components, thanks to their superior durability and strength. With growing interest in sustainable and high-performance materials, this segment is expected to see continued expansion.

India's petrochemical industry is experiencing consistent growth, with production across major categories increasing between **7% and 16% over the past three years**.

Polymers continue to dominate the sector, driven by their widespread use in packaging and industrial applications. Elastomers and performance plastics are witnessing strong demand, fuelled by technological advancements and innovation. Meanwhile, synthetic fibres and detergents are maintaining a steady growth trajectory, supported by urbanization and increasing consumer spending.

Backed by government initiatives, industrial expansion, and a focus on sustainability, India's petrochemical industry is poised to play a key role in the nation's economic development and its vision of becoming a global leader in petrochemical manufacturing.

5.3.4 Petrol/ Diesel Retail Network in India

The petrol and diesel retail network in India is primarily dominated by state-owned companies like Indian Oil Corporation (IOC), Bharat Petroleum Corporation Limited (BPCL), and Hindustan Petroleum Corporation Limited (HPCL), operating a vast network of fuel stations across the country, with IOC holding the largest market share, followed by BPCL and HPCL; private players like Nayara Energy also have a significant presence in the market, contributing to the overall retail network of around 93,000 petrol pumps nationwide.

Table 6 Petrol, Diesel and Gas Infrastructure: as of 01/01/2025

Particulars	Dec 2022	Dec 2023	Dec 2024
Retail Outlets (Ros) (total)	85,529	88,793	93,839
out of which Rural ROs	24,076	25,143	26,849
LPG Distributors (total) (Nos.) (PSUs only)	25,341	25,449	25,542
LPG Bottling plants (Nos.) (PSUs only)	206	210	212
CNG_LNG	4247	5315	6,471
Auto LPG	669	582	539
Compressed Bio-Gas outlets	77	116	219

Table 7 Petrol, Diesel and Gas Infrastructure (Major Companies): as of 01/01/2025

Particulars	IOCL	BPCL	HPCL	RIL/RBML/ RSIL	NEL	Shell	MRPL & Others	Total
Retail Outlets (Ros) (total)	39,008	22,921	22,953	1,865	6,614	360	118	**93,839**
out of which Rural ROs	12,806	5,945	5,755	130	2,091	86	36	**26,849**
LPG Distributors (total) (Nos.) (PSUs only)	12,908	6,264	6,370	-	-	-	-	**25,542**
LPG Bottling plants (Nos.) (PSUs only)	99	54	56	-	-	-	3	**212**
CNG_LNG	2,328	2,215	1,851	39	34	0	4	**6,471**
Auto LPG	310	43	92	44	50	0	0	**539**
Compressed Bio-Gas outlets	114	41	57	33	-	-	-	**219**

Source: Ministry of Petroleum

Public Sector Undertakings (PSUs) in Fuel Retailing

1. **Indian Oil Corporation Limited (IOCL**): As India's largest fuel retailer, IOCL operates an expansive network of fuel stations across the country. The company plays a pivotal role in ensuring the availability of petrol, diesel, compressed natural gas (CNG), and other fuel products to consumers, businesses, and industries. IOCL's widespread presence extends from metropolitan cities to remote rural areas, making it one of the most accessible fuel providers in India.

2. **Hindustan Petroleum Corporation Limited (HPCL**): HPCL manages over 22,000 retail outlets across India, with a well-balanced distribution approximately 40% located in urban centres, while the rest serve highways and rural regions. These outlets operate under multiple business models, including:

To enhance customer service, HPCL has introduced its premium 'Club HP' branded outlets, offering superior vehicle care and personalized fuel services. Additionally, all operational HPCL retail outlets have been automated, significantly improving operational efficiency, fuel dispensing accuracy, and customer experience.

3. **Bharat Petroleum Corporation Limited (BPCL):** BPCL operates a vast network of fuel stations across the country, ensuring reliable fuel distribution for private, commercial, and industrial consumers. Customers can easily locate BPCL retail outlets by selecting their state and district on the company's official website, making it more convenient to find nearby fuel stations.

Private Sector Players in Fuel Retailing: Alongside PSUs, private companies have made substantial strides in India's fuel retail market, increasing competition and offering consumers greater choice. Prominent private-sector fuel retailers include:

1.Reliance Industries Limited (RIL) – Operates one of the most advanced fuel retail networks, with a strong presence along highways and major transport routes.

2.Nayara Energy (formerly Essar Oil) – A key player in India's private fuel sector, Nayara Energy has been expanding its fuel station network to reach more consumers.

3.Shell India – A global leader in energy solutions, Shell has established premium fuel stations in urban areas, offering high-quality fuels and superior service experiences.

A notable example of this innovation is: The first store was launched in Mumbai in September 2021, with additional locations rolled out in other major cities, catering to the growing demand for on-the-go shopping options. Additionally, fuel retailers are adopting advanced automation technologies, digital payment systems, and AI-driven analytics to streamline operations and improve customer interactions at fuel stations.

India's petrol and diesel retail sector is rapidly evolving, driven by the increasing demand for fuel, growing vehicle ownership, and the need for a seamless fuelling experience. Both public and private sector players are making significant investments in infrastructure, digital solutions, and service diversification, ensuring better accessibility and enhanced convenience for consumers. As the industry continues to innovate and expand, India is well-positioned to build a more efficient, technology-driven, and consumer-friendly fuel retail network in the coming years.

5.3.5 City Gas Distribution (CGD) Network in India

India's City Gas Distribution (CGD) network has undergone significant expansion over the past decade, greatly improving natural gas accessibility across the country. In 2014, the CGD network covered only 66 districts, but by 2023, this coverage had expanded to 630 districts, reflecting a substantial increase in reach. To further support this growth, the Petroleum and Natural Gas Regulatory Board (PNGRB) has authorized 307 Geographical Areas for CGD development, with the goal of covering nearly 100% of India's area and population. In terms of infrastructure, as of September 30, 2024, the CGD network includes approximately 13.6 million domestic Piped Natural Gas (PNG) connections and 7,259 Compressed Natural Gas (CNG) stations, demonstrating the accelerated adoption of cleaner fuel alternatives. Additionally, the number of domestic PNG connections surged from 2.54 million in 2014 to 10.39 million in 2023, highlighting the growing shift towards sustainable energy solutions across Indian households.

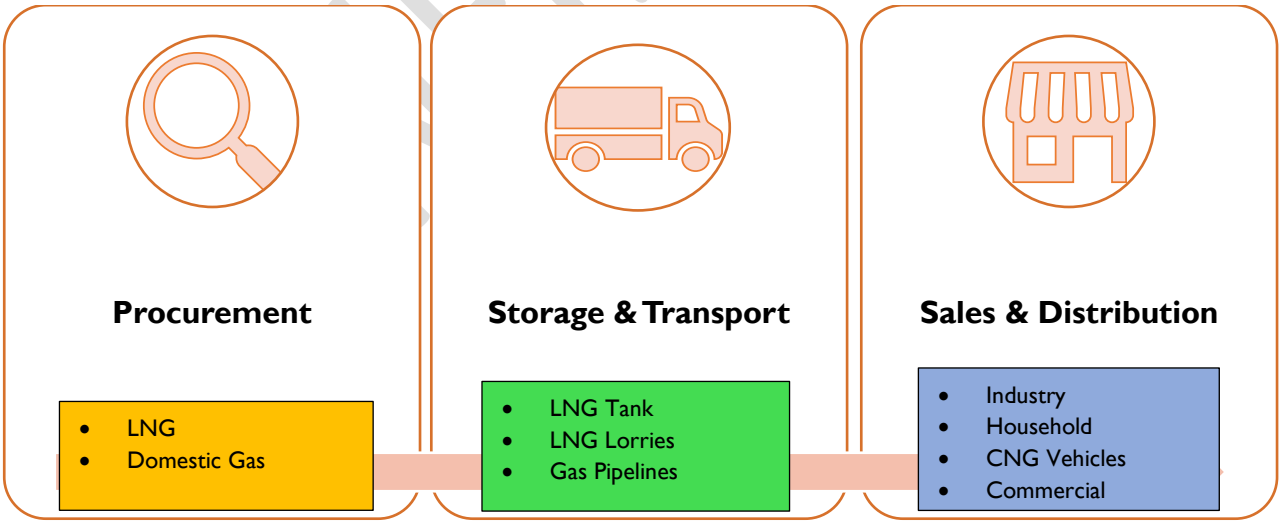
Table 8 Status of PNG connections and CNG stations across India (Nos.) as on November 2024(P):

State/UT (State/UTs are clubbed based on the GAs authorized by PNGRB)	CNG Stations	PNG connections		
		Domestic	Commercial	Industrial
Andhra Pradesh	196	2,78,076	529	53
Andhra Pradesh, Karnataka & Tamil Nadu	47	12,816	14	11
Assam	26	64,972	1,427	470
Bihar	159	1,89,021	164	25
Bihar & Jharkhand	18	9,573	11	0
Bihar & Uttar Pradesh	26	13,039	0	0
Chandigarh (UT), Haryana, Punjab & Himachal Pradesh	34	28,731	189	53
Chhattisgarh	25	6,663	0	0
Dadra & Nagar Haveli (UT)	6	12,868	60	66
Daman & Diu (UT)	5	5,326	97	59
Daman and Diu & Gujarat	15	8,685	36	0
Goa	14	16,547	42	49
Gujarat	1,025	34,63,287	24,036	5,834
Haryana	438	4,13,366	1,218	2,652
Haryana	25	27,881	144	72
Haryana & Himachal Pradesh	14	56	1	0
Haryana & Punjab	27	2,163	0	0
Himachal Pradesh	16	8,487	36	6
Jharkhand	104	1,41,105	61	10
Karnataka	411	4,77,844	640	388
Kerala	175	1,12,972	106	30
Kerala & Puducherry	25	7,745	0	0
Madhya Pradesh	319	2,55,092	555	565
Madhya Pradesh and Chhattisgarh	9	0	0	0
Madhya Pradesh and Rajasthan	37	1,145	2	0
Madhya Pradesh and Uttar Pradesh	20	0	0	3
Maharashtra	950	37,06,961	5,067	1,082
Maharashtra & Gujarat	75	2,10,135	11	43

Maharashtra and Madhya Pradesh	16	0	0	0
National Capital Territory of Delhi (UT)	494	16,50,646	4,402	1,918
Odisha	125	1,33,887	26	3
Puducherry	10	0	0	0
Puducherry & Tamil Nadu	8	456	4	1
Punjab	227	98,457	775	337
Punjab & Rajasthan	22	5,929	0	0
Rajasthan	347	3,61,553	366	1,773
Tamil Nadu	343	49,857	26	38
Telangana	200	2,19,173	144	141
Telangana and Karnataka	12	126	0	2
Tripura	22	64,104	508	62
UT of Jammu and Kashmir	2	0	0	0
Uttar Pradesh	1,031	17,34,487	3,081	3,689
Uttar Pradesh	29	9,167	36	8
Uttar Pradesh & Rajasthan	47	24,234	65	352
Uttar Pradesh and Uttarakhand	32	16,350	0	0
Uttarakhand	37	75,355	111	124
West Bengal	150	52,399	7	1
Grand Total	7,395	1,39,70,736	43,997	19,920

Source: Petroleum Planning & Analysis Cell

The **City Gas Distribution (CGD) value chain** in India encompasses several key stages, each integral to delivering natural gas to end-users across domestic, commercial, industrial, and automotive sectors. The process is regulated by the **Petroleum and Natural Gas Regulatory Board (PNGRB)**, which authorizes entities to develop and operate CGD networks.



- **Natural Gas Procurement:** City Gas Distribution (CGD) entities source natural gas from domestic production fields and imported Liquefied Natural Gas (LNG). The government regulates domestic gas prices for priority sectors such as Piped Natural Gas (PNG) for households and Compressed Natural Gas (CNG) for transportation. Meanwhile, industries and commercial establishments often depend on imported LNG to meet their energy requirements.

- **Transportation via Transmission Pipelines:** After procurement, natural gas is transported through high-pressure transmission pipelines to various Geographical Areas (GAs). These pipelines serve as the foundation of the CGD infrastructure, enabling the safe and efficient movement of gas across long distances.
- **City Gate Stations (CGS):** Upon reaching a Geographical Area (GA), the gas first enters a City Gate Station (CGS), where its pressure is reduced to levels appropriate for local distribution. Additionally, the gas undergoes filtration and odorization to enhance safety and detectability before being supplied to consumers.
- **Distribution Network:** From the City Gate Station, the gas is routed through a network of medium and low-pressure pipelines, ensuring its delivery to households, businesses, and industries. This extensive distribution infrastructure enables seamless gas supply across urban and semi-urban areas.
- **End-User Delivery: Households**: PNG is supplied for cooking and heating applications. Commercial & Industrial Users: Businesses utilize PNG for various industrial processes, benefiting from its efficiency and lower carbon emissions. Automotive Sector: CNG is distributed to fuelling stations, where it is compressed and supplied to vehicles as an eco-friendly alternative to petrol and diesel.

The Indian government introduced the Sustainable Alternative Towards Affordable Transportation (SATAT) initiative on October 1, 2018, with the objective of promoting the production and utilization of Compressed Biogas (CBG) as a cleaner fuel alternative. As of November 30, 2024, a total of 80 CBG plants have been commissioned, while an additional 72 plants are currently under construction, further strengthening India's bio-energy infrastructure.

The City Gas Distribution (CGD) sector is set for continued expansion, driven by proactive government policies and substantial investments aimed at increasing the share of natural gas in India's energy mix from 5.78% to 15% by 2030, aligning with the nation's commitment to sustainable and cleaner energy solutions. Entities like Indian Oil Corporation Limited (IOCL) play a crucial role in expanding CGD infrastructure across multiple states and districts, enhancing natural gas availability for a broader population. This well-structured value chain ensures safe, efficient, and widespread gas distribution, supporting India's commitment to increasing natural gas adoption in its energy mix and promoting a cleaner, greener future.

5.3.6 Regulatory Factors Governing India's Oil & Gas Infrastructure

India's oil and gas sector is managed through a detailed regulatory system that oversees all activities from exploration to marketing, ensuring effective use of resources, protection of the environment, and a secure energy supply. This framework involves several key regulatory bodies and policies.

The Ministry of Petroleum and Natural Gas (MoPNG): It is the Indian government's main body for overseeing the oil and gas industry. It handles everything from finding and producing oil and gas to refining, distributing, and selling related products, as well as managing imports, exports, and conservation efforts. The MoPNG sets policies and guidelines to help the sector grow in a structured way.

The Petroleum and Natural Gas Regulatory Board (PNGRB): It is established in 2006, is a statutory body that regulates downstream activities in the oil and gas sector, including refining, transportation, distribution, storage, marketing, supply, and sale of petroleum products and natural gas. The PNGRB's functions include developing technical and safety standards, issuing licenses, and ensuring compliance with regulations to protect consumers' interests, promote competitive markets, and maintain infrastructure integrity and operational safety. The PNGRB is also responsible for regulating the laying and expanding of natural gas and petroleum pipelines, as well as city or local gas distribution networks.

Key Policies and Guidelines

The Hydrocarbon Exploration and Licensing Policy (HELP), launched in 2016, replaced the New Exploration Licensing Policy (NELP) of 1997 to streamline the exploration and production of all types of hydrocarbons, including oil, gas, coal bed methane, and shale. HELP introduced a uniform licensing system, allowing companies to explore any available area, share revenue with the government, and freely market and price the hydrocarbons they produce.

The policy is composed of four components:

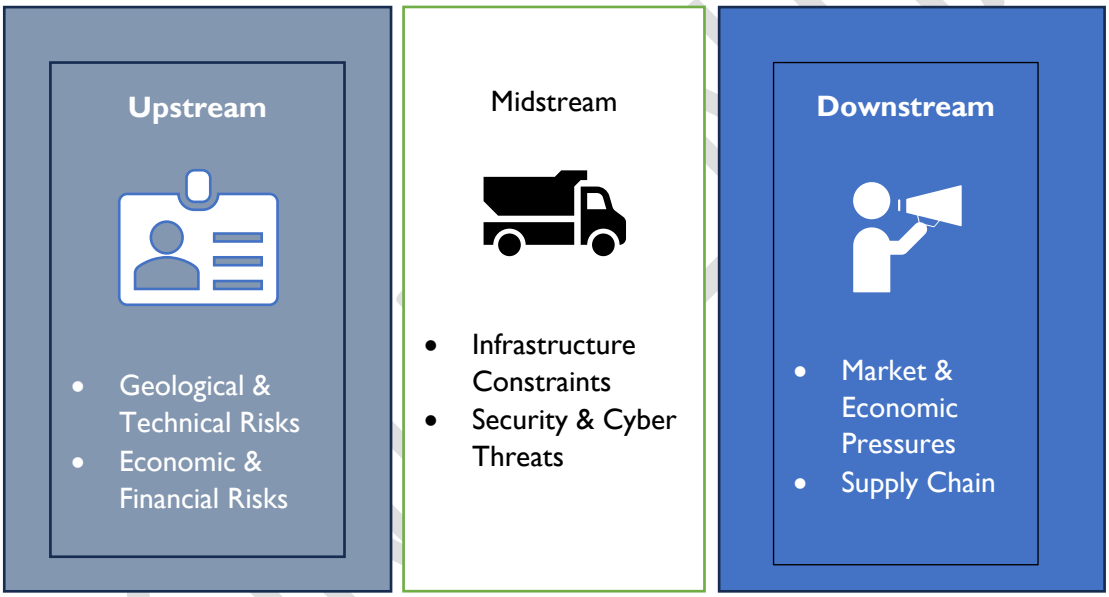
HELP	
	Uniform licence for exploration and production of all forms of hydrocarbon. This streamlines licencing, as the government requires only a single uniform licence for all forms of hydrocarbons, which includes gas from coal mining. There were previously different policy frameworks for different hydrocarbon exploration operations.
	Open acreage policy. Through this, an explorer can study and bid for any block in accordance with its competitive advantage.
	Revenue sharing model. This encourages cost efficiency in mining operations by replacing the profit-sharing contract established by NELP. The contractor pays the government a share of its revenue (net of royalty) as per the contract.
	Marketing and pricing freedom. The contractor is free to sell crude oil in the domestic market through a transparent bidding process.

The Guidelines for Laying Petroleum Product Pipelines aim to encourage investment in pipelines by adhering to the common carrier principle. These guidelines detail the procedures for pipeline construction, ensuring a transparent process and equal access to pipeline infrastructure for all stakeholders. These regulatory bodies and policies are designed to cultivate a strong, secure, and effective oil and gas infrastructure in India, carefully balancing the use of resources with environmental and economic concerns.

5.3.7 Key Threats & Challenges

The oil and gas industry specially in the value chain area navigating a complex landscape challenge that have far-reaching implications for its operational efficiency and overall productivity. These challenges stem from a confluence of factors, including escalating geopolitical tensions that disrupt established trade routes and introduce regulatory uncertainties, increasingly stringent environmental regulations that necessitate costly adaptations in extraction and production methods, volatile cost structures influenced by fluctuating commodity prices and inflationary pressures, and persistent labour and material uncertainties that hinder project timelines.

The key threats and challenges in the oil and gas industry have been categorized into the three major stages of the **value chain—upstream, midstream, and downstream**—aligning with the industry's procedural flow from exploration to delivering the final product to the end user.



Upstream (Exploration & Production)

- **Geological & Technical Risks:** The upstream sector faces the challenge of declining conventional reserves, which necessitates exploring unconventional sources that often involve complex extraction methods and increased drilling uncertainties. Successfully navigating these geological and technical risks requires substantial investments in advanced technologies and expertise.
- **Economic & Financial Risks:** High exploration costs, coupled with oil price volatility, pose significant economic and financial risks in the upstream sector. The need for large capital expenditures (CAPEX) further exacerbates these challenges, making project viability highly sensitive to market fluctuations. Companies are turning to technology-driven solutions and AI-powered predictive models to mitigate risks and enhance exploration success rates.

Midstream (Transportation & Storage)

- **Infrastructure constraint:** Midstream Oil and Gas Market faces infrastructure constraints and bottlenecks that impede the efficient transportation and distribution of energy resources. Rapid production growth, especially in shale plays like the Permian Basin, has outpaced infrastructure development, resulting in pipeline capacity limitations. Insufficient pipeline networks or inadequate storage facilities lead to logistical challenges, hampering the timely and cost-effective movement of crude oil, natural gas, and related products to refineries, export terminals, or end consumers.
- **Security & Cyber Threats:** The oil and gas industry faces significant security and cyber threats, including physical risks like vandalism and sabotage, and cyberattacks such as data breaches and ransomware. Physical security requires advanced measures like surveillance and access control. Cybersecurity is crucial, necessitating firewalls and regular audits, especially given the rise in cyberattacks. The industry is also threatened by sophisticated cyber threats that can originate with state-sponsored actors, hacktivists, and criminal syndicates. Addressing these risks requires comprehensive visibility into all cyber-physical systems.

Downstream (Refining & Marketing) Challenges

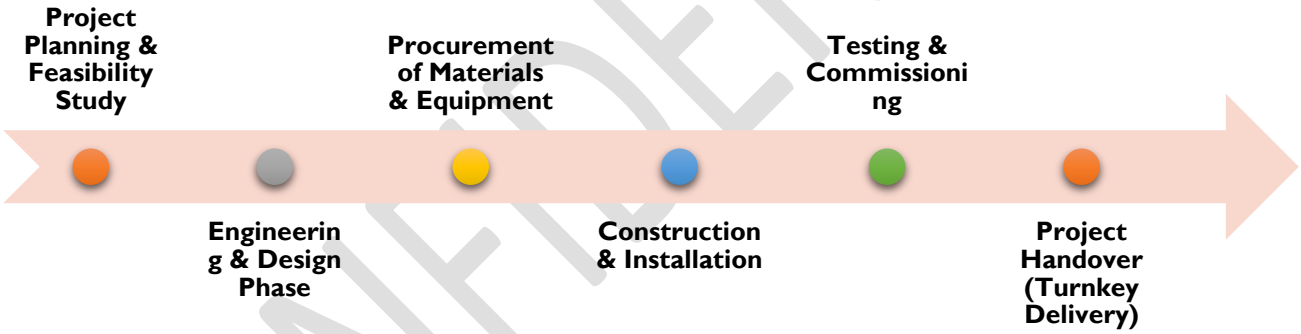
- **Market and economic pressure:** Market and economic pressures exert considerable influence on the oil and gas industry, encompassing overcapacity, decreasing fossil fuel demand, and intense pricing competition. Economic downturns in populous countries can diminish petroleum demand as businesses curtail activities and households reduce gasoline consumption. While economic development and GDP growth typically correlate with increased oil demand, the potential for wavering commitment among OPEC+ nations to maintain production cuts introduces a downside risk to oil prices. These factors, combined with geopolitical tensions, macroeconomic weaknesses, and the energy transition, shape the crude oil and natural gas market. Despite these challenges, oil and gas companies are prioritizing high-return investments and production efficiency, resulting in increased capital expenditures and net profits over the past four years.
- **Supply Chain & Geopolitical Risks:** Supply chain and geopolitical risks pose significant challenges to the oil and gas industry, causing disruptions, regulatory shifts, and increased business uncertainty. Conflicts like the Ukraine war, Israeli-Hamas tensions, US-China trade disputes, and issues in the South China Sea impact global operations, forcing companies to reassess sourcing and strategies. The sector also faces threats from workforce instability, extreme weather, cyberattacks, and market volatility. To build resilience, companies are investing in workforce upskilling, embracing digital technologies, and enhancing operational efficiency to adapt to an evolving and uncertain global energy landscape.

6. Prevalent Business Model in Construction Projects in Energy Sector

6.1 Engineering, Procurement & Construction (EPC) Model

In India's oil and gas sector, the Engineering, Procurement & Construction (EPC) model is a project execution approach in which a single contractor oversees the entire process, including design, procurement of materials, and construction of the facility. This method delivers a fully operational project as a "turnkey" solution, ensuring streamlined execution and clear accountability, making it a preferred choice for large-scale developments. It is a contractual project delivery model utilized by oil and gas companies for executing large-scale projects.

The Engineering, Procurement, and Construction (EPC) model is widely adopted across a broad range of industries due to its ability to provide single-point accountability, streamlined coordination, and efficient project execution. While it is well established in sectors such as oil & gas, power generation, petrochemicals, and renewable energy, the model is also increasingly applied in areas like water and wastewater treatment, mining and mineral processing, pharmaceuticals, food and beverage manufacturing, data centres, logistics and warehousing, transportation infrastructure, and road construction. Its effectiveness in managing complex, capital-intensive projects make it a preferred approach for delivering large-scale industrial facilities and infrastructure assets with high technical and quality requirements.



The project involves assessing technical, financial, and environmental feasibility, conducting market analysis, and securing regulatory approvals (MoPNG, DGCA, EIA, PNGRB). The engineering phase includes FEED, detailed design, and compliance with industry standards (OISD, API, ASME), integrating automation systems. Materials and equipment are sourced from trusted vendors, ensuring quality control and cost-effective contracts. During construction, infrastructure is installed, automation technologies are integrated, and HSE protocols are followed. Extensive testing and commissioning are performed for safety and operational efficiency, training teams and conducting final inspections. Finally, the project is handed over with operational manuals, support for initial operations, and regulatory clearances, completing financial settlements and marking successful project completion.

The EPC model in India's oil and gas sector offers key advantages, ensuring clear accountability by assigning a single contractor, reducing disputes and miscommunication. Its integrated approach streamlines project execution, minimizing delays and enhancing economic impact. Cost certainty through fixed-price contracts aids budget management, especially in government-funded projects. By shifting risk management to contractors, project owners can focus on core operations.

Drivers in the Indian Oil and Gas EPC Sector

- **Energy Demand Growth:** India's energy demand is expected to rise substantially, driven by rapid industrialization and urbanization. This increasing demand necessitates the expansion of oil and gas infrastructure, including refineries, pipelines, and exploration activities.
- **Petroleum Products:** The growing demand for petroleum products such as motor gasoline, diesel, and LPG is driving the need for expanded refining capacity and infrastructure development.
- **Private and Foreign Participation:** Foreign companies are increasingly participating in bidding rounds under the Discovered Small Field Policy (DSF) and Open Acreage Licensing Programme (OALP), reflecting rising global interest in India's oil and gas sector.

Preferred business models in Oil & Gas Sector:

A multi-disciplinary approach is essential, with firms like Fichtner India providing integrated engineering services across process, mechanical, piping, electrical, and civil domains. Front-End Engineering Design (FEED) is key for feasibility studies, risk assessment, and preliminary designs. Companies like Vee Technologies and PROCESS specialize in process and refinery unit design, equipment specifications, and safety evaluations. Advanced tools like CAD and SolidWorks enhance precision in piping and mechanical designs.

The government's Purchase Preference Policy (PP-LC) promotes local procurement in Oil & Gas projects. It mandates purchase preference for suppliers meeting local content targets, monitored by the Ministry of Petroleum and Natural Gas through annual reviews and standard procedures. Technologies like automated welding and ultrasonic testing boost efficiency and cost-effectiveness. Notable innovations include HDD across the Brahmaputra River. There is a growing focus on sustainability, environmental compliance, and safe project execution supported by detailed engineering documentation. Following are some EPC projects:

Tata Projects:

- ONGC Bokaro: CBM Wells, Pipelines, Gas Processing & Compression.
- U-Field (ONGC Kakinada): Deep-water gas, subsea and onshore facilities.

Engineers India Ltd (EIL):

- Deen Dayal: HP-HT reservoirs, subsea pipelines, processing platforms.
- Western Onshore: Pre-engineering, surveys, residual design, dismantling.
- SHG Platform (ONGC): Consultancy & project management.
- Visakh Refinery: Engineering, construction, and PMC services.

India's Oil & Gas EPC Industry Market: Historical Trend and Forecasted Market Growth (CY 2021-CY 2031):

India Oil & Gas EPC Market (USD Billion)	Revenues	Percentage Contribution (Oil and Gas EPC)
2021	21.3	15.20%
2022	23.5	15.30%
2023	24.8	15.50%
2024	25.6	15.60%
CAGR (2021-2024)	6.40%	
2025E	26.5	15.80%
2026F	27.5	15.90%
2027F	28.6	16.10%
2028F	29.9	16.20%
2029F	31.3	16.40%
2030F	32.9	16.50%
2031F	34.7	16.70%
CAGR (2025E-2031F)	4.60%	

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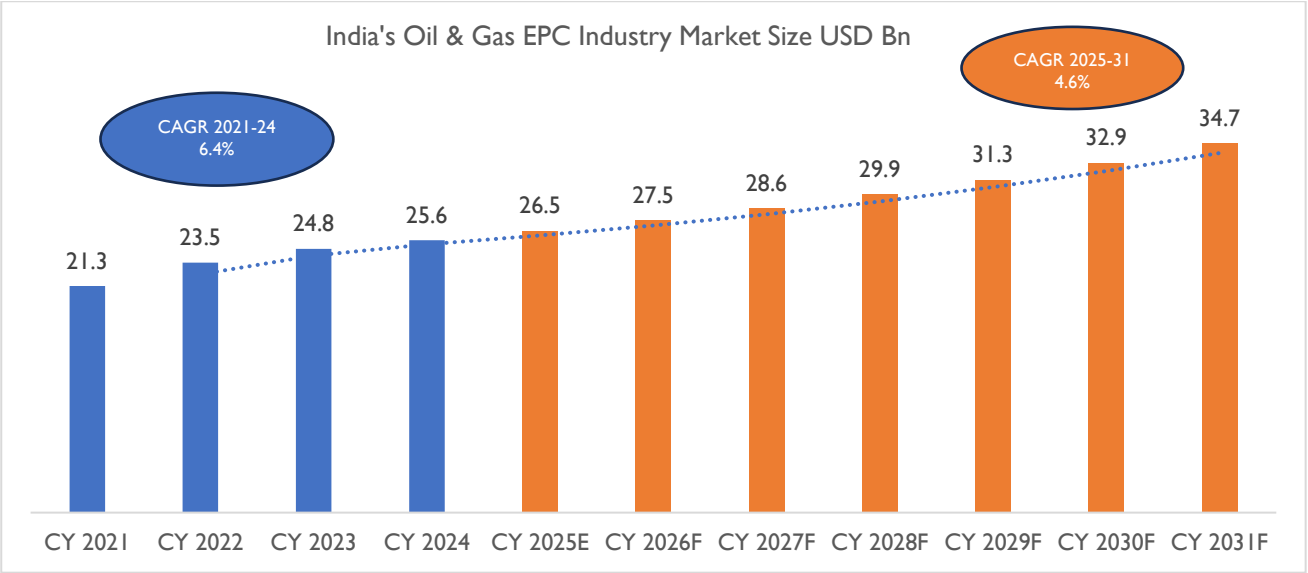
2026F	27.5	15.90%
2027F	28.6	16.10%
2028F	29.9	16.20%
2029F	31.3	16.40%
2030F	32.9	16.50%
2031F	34.7	16.70%
CAGR (2025E-2031F)	4.60%	



Source: Primary and Secondary Research

The India Oil & Gas EPC (Engineering, Procurement, and Construction) market has demonstrated consistent growth from 2021 to 2024, with revenues increasing from USD 21.3 billion in 2021 to USD 25.6 billion in 2024, reflecting a Compound Annual Growth Rate (CAGR) of 6.4%. This period of growth is likely driven by factors such as rising energy demands, infrastructure development, and investments in the oil and gas sector in India.

Looking ahead, the market is expected to continue expanding, albeit at a slower pace, with projections of USD 26.5 billion in 2025 and reaching USD 34.7 billion by 2031. This represents a lower CAGR of 4.6% for the 2025-2031 period, which suggests that growth will be more moderate as the market matures and faces potential challenges like geopolitical instability, price fluctuations, and regulatory changes.

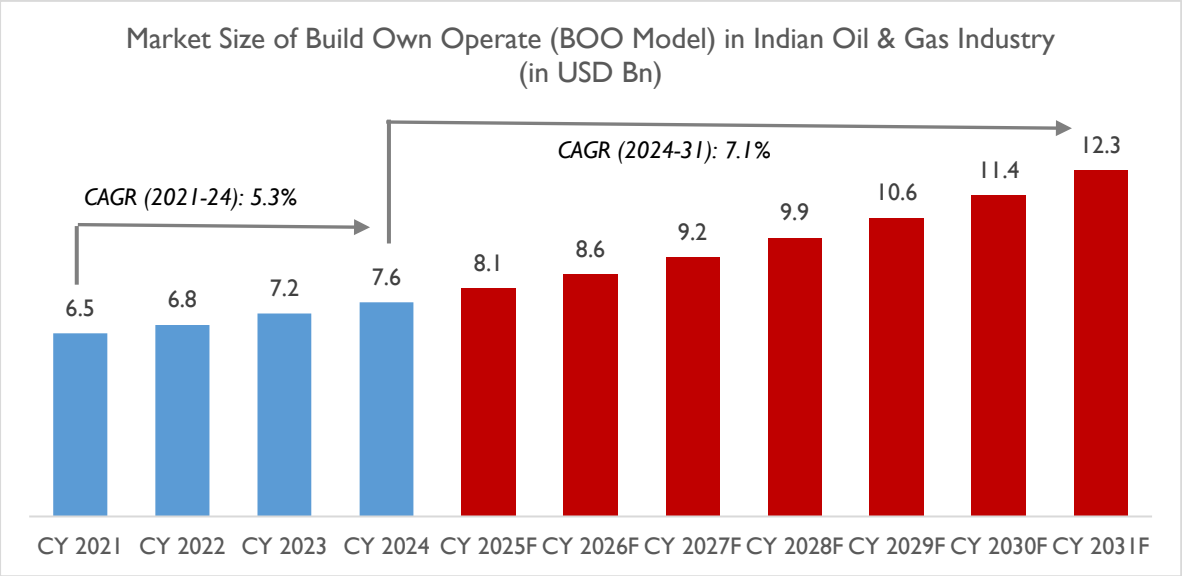
Furthermore, the percentage contribution of the Oil & Gas EPC segment within the broader market has shown a steady increase. It was 15.2% in 2021 and is expected to rise gradually to 16.7% by 2031. This indicates a growing importance of the Oil & Gas EPC sector relative to other industries in India, signaling the continued development and prioritization of energy infrastructure projects. The gradual rise in percentage contribution is also reflective of India's broader energy transition goals, which might require an expanded EPC capacity for both traditional and emerging energy needs.

Governments are actively supporting the EPC industry by eliminating barriers that hinder ongoing projects and encouraging new bids for upcoming initiatives. This includes policy reforms, streamlined approval processes, and financial incentives to attract investments. Such measures are fostering a more favourable business environment, accelerating project execution, and contributing to the overall expansion of the oil and gas EPC market.

6.2 Build Own Operate (BOO) Model

The Build Own Operate (BOO) model in India's Oil and Gas sector is a key strategy where private players or

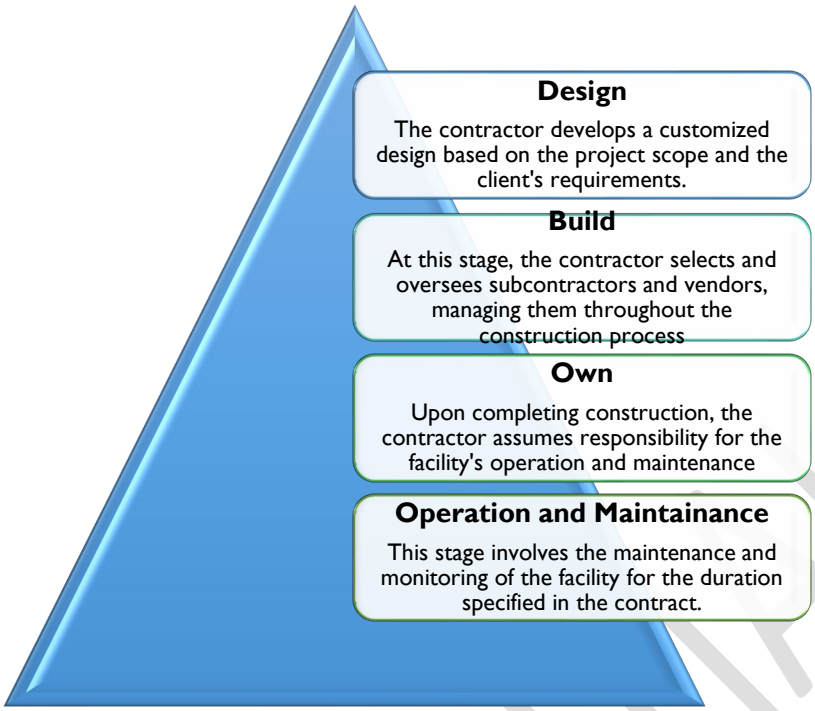
consortiums are responsible for constructing, owning, and operating infrastructure and facilities, typically in partnership with government entities or state-run corporations. In this model, companies invest in the development of critical infrastructure, such as pipelines, refineries, storage terminals, and gas processing plants, and are granted long-term operational control. The BOO model allows these companies to manage and maintain assets, ensuring their efficient operation while recovering their investments through the revenue generated from their use. This model has gained prominence in India due to its ability to attract private sector capital, improve operational efficiency, and reduce the financial burden on public funds, while also contributing to the country's energy security.



Source: D&B Research

Indian Oil & Gas Build-Own-Operate (BOO) Model Market has shown a steady growth trajectory, with revenues increasing from USD 6.5 billion (CY 2021) to USD 12.3 billion (CY 2031). The market experienced a compound annual growth rate (CAGR) of 5.3% between the initial years (CY 2021), with a notable acceleration in recent years, reaching a CAGR of 7.0% (CY 2031). This indicates strong expansion, driven by increasing demand and investments in the oil and gas infrastructure, suggesting a robust future outlook for the sector. The consistent growth reflects the sector's growing importance in India's energy landscape, with a greater emphasis on self-reliance in energy production and infrastructure development.

Additionally, it provides flexibility for private players to bring in technological innovations, optimize operations, and address infrastructure gaps in the rapidly growing oil and gas market. Although direct government funding is not provided, financial benefits such as tax exemptions may be offered. In this model, the developer retains full ownership and operational control of the facility.



Key Aspects of the BOO Model

- **Private Sector Financing** – The project is fully funded by the private entity, eliminating the need for upfront public investment and reducing the financial burden on the government.
- **Ownership Retention** – Unlike the Build-Own-Operate-Transfer (BOOT) model, where ownership eventually reverts to the public sector, the BOO model ensures permanent private ownership, offering long-term stability and operational control.
- **Operation & Revenue Generation** – The private company oversees daily operations, maintenance, and service delivery, recovering costs through user fees, tariffs, or long-term contracts.
- **Long-Term Agreements** – BOO contracts typically span 25 years or more, with options for renegotiation, contract extension, or continued private ownership upon expiration.
- **Risk Allocation** – The private sector bears most of the financial, operational, and regulatory risks, ensuring efficiency and accountability in project execution.
- **Specialized Expertise** – The model is particularly suited for complex, technology-driven sectors such as wastewater treatment, desalination, and oil & gas infrastructure, where private players bring advanced technical knowledge and innovation.

Applications of the BOO Model in India's Oil & Gas Sector

- LNG Terminals: Petronet LNG Ltd. uses the BOO model to operate India's largest LNG terminals in Dahej and Kochi for LNG import and regasification.
- Private Refineries: Reliance Industries and Nayara Energy utilize the BOO model to run large-scale refineries supplying domestic and international markets.
- City Gas Distribution (CGD): Companies like Adani Gas, IGL, and Gujarat Gas develop and operate CGD

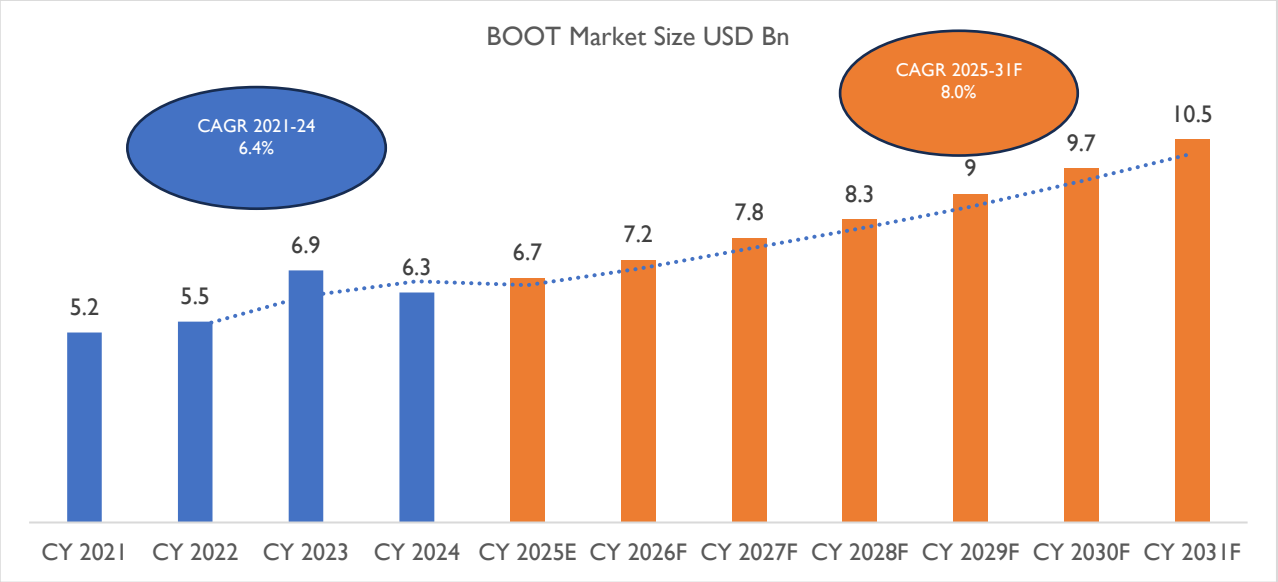
networks under BOO to deliver PNG to households and CNG to vehicles.

- Natural Gas Pipelines: GAIL and GSPL build and operate gas pipelines under BOO or hybrid models for regional gas transportation.
- The BOO model drives private investment, innovation, and infrastructure growth in India's oil and gas sector.
- With growing focus on energy diversification, the BOO model remains a key strategy despite regulatory and financial challenges.

6.3 Build Own Operate Transfer (BOOT) Model

It is a type of Public-Private Partnership (PPP) model, the developer is responsible for designing and constructing a facility with minimal or no financial burden on the government. The developer retains ownership and operates the facility as a business for a predetermined period, typically ranging from **10 to 30 years**. After this period, the facility is transferred to the government either at a pre-agreed price or at market value.

Here is the Historical Growth and Estimated Market Size of Build Own Operate Transfer (BOOT) model in India from 2021-2031:

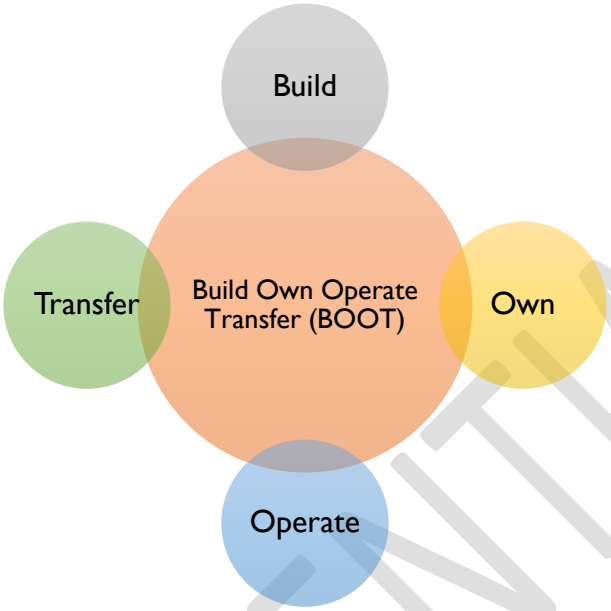


Indian Oil & Gas Build-Own-Operate-Transfer (BOOT) Model Market has experienced consistent growth, with revenues increasing from USD 5.2 billion in 2021 to USD 6.3 billion in 2024, reflecting a CAGR of 6.4%. The market is expected to continue expanding at a solid pace, with projected revenues reaching USD 10.5 billion by 2031, driven by a CAGR of 8.0% from 2025 to 2031. This growth reflects increasing investments in oil and gas infrastructure, as well as the growing need for self-sustaining energy projects in India, underlining a positive outlook for the sector in the coming decade.

The shift towards Build-Own-Operate-Transfer models in the oil and gas sector is part of India's broader strategy to enhance its energy infrastructure without overburdening the government with the full financial and operational responsibility. By involving private players in the ownership and operation of energy assets with eventual transfer to the government, India aims to improve efficiency, bring in advanced technology, and ensure long-term sustainability.

Overall, the market outlook for the India Oil & Gas BOOT Model remains positive, with steady growth expected through 2031, driven by the ongoing evolution of India's energy infrastructure needs, regulatory support, and the growing trend towards privatization and private-public partnerships in large-scale infrastructure projects.

Overview of BOOT Model:



The BOOT (Build-Own-Operate-Transfer) model in India's oil and gas sector begins with a detailed assessment of site-specific heating requirements, followed by a tailored system design that considers fuel availability, space, and integration needs. Once finalized, the private developer takes full responsibility for installation, commissioning, and quality assurance, ensuring seamless project execution. Throughout the contract period, the private entity retains ownership and operational control, managing all aspects of operations and maintenance using advanced technologies like IoT and data analytics to enhance performance and reliability. The payment structure is designed to be flexible, with clients paying based on the actual energy output, which minimizes capital burden and ensures cost efficiency. At the end of the contract, system ownership is transferred to the client with full documentation, training, and continued technical support to ensure smooth operation post-handover.

Benefits of the BOOT Model in the Oil & Gas Sector

- **Capital Optimization**: Reduces upfront investment; clients pay over time, preserving capital for other priorities.
- **Risk Sharing**: Private entities bear key project risks, reducing the financial and operational burden on public partners.
- **Innovation & Efficiency**: Long-term responsibility incentivizes private firms to adopt advanced, cost-effective technologies.
- **Stronger Public-Private Partnerships (PPPs)**: BOOT fosters collaboration, enabling large infrastructure projects without immediate public investment.
- **Access to Expertise**: Ensures operational excellence with expert-led design, execution, and asset management

6.4 Oil & Gas EPC Industry in India

The Oil & Gas Engineering, Procurement, and Construction (EPC) industry in India plays a critical role in supporting the country's energy infrastructure and driving its energy security. The EPC sector is responsible for designing, procuring, and constructing oil and gas facilities, including refineries, pipelines, offshore platforms, and terminals.

The oil and gas EPC sector is experiencing significant growth, driven by advancements in technology, increased investments, and a rising number of agreements between companies. These factors are enhancing project efficiency, reducing costs, and enabling the development of new oil and gas infrastructure. Companies are also focusing on improving break-even points and adopting innovative approaches to meet the increasing global energy demands.

Benefit for the Company:

Oswal Energies Limited, which generates around 80% of its revenue from the Oil & Gas EPC (Engineering, Procurement, and Construction) segment, is positioned to benefit from the growth trends observed in the India Oil & Gas EPC market. The expected market expansion, particularly in the period from 2025 to 2031, with consistent growth in demand for oil and gas infrastructure projects, will likely provide Oswal Energies with a larger share of contracts, particularly in upstream, midstream, and downstream sectors. Furthermore, as the oil and gas EPC market's percentage contribution gradually rises (from 15.6% in 2024 to 16.7% by 2031), Oswal Energies could see its market share grow proportionally.

With the market projected to grow at an overall pace of 4.6%, Oswal Energies can expect its Oil & Gas EPC revenue to increase, benefitting from rising investments in oil and gas infrastructure. If Oswal Energies can effectively capture a portion of this growth, it could see significant revenue increases, especially with the long-term trend towards infrastructure development and the ongoing transition to more advanced technologies in the EPC space. Thus, the market's overall growth directly benefits Oswal Energies' EPC business, providing a strong revenue stream and opportunities for business expansion over the next decade.

6.5 Overview of Oil & Gas EPC Industry, Key Activities / Operations

The sector is driven by the rising demand for energy and the government's emphasis on boosting domestic production, the EPC sector has attracted significant investments. Leading companies such as L&T, Punj Lloyd, and Essar, along with international firms, are actively involved in delivering EPC services to the industry. The sector benefits from technological innovations, robust government backing, and a skilled workforce.

In recent years, the Indian EPC market has shifted towards more intricate projects, including offshore oil fields, deepwater exploration, and sophisticated refinery developments. The government's focus on energy security, environmental sustainability, and the adoption of green technologies is encouraging the integration of renewable energy solutions, such as biofuels and carbon capture, alongside conventional oil and gas projects.

Key Activities/Operations in the Oil & Gas EPC Industry:

Engineering Design and Planning: This is the first and critical phase of the EPC lifecycle, where comprehensive feasibility studies and detailed designs are developed. The engineering activities include process design, detailed engineering, instrumentation, and electrical design, ensuring compliance with regulatory and safety standards.

Key Operations:

- Design of upstream facilities like drilling rigs, offshore platforms, and FPSOs (Floating Production Storage and Offloading units).
- Design and engineering for midstream projects like pipelines, storage tanks, and LNG terminals.
- Design of downstream refinery systems, storage units, and distribution networks.

Procurement and Supply Chain Management: The procurement phase involves sourcing all the materials, equipment, and services required for the construction of oil and gas facilities. This includes everything from raw materials like steel and cement to specialized components such as turbines and compressors.

Key Operations:

- Sourcing materials and equipment for refining units, pipelines, and LNG terminals.
- Managing the supply of critical machinery for offshore exploration platforms.
- Vendor management and procurement for quality control and cost optimization.

Construction and Installation: The construction phase is where the actual physical infrastructure is built. This involves civil, mechanical, electrical, and instrumentation work. The EPC contractors manage the entire construction process, ensuring the timely completion of projects within budget.

Key Operations:

- Building oil and gas exploration platforms, refinery units, and LNG terminals.
- Laying pipelines across various terrains, including urban, rural, and offshore environments.

- Installing critical infrastructure such as storage tanks, separators, and compressors.

Commissioning and Testing: Commissioning involves the final testing, integration, and verification of systems and equipment before the facility becomes operational. This phase ensures that all systems are functioning according to design specifications.

Key Operations:

- Testing of refinery systems, pipelines, and offshore installations to ensure safety and performance.
- Integration of systems such as automation, control systems, and safety protocols.
- Description: After the facility becomes operational, ongoing maintenance and operational support are crucial to ensure continuous production and safety. The EPC contractors may provide support services, including routine maintenance, emergency repairs, and upgrades.

Overview and Insights on Working Capital in Oil & Gas (EPC) Sector in India

The Oil & Gas EPC (Engineering, Procurement, and Construction) sector in India is characterized by capital-intensive and long-gestation projects, making effective working capital management critical for operational sustainability. Working capital in this industry involves managing high-value inventories, extended receivable cycles, and milestone-based payments. Due to the nature of turnkey contracts and the heavy dependence on upstream and midstream projects, EPC companies often face challenges in aligning project cash flows with liabilities, especially during delays in project execution or clearance bottlenecks.

A key driver of working capital requirements is the large amount of capital locked in work-in-progress (WIP) and receivables. Most Oil & Gas EPC contracts with public sector undertakings (PSUs) such as ONGC, GAIL, and IOCL involve extended payment cycles, often ranging from 90 to 180 days. This strain is further exacerbated when project billing is linked to physical completion milestones, causing delays in revenue recognition despite incurring procurement and subcontractor expenses upfront. Additionally, slow clearance of invoices and contract modifications frequently leads to disputed receivables, which are either long outstanding or written off entirely, adversely affecting cash flow.

Moreover, inventory holding especially in offshore or refinery projects remains high due to the need to stock long-lead equipment and critical components in advance. This increases the cash conversion cycle. Vendors and subcontractors often demand shorter payment terms, forcing EPC firms to rely on external borrowing. Consequently, the sector sees high dependence on working capital borrowings and bank guarantees, driving up interest and finance costs. In recent years, the tightening of bank lending norms post-IL&FS and the pandemic-related liquidity crunch further stressed working capital cycles.

To manage these pressures, leading Indian EPC players have focused on negotiating more favourable payment terms, adopting just-in-time procurement strategies, and improving cash flow forecasting. Digital project management tools are being leveraged to track milestone completion and billing efficiency. However, systemic

inefficiencies, bureaucratic delays in public contracts, and dependence on international suppliers continue to pose structural challenges. Strengthening contract enforcement, improving payment discipline among PSUs, and encouraging adoption of performance-linked early payment systems could help improve the working capital profile of the Oil & Gas EPC sector in India.

Future Outlook for the Oil & Gas EPC Industry in India:

- **Infrastructure Development:** With the government's focus on increasing refining capacity, expanding pipeline networks, and promoting LNG terminals, the EPC industry is expected to see continued demand for construction and engineering services.
- **Offshore Exploration**: As India continues to explore its offshore oil and gas reserves, the EPC industry will benefit from projects related to deepwater exploration and subsea installations.
- **Sustainability Focus:** With an increasing emphasis on cleaner energy, the sector is expected to see a shift towards sustainable projects, including green refineries and the integration of renewable energy with traditional oil and gas infrastructure.

The Oil & Gas EPC industry in India is integral to meeting the country's growing energy demands, and its role in the continued expansion of energy infrastructure remains critical to the nation's long-term economic growth Furthermore, growth in the sector is supported by strategic initiatives like the expansion of pipeline networks and the development of new LNG terminals, which align with India's goals to enhance its energy infrastructure and reduce reliance on imported fuels.

Major Players:

Power		
No.	**Key Player**	**Head Office**
1	L & T	Mumbai
2	Bharat Heavy Electricals (BHEL)	New Delhi
3	Ercom Engineers Pvt. Ltd	Chennai
4	Holtec Consulting Pvt Ltd	Gurgaon
5	Penta India Technical Consulting Pvt Ltd	Navi Mumbai
6	Dimond Group	Chennai
7	Elecon	Gujrat
8	Promac Engineering Industries Ltd	Bangalore
9	McNally Bharat Engineering Co. Ltd	Kolkata
Oil & Gas		
1	L&T	Mumbai
2	Bharat Heavy Electricals (BHEL)	New Delhi
3	BGR Energy System	Chennai

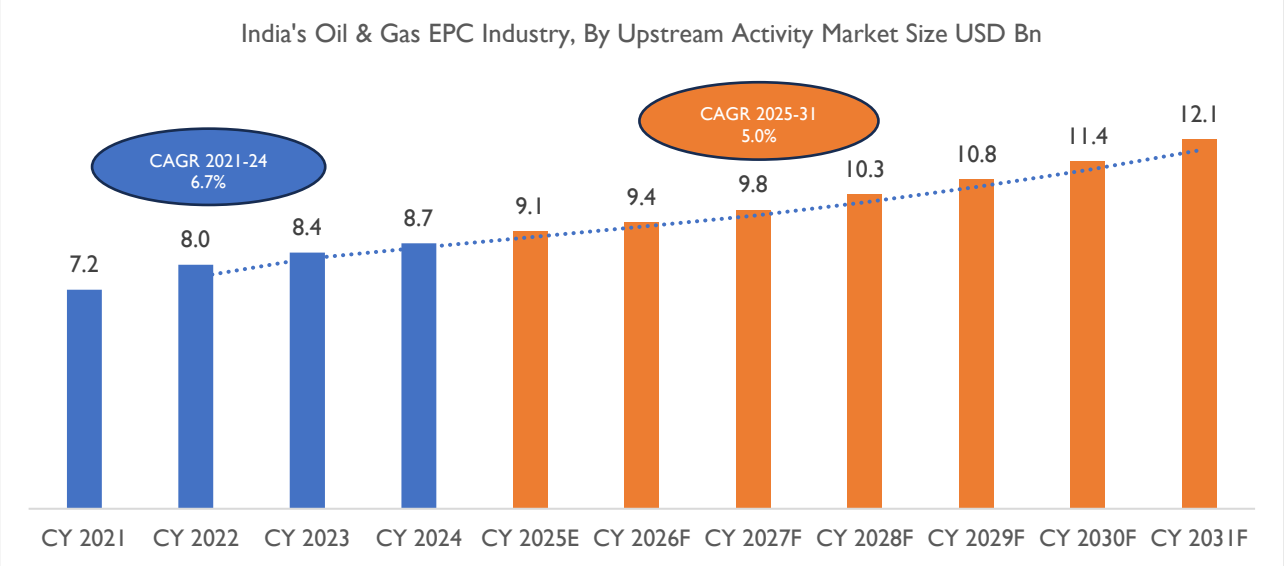
4	BMGI India	Mumbai
5	Dolphin Offshore Enterprises	Mumbai
6	PWC Group	Ahmedabad
7	ABB India	Bangalore
8	Procon India	Delhi
9	Equinox Engineering India	Pune
10	TOYO India	Mumbai
11	Punj Lloyd	Gurgaon

Market Segments:

- **Upstream:** Exploration and production (E&P) facilities, offshore platforms, and subsea installations.
- **Midstream:** Pipelines, LNG terminals, and transportation infrastructure.
- **Downstream:** Refining, storage tanks, and distribution networks.

India Oil & Gas EPC Market, By Activity: Historical Trend and Forecasted Market Growth (CY 2021-CY 2031F):

EPC in Upstream Activity:



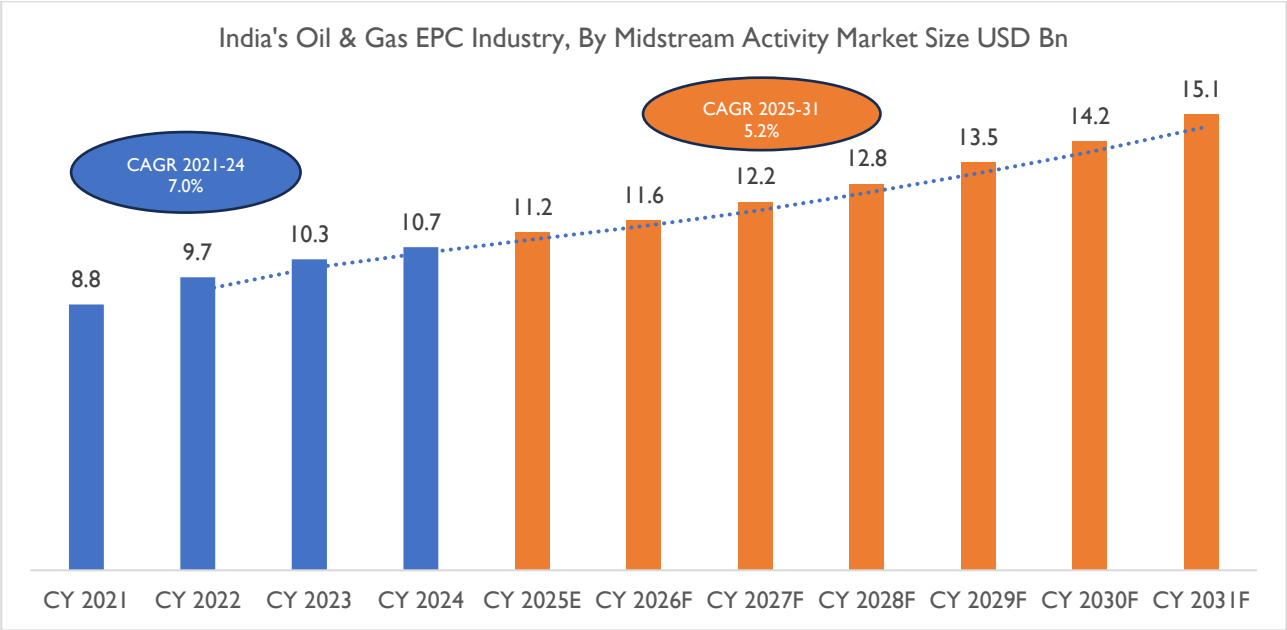
Source: Primary and Secondary Research

The India Oil & Gas EPC market, particularly in the upstream sector, is poised for significant growth driven by exploration, drilling, and production activities. With the increasing demand for energy, India is focusing on expanding its oil and gas production, particularly through new reserves and enhanced oil recovery (EOR) techniques.

Key Driver: Rising Energy Demand & Production Expansion: India's increasing energy needs are driving the expansion of oil and gas production, including exploration of new reserves and implementation of Enhanced Oil Recovery (EOR) techniques. Focus on Key Exploration Basins: Investments in exploration activities, particularly in significant onshore and offshore fields like the Krishna-Godavari Basin, are fueling demand for EPC services.

Technological Advancements: The adoption of advanced technologies such as digital oilfields and automated drilling is enhancing efficiency and driving the need for EPC companies to provide sophisticated solutions. Government Initiatives and Policies: Government initiatives focused on increasing domestic production and reducing import dependency are driving the EPC market.

EPC in Midstream Activity:



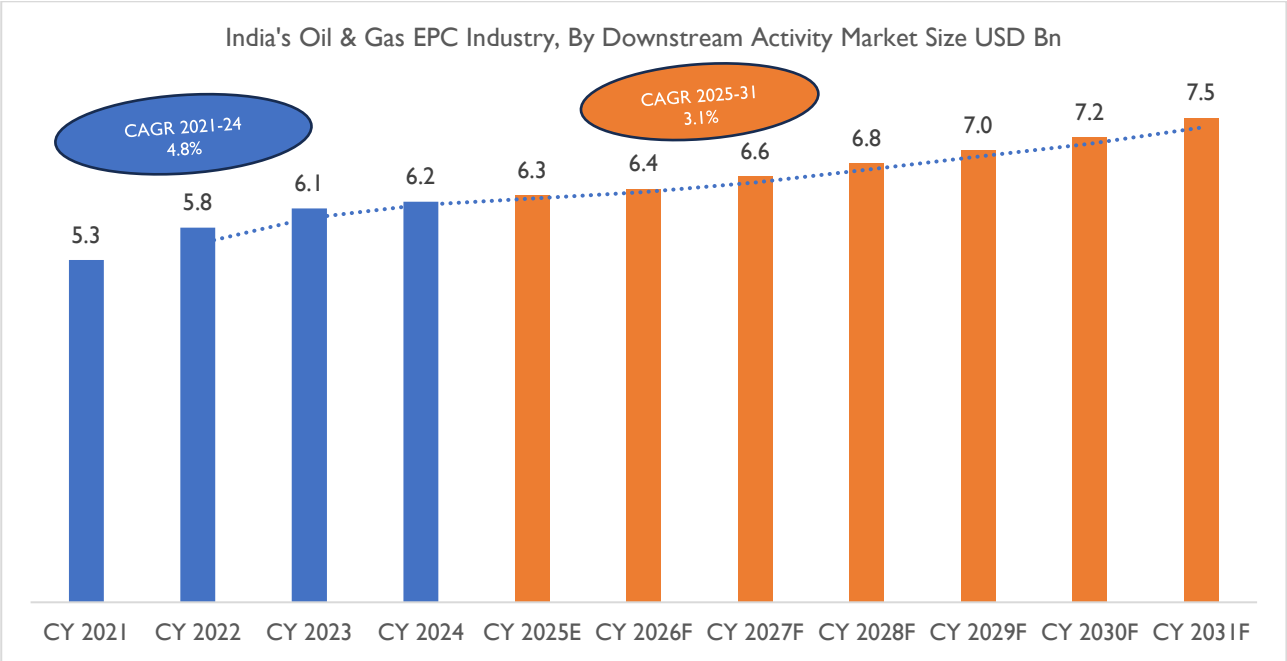
Source: Primary and Secondary Research

The India Oil & Gas EPC market in the midstream sector is focused on the transportation, storage, and distribution of oil and gas. This includes the construction and maintenance of pipelines, terminals, storage facilities, and liquefied natural gas (LNG) infrastructure. As India continues to expand its energy infrastructure to meet growing domestic demand, the midstream sector is experiencing significant investment, particularly in pipeline projects that connect oil and gas fields with refineries, distribution networks, and ports.

The government's push for energy security and infrastructure development, including the expansion of the National Gas Grid and cross-country pipeline projects, is driving demand for EPC services in this segment. Technological advancements in pipeline construction, monitoring systems, and safety standards are also enhancing the efficiency and safety of midstream operations.

Additionally, the rise in LNG imports and the development of related infrastructure, such as regasification terminals, further contributes to the growth of the midstream EPC market. In summary, the midstream EPC market in India is expanding due to ongoing infrastructure development, government support, and technological innovations aimed at improving the efficiency and security of oil and gas transportation and storage.

EPC in Downstream Activity:



Source: Primary and Secondary Research

The India Oil & Gas EPC market in the downstream sector focuses on the refining, processing, and distribution of petroleum products. This includes the construction and maintenance of refineries, petrochemical plants, and distribution infrastructure such as fuel storage facilities, retail outlets, and pipelines. As India's demand for refined petroleum products continues to grow, driven by urbanization, industrialization, and increasing vehicle usage, significant investments are being made in expanding and upgrading refinery capacities and introducing advanced refining technologies.

The government's push for cleaner fuels, including the shift towards Bharat Stage VI (BS-VI) fuel standards, is also stimulating demand for modernized refining infrastructure. Additionally, the increasing focus on petrochemical production and the development of integrated oil and gas facilities are driving growth in the downstream EPC market. Technological innovations in refining processes, environmental compliance, and automation are expected to further enhance the efficiency of downstream operations. Overall, the downstream EPC market in India is set for growth due to rising domestic demand, regulatory changes, and the need for modernization of infrastructure to meet global standards.

6.6 O&M Landscape in Oil & Gas Segment

Oil and gas operations today face a myriad of challenges, from volatile market conditions to stringent environmental regulations. Maintaining operational efficiency and ensuring safety in hazardous environments are paramount concerns.

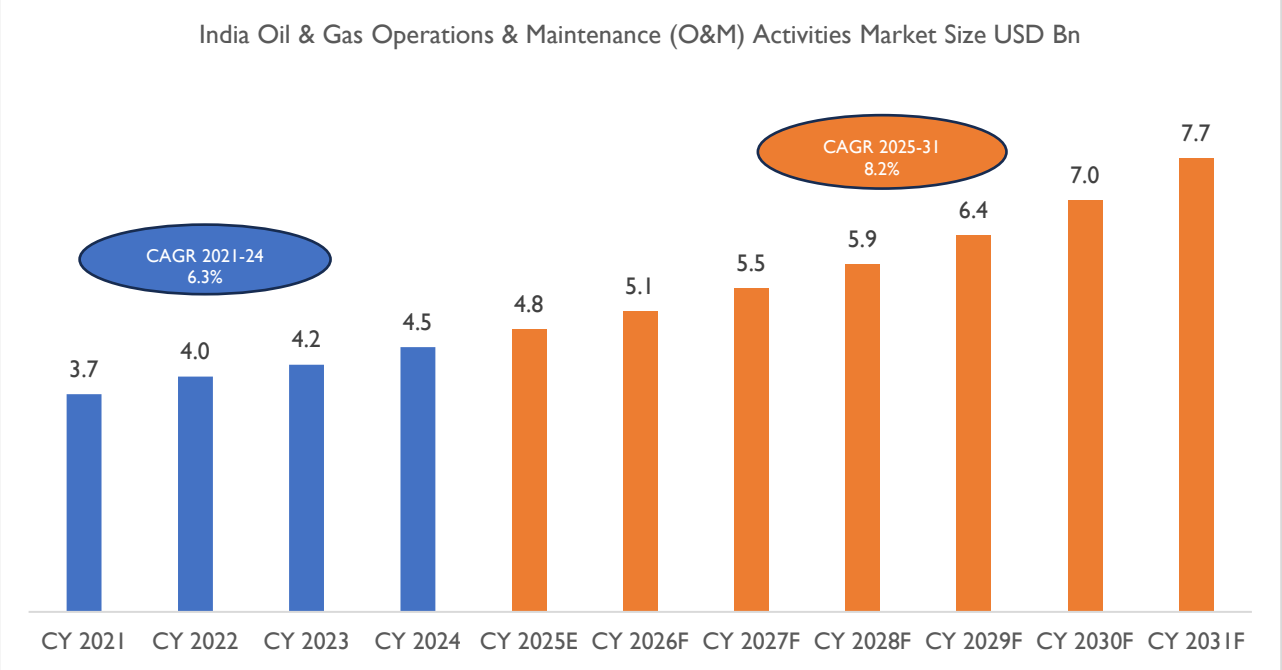
Traditional methods of inspection, monitoring, and maintenance are often labour-intensive, costly, and fraught with risk. The industry is at a crossroads, necessitating innovative solutions to overcome these hurdles and sustain profitability.

This segment encompasses a wide range of activities aimed at maintaining and optimizing the performance of oil and gas infrastructure, including refineries, pipelines, and processing plants.

Importance of O&M: Effective O&M practices are essential for minimizing downtime, reducing operational costs, and enhancing production efficiency. The oil and gas sector requires rigorous maintenance protocols to prevent equipment failures that could lead to costly interruptions or safety incidents.

Market Dynamics: The Indian O&M market is experiencing growth due to increasing investments in oil and gas infrastructure, driven by rising domestic energy demand. Companies are focusing on adopting advanced technologies such as predictive maintenance and condition monitoring to enhance operational efficiency.

India Oil & Gas Operations & Maintenance (O&M) Activities Market (USD Billion): Historical Trend and Forecasted Market Growth (CY 2021-CY 2031F):



Source: Primary and Secondary Research

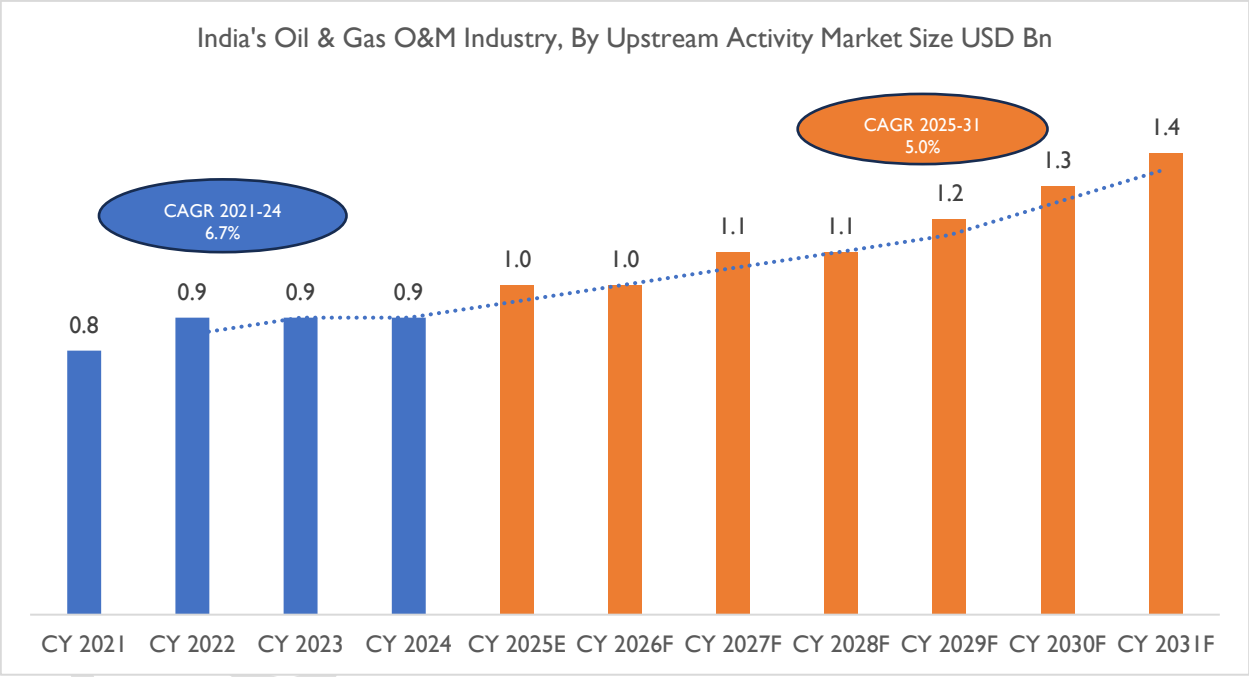
O&M Segmentation by Upstream, Midstream and Downstream Segment:

In India, the Operation & Maintenance (O&M) activities in the Oil & Gas industry are segmented into upstream, midstream, and downstream. Upstream O&M focuses on maintaining exploration and production

facilities, ensuring efficient and safe extraction of oil and gas. Midstream O&M involves the upkeep of pipelines, storage tanks, and transportation infrastructure to ensure smooth and secure transit of hydrocarbons. Downstream O&M covers the maintenance of refining, processing, and distribution facilities, ensuring optimal production and distribution of petroleum products. Each segment is critical to maintaining the efficiency, safety, and reliability of the entire supply chain in India's oil and gas sector.

India Oil & Gas Operation & Maintenance (O&M) Market, By Activity: Historical Trend and Forecasted Market Growth (CY 2021-CY 2031F):

O&M in Upstream Activity: The upstream sector focuses on crude oil and natural gas exploration and production, requiring intensive O&M due to complex extraction processes. Key activities include geological surveys, drilling, and well maintenance. High costs arise from advanced technology, skilled labour, and strict safety regulations. Managing thousands of wells and equipment presents logistical challenges. O&M involves maintaining rigs, wells, and production facilities, leveraging IoT sensors and predictive analytics to optimize performance, reduce downtime, and enhance efficiency.



Source: Primary and Secondary Research

The India Oil & Gas Operations & Maintenance (O&M) Activities market, particularly in the upstream sector, has shown steady growth from 2021 to 2024, with revenues increasing from USD 0.8 billion in 2021 to USD 0.9 billion in 2024, reflecting a modest CAGR of 4.5%. This growth is primarily driven by the ongoing exploration, drilling, and production activities in the oil and gas sector, which require continuous maintenance and operational support to ensure the efficient extraction of resources.

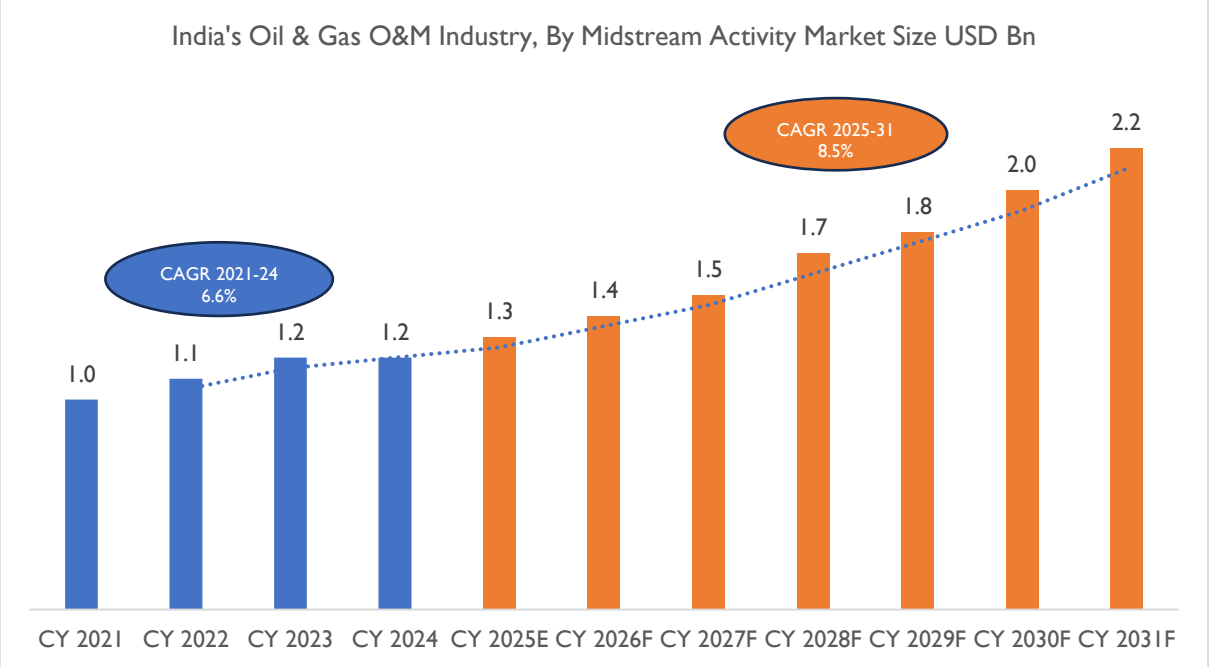
Looking ahead, the market is expected to experience a stronger expansion, with projected revenues reaching USD 1.4 billion by 2031, reflecting a CAGR of 6.2% from 2025 to 2031. This growth can be attributed to the

increasing investments in upstream infrastructure, as well as the rising complexity of operations in exploration and extraction processes, which necessitate enhanced O&M services.

The steady rise in the upstream O&M market suggests that, as exploration and production activities increase, the need for regular maintenance, equipment servicing, and operational optimization will grow. The market's future growth is also driven by technological advancements in the upstream oil and gas sector, which require specialized maintenance and operations to ensure smooth functioning, such as the implementation of digital oilfields and advanced drilling techniques. Additionally, the drive for more efficient and sustainable energy extraction methods is expected to fuel demand for advanced O&M services, contributing to the sector's expansion in the coming years.

O&M in Midstream Activity:

The midstream sector handles transportation, storage, and processing of oil and gas, requiring critical O&M for safe and efficient resource movement. Key activities include maintaining pipelines, storage facilities, and transportation fleets. Pipeline integrity is vital to prevent leaks and environmental risks. O&M focuses on maintaining terminals and transport infrastructure. Big data analytics enhances logistics and cost efficiency by optimizing inventory management, supplier performance, and demand forecasting, ensuring seamless operations.



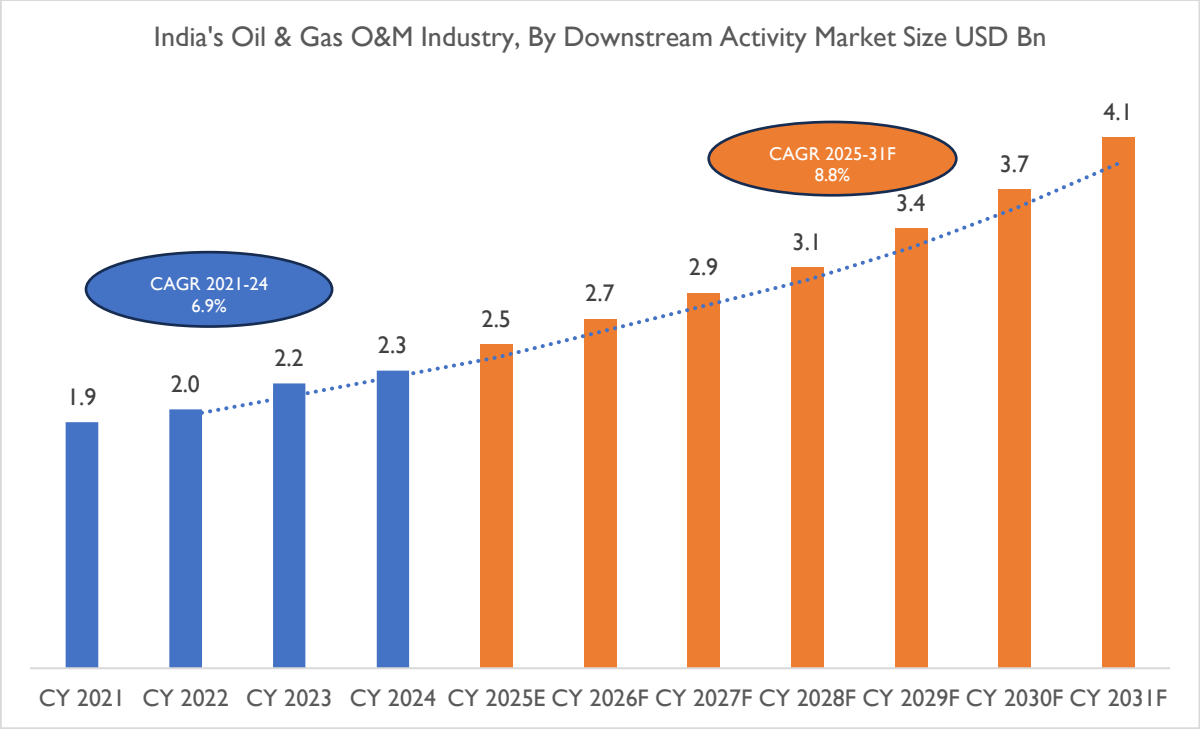
Source: Primary and Secondary Research

The India Oil & Gas Operations & Maintenance (O&M) market in the midstream sector has grown steadily from USD 1.0 billion in 2021 to USD 1.2 billion in 2024, with a CAGR of 6.6%. This growth is driven by the expansion of critical midstream infrastructure, including pipelines and storage facilities, which are vital for the efficient movement of oil and gas. Going forward, the market is expected to accelerate, reaching USD 2.2 billion by 2031, driven by ongoing pipeline and LNG infrastructure development, energy security initiatives,

and the need for regular maintenance. Technological advancements like pipeline monitoring, predictive maintenance, and automation will further boost operational efficiency and safety, increasing demand for skilled O&M services.

O&M in Downstream Activity:

The downstream sector includes refining, gas processing, and product distribution, requiring continuous O&M to prevent costly unplanned shutdowns. Maintenance focuses on refineries, petrochemical plants, and distribution networks, with predictive and reliability-cantered strategies ensuring efficiency and safety. Downstream O&M involves maintaining refineries and petrochemical plants. AI and machine learning optimize processes and reduce costs, while historical data analysis enhances risk identification and safety measures.



Source: Primary and Secondary Research

The India Oil & Gas Operations & Maintenance (O&M) market in the downstream sector has grown steadily from USD 1.9 billion in 2021 to USD 2.3 billion in 2024, with a CAGR of 6.9%. This growth is driven by expanding refining capacity, rising demand for refined products, and infrastructure modernization. Looking ahead, the market is expected to accelerate, reaching USD 4.1 billion by 2031, with a CAGR of 8.8%. This is driven by increased refining, the shift to cleaner fuels, and the need for advanced O&M services. Technological innovations like automation and process optimization will further enhance operational efficiency, supporting the sector's growth.

Key Trends in O&M:

- **Predictive Maintenance**: The adoption of predictive maintenance strategies is on the rise, utilizing data analytics and real-time monitoring to anticipate equipment failures. This proactive approach minimizes unplanned downtime, enhances safety, and reduces maintenance costs.

- **Digital Integration:** The industry is increasingly embracing digital tools such as Computerized Maintenance Management Systems (CMMS) and the Industrial Internet of Things (IIoT). These technologies facilitate efficient data management, predictive analytics, and streamlined maintenance workflows, leading to improved operational efficiency.
- **Asset Integrity Management Systems (AIMS):** Implementing AIMS ensures that assets perform their required functions effectively while safeguarding health, safety, and the environment. This comprehensive approach covers the entire asset lifecycle, from design and maintenance to decommissioning.
- **Integrated Operations (IO):** IO involves the use of advanced technologies and collaborative work processes to enhance decision-making and operational efficiency. By enabling real-time data sharing and remote collaboration, IO reduces the need for offshore personnel and optimizes resource utilization.
- **Sustainability Initiatives:** There is a growing emphasis on reducing the environmental footprint of O&M activities. This includes investments in technologies that lower emissions, improve energy efficiency, and support the transition to renewable energy sources.
- **Supply Chain Management:** Effective management of spare parts and consumables is crucial for maintaining operational continuity. This includes logistics planning for timely procurement and inventory management.

Challenges Faced by EPC Companies:

- **Aging Infrastructure:** Many oil and gas facilities are operating beyond their intended lifespans, leading to increased maintenance requirements and higher operational costs. Addressing the challenges of aging infrastructure is critical for maintaining safety and efficiency.
- **Skilled Workforce Shortage:** The industry faces a shortage of skilled maintenance professionals, necessitating investments in training and development programs to build a competent workforce capable of managing advanced O&M technologies.
- **Regulatory Compliance:** Adhering to stringent environmental and safety regulations requires continuous monitoring and adaptation of O&M practices to ensure compliance and avoid potential penalties.

Technology Advancements in EPC:

- **Robotics:** The integration of robotics is revolutionizing traditional operations, promising unprecedented improvements in efficiency, safety, and cost-effectiveness.
- **Drones:** Unmanned Aerial Vehicles (UAVs) equipped with optical sensors and artificial intelligence are utilized for pipeline surveillance, enabling real-time data transmission and access to hard-to-reach areas, thereby enhancing monitoring efficiency and safety.

- **Artificial Intelligence (AI) and Machine Learning:**
  - **Predictive Maintenance:** AI algorithms analyse data from equipment to predict failures and schedule maintenance proactively, reducing downtime and maintenance costs.
  - **Deep Learning Applications:** Deep learning techniques are applied for diagnostics and prognostics of oilfield equipment, enhancing predictive maintenance capabilities.
  - **Real-Time Monitoring: IIoT** devices collect and transmit data from machinery and infrastructure, facilitating real-time monitoring and decision-making to improve operational efficiency.
- **Digitalization & Data Analytics:**
  - **Digital Oilfields:** The adoption of digital oilfield technologies, encompassing analytics, cloud computing, and IIoT, is projected to surpass USD 20 billion by 2025, enabling real-time monitoring and optimization of operations.
  - **Prescriptive Analytics:** This approach analyses data to prescribe specific actions for optimizing drilling, completion, and production processes, thereby enhancing efficiency and reducing costs.
  - **Eelume Subsea Robot** – A self-propelled, snake-like robot designed for underwater inspection and maintenance without needing a remotely operated vehicle (ROV).
  - **Eddyfi Inspection Tool for Corrosion Under Insulation:** An advancement that is also likely to impact maintenance is a new technology for non-destructive testing (NDT) created by Eddyfi.

6.7 SWOT: Oil & Gas EPC

The Oil and Gas engineering sector in India is characterized by several strengths that contribute to its robust performance and growth potential.[8]

[8] https://www.transect.com/blog/top-9-challenges-epcs-face

Strength:

The Oil & Gas Engineering, Procurement, and Construction (EPC) sector in India is a vital component of the country's energy infrastructure. It has several strengths that contribute to its robust performance and growth potential.

- **Growing Demand for Energy:** Rising Energy Needs**:** With India's energy demand projected to increase significantly over the next decade, driven by economic growth and urbanization, the EPC sector is well-positioned to benefit from this trend. The country aims to increase its oil demand from approximately 5.4 million barrels per day (b/d) in 2023 to about 6.7 million b/d by 2030, creating substantial opportunities for EPC contracts in oil and gas projects.
- **Government Support and Policy Framework:** Favourable Policies**:** The Indian government has implemented favourable policies to attract investments in the oil and gas sector, including allowing 100% Foreign Direct Investment (FDI) in various segments. This supportive environment encourages EPC companies to invest in new projects and expand their operations.
- **Technological Advancements:** Innovation Adoption: The sector is increasingly adopting advanced technologies such as digital twins, IoT, and data analytics to enhance operational efficiency and project management. These innovations improve project delivery timelines and reduce costs, making Indian EPC firms more competitive.
- **Access to Global Markets:** International Expansion**:** Indian Oil & Gas EPC companies are increasingly venturing into international markets, leveraging their expertise to compete globally. This expansion not only diversifies their revenue streams but also enhances their capabilities through exposure to international standards and practices.

Weakness:

The Oil & Gas Engineering, Procurement, and Construction (EPC) industry in India faces several weaknesses that can hinder its growth and operational efficiency.

- **Regulatory Challenges:** Complex Approval Processes**:** The sector encounters slow-paced approvals for exploration and production activities, which can stall projects and extend timelines. Issues such as high cess rates (20% ad-valorem) and the need for multiple clearances from various governmental bodies complicate the regulatory landscape. Environmental Compliance: Stricter environmental regulations require companies to invest significantly in compliance measures, increasing operational costs and potentially delaying project execution.
- **Talent Shortages:** The industry is experiencing a shortage of skilled labour due to an aging workforce and limited entry of new talent. This shortage can impact productivity, safety, and the ability to implement new technologies effectively.
- **Price Volatility:** Market Fluctuations: Price volatility leads to unpredictable costs for raw materials, equipment, and labour. EPC companies often have fixed-price contracts for long-term projects, making it difficult for them to account for price fluctuations in materials like steel, cement, and equipment. If

prices rise unexpectedly, the margins for EPCs shrink, and they may end up incurring losses if they cannot renegotiate terms or pass the costs onto clients.

- **Corruption Risks:** The EPC sector is susceptible to corruption due to its complexity and competitive nature. Corruption can lead to substantial financial losses and damage the reputation of companies involved in public procurement processes.

Opportunities:

The Oil & Gas Engineering, Procurement, and Construction (EPC) industry in India is positioned for significant growth due to various emerging opportunities.

- **Government Initiatives and Policy Support:** Increased Exploration Acreage**:** The Indian government aims to increase exploration acreage to 1 million square kilometres by 2030, with a 16% increase expected in 2025. This expansion opens up new opportunities for EPC contracts in exploration and production activities [6].GST Inclusion: The ongoing discussions regarding the inclusion of petroleum products under the Goods and Services Tax (GST) can lead to improved tax efficiency and reduced costs for the sector, thereby enhancing investment attractiveness.
- **Technological Advancements:** Adoption of New Technologies**:** The integration of advanced technologies such as artificial intelligence (AI), the Internet of Things (IoT), and digital twins is transforming project management and operational efficiency within the EPC sector. These technologies can enhance predictive maintenance, reduce operational costs, and improve project timelines.
- Hydraulic Fracturing and Horizontal Drilling: The development of these technologies enables access to previously unreachable reserves, creating opportunities for EPC firms to engage in innovative projects that tap into new oil and gas fields.
- **Focus on Green Energy Transition:** Investment in Renewable Energy**:** As the sector progresses toward net-zero emissions targets, there is a growing emphasis on green hydrogen, compressed biogas plants, and other renewable energy initiatives. This transition presents EPC companies with opportunities to diversify their portfolios into sustainable energy projects.
- Carbon Capture and Storage (CCS): The demand for environmentally friendly solutions, including CCS technologies, is increasing as companies seek to reduce their carbon footprints. EPC firms can capitalize on this trend by developing expertise in sustainable practices.
- **Rising Demand for Infrastructure Development:** Pipeline and LNG Infrastructure**:** Significant investments are being made in expanding pipeline networks and LNG terminals to meet growing energy demands. This infrastructure development creates substantial opportunities for EPC contractors specializing in construction and installation services.
- Upstream, Midstream, and Downstream Projects: The diversification of projects across upstream (exploration), midstream (transportation), and downstream (refining) sectors allows EPC firms to engage in a wide range of activities, thereby mitigating risks associated with reliance on a single segment.
- **International Market Expansion: I**ndian EPC companies are increasingly exploring opportunities in international markets where energy demand is rising. Expanding into emerging markets across Asia-Pacific and Africa provides avenues for growth beyond domestic projects.

- **Aging Infrastructure:** The aging infrastructure in India's oil and gas sector represents a significant opportunity for companies to offer solutions that focus on modernization, safety, efficiency, and sustainability. By addressing the challenges posed by aging infrastructure, companies can unlock substantial growth potential, improve operational performance, and help the sector transition toward more sustainable and resilient energy practices.

Threats:

- **Environmental Regulations:** Stricter environmental regulations are pressuring the sector to reduce its carbon footprint. Compliance with these regulations may require significant investments in cleaner technologies and practices, impacting profitability.
- **Market Volatility:** Oil and gas prices are highly susceptible to global market dynamics, which can lead to unpredictable revenue streams for companies in the sector. Price fluctuations pose significant financial risks, particularly for smaller players who may lack the capital reserves to weather downturns.
- **High Import Dependency:** Reliance on Imports**:** India imports around 88% of its crude oil requirements, which exposes the industry to global price fluctuations and supply chain vulnerabilities. This heavy reliance can lead to increased costs and economic instability during periods of geopolitical tension or market volatility.
- **Economic Slowdown Risks:** Any potential economic slowdown could reduce energy consumption, leading to decreased demand for oil and gas products. This scenario could negatively impact revenues for companies operating within the sector.

7. Heavy Equipment Manufacturing Sector in India

Introduction:

The heavy equipment manufacturing sector in India plays a vital role in supporting the country's energy and oil & gas industries, producing critical machinery for energy generation, oil exploration, refining, and distribution. As India's energy demand grows, the sector is focusing on both renewable energy (solar, wind, etc.) and traditional power (thermal, hydro, etc.). The country is emerging as a significant player in manufacturing renewable energy equipment, such as solar panels and wind turbines, alongside oil and gas infrastructure like drilling rigs, refineries, and pipelines.

The capital goods sector plays a significant role in India's economy, contributing around 12% to the country's GDP. Additionally, it is a major source of employment, providing jobs to nearly 5.5 million people across the nation. This sector encompasses industries involved in the manufacturing of machinery and equipment used in other production processes, making it essential for the overall growth of India's industrial and infrastructure development.

Table 9 Five Year Trends on Production, Exports and Imports of Capital Goods Manufacturing Sector:

Indicators (in INR crores)	2018-19	2019-2020	2020-2021	2021-2022	2022-2023
Production	2,03,393	2,87,233	2,66,315	3,32,473	3,78,392
Export	75,211	81,375	78,126	98,412	1,21,041
Imports	1,25,062	1,17,716	98,729	1,23,431	1,67,182

Source: Ministry of Heavy Industries, India

Driven by technological advancements and government initiatives like the PLI Scheme for solar manufacturing, India's energy equipment manufacturing is growing rapidly. With ambitious targets such as 500 GW renewable energy capacity by 2030, the sector is positioned for continued expansion, offering substantial opportunities for innovation and global competitiveness. This growth is crucial to India's economic development and energy security.

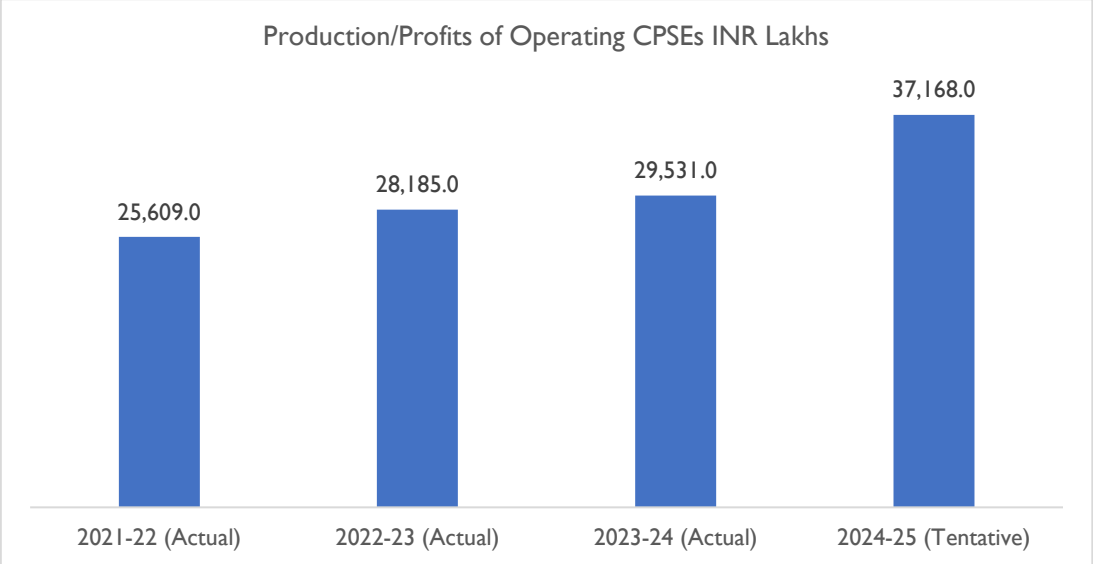
7.1 India's Capability in Heavy Equipment / Capital Goods Manufacturing

Indian manufacturers have developed a diverse product portfolio, producing a wide range of heavy equipment such as turbines, compressors, boilers, heat exchangers, pressure vessels, reactors, and drilling rigs, primarily catering to the energy, oil & gas, and petrochemical sectors. In line with the global green energy transition, companies are also expanding into the renewable energy space, producing wind turbines, solar components, and hydrogen infrastructure. Strategic partnerships with global firms, such as BHEL-Siemens and L&T with various OEMs, have allowed Indian manufacturers to access cutting-edge technology, enabling the production of high-efficiency equipment.

The country's cost competitiveness is bolstered by lower labour costs and increasing automation in production processes, allowing manufacturers to deliver high-quality products at competitive prices. Government initiatives like Make in India and the National Manufacturing Policy have further fostered investments and technology collaborations in heavy industries. Leading companies such as Larsen & Toubro (L&T) and Bharat Heavy Electricals Limited (BHEL) have developed world-class facilities that cater not only to the domestic market but also to global markets, enhancing India's presence in the global manufacturing arena.

Production and Manufacturing Capabilities of Heavy Industries in India:

The Ministry of Heavy Industries (MHI) oversees 22 Central Public Sector Enterprises (CPSEs). Out of these, 16 are currently operational, while 5 are in the process of closure. One CPSE, the National Bicycle Corporation of India Limited (NBCIL), is non-operational and also under closure. Additionally, 15 CPSEs are undergoing liquidation, managed by the Official Liquidator.



Source: Ministry of Heavy Industries (MHI) & Central Public Sector Enterprises (CPSE)

India's Heavy Equipment Manufacturing Landscape: Renewable Energy and Oil & Gas Sectors

Renewable Energy Equipment:

- **Wind Energy:**
  - Turbine Blades: Carbon/glass fibre for strength and efficiency
  - Nacelles: House generator and gearbox
  - Towers: Elevate turbines for optimal wind access
  - Gearboxes: Convert mechanical energy to electrical
- **Solar Energy:**
  - PV Panels: Silicon/thin-film; widely made in India
  - Inverters: Convert DC to AC power
  - Tracking Systems: Optimize panel orientation for sunlight
- **Hydropower:**
  - Turbines: Francis, Kaplan, Pelton types
  - Generators: Turn turbine motion into electricity
  - Control Systems: Automate and optimize operations

Government Support & Initiatives for Heavy Equipment Industry:

- **National Solar Mission: Incentivizes local solar manufacturing to reduce imports and boost solar power growth.**
- **Production-Linked Incentive (PLI) Scheme: Financial support for solar module manufacturers to increase domestic production.**
- **Wind Energy Policy: State-level incentives, grid connectivity, and land policies to promote wind energy.**
- **Capital Goods Scheme: Supports large-scale domestic manufacturing, reducing import dependence.**
- **Make in India: Encourages local production of heavy machinery (excavators, loaders, cranes) to boost infrastructure and jobs**.
- **Capital Goods Policy**: General Overview of Capital Goods Policies
  - National Capital Goods Policy 2016: Aims for global competitiveness by increasing domestic production, exports, and R&D.
  - Future policies are expected to focus on promoting indigenous manufacturing to reduce import dependence, supporting technology upgradation for enhanced competitiveness, and boosting exports to strengthen India's global capital goods presence. Emphasis will also be placed on sustainability and innovation in design and production.
  - To support these goals, policies may include investment incentives like tax benefits and subsidies, infrastructure development to improve logistics, and skill development programs to equip the workforce for modern manufacturing demands.

Oil and Gas Equipment:

- **Hydro processing Reactors and Separators:** Specialized for refining processes like hydrocracking and hydrotreating, these reactors are designed to handle extreme pressures and temperatures. They enable the removal of impurities and improve the quality of fuels.
- **Ammonia Converters and Urea Reactors:** Used in fertilizer production, these reactors facilitate chemical reactions under high-pressure and high-temperature conditions to convert feedstocks into ammonia or urea. As Urea production from level of 225 LMT per annum during 2014-15 to a record Urea Production at 314.07 LMT during 2023-24.
- **Heavy Wall Columns:** Engineered for fractionation and separation processes, they are designed with thick walls to withstand high internal pressures in refining and petrochemical operations. Ex - Indian firms supply to petrochemical hubs in Gulf countries and SE Asia.
- **Heavy Wall Process Separators & Drums:** These components separate gases, liquids, and solids in processing units, designed for durability under extreme operational stress. India has expanded domestic capacity to support over 300 LPG bottling plants and bulk storage solutions exported to African and ASEAN countries.
- **Large Diameter Columns & Towers:** Ideal for distillation and chemical processing, these large-scale structures enable efficient separation and refining of hydrocarbons.
- **Storage Bullets:** Designed for the safe storage of pressurized gases like LPG, these horizontal tanks ensure safety and stability during storage and handling.
- **Shell & Tube Heat Exchangers:** A critical part of thermal management systems, these heat exchangers facilitate heat transfer between two fluids in refining and chemical processes.
- **Pipelines:** India manufactures high-pressure pipelines used for the transportation of oil and gas from production sites to refineries or storage facilities. These pipelines are made with high-strength steel and undergo extensive testing for safety and durability. Ex- The length of operational Natural Gas Pipeline in the India has increased from 15,340 Km in 2014 to 24,945 Kms in September 2024.

Downstream Equipment (Refining and Distribution):

- **Refining Equipment:** India manufactures refineries and the essential equipment for the refining process, including distillation columns, crude distillation units, hydrocrackers, and catalytic reformers.
- **Storage Tanks**: For storing refined products such as gasoline, diesel, and liquefied natural gas (LNG), large capacity storage tanks are manufactured in India. LNG Terminals: India has developed facilities for the import, storage, and regasification of LNG, including floating storage units and regasification terminals.
- **Oilfield Services Equipment:** Pressure vessels are essential in oil and gas refining and natural gas processing stages. Pumps and compressors support operations like water injection, gas lift, and drilling through mud pumps.

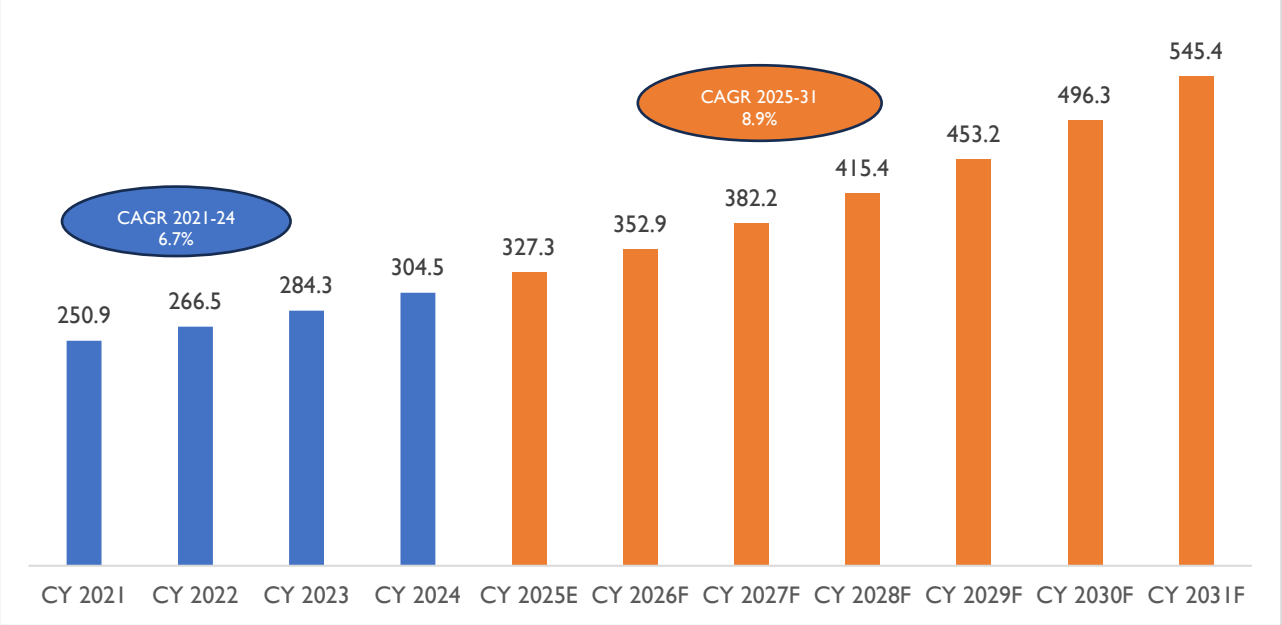
7.2 Key Players in Heavy Equipment Manufacturers

Energy				
	No.	**Key Players**	**Heavy Equipment**	**Key Projects**
Power	1	Larson & Toubro (L&T)	Steam Turbines & Generators Boilers & Heat Recovery Steam Generators, Condensers & Cooling Systems	Khargone Thermal Power Plant, Madhya Pradesh **Capacity:** 2x660 MW
	2	Bharat Heavy Electricals Limited (BHEL)	Thermal Powe, Gas Turbines, Hydropower Turbines, Nuclear Power Components, Transformers & Switchgear	Yadadri Thermal Power Plant, Telangana **Capacity:** 5×800 MW (4,000 MW)
	3	Thermax Limited	Industrial Boilers, Water Treatment Plants, Absorption Chillers.	
Solar	1	Tata Power Solar	Solar Panels, Solar Inverters, Floating Solar Panels	Solar PV Plant with Battery Energy Storage, Lakshisarai Bihar **185 MW Solar** PV Plant 254 MWh battery
	2	Vikram Solar	High-Efficiency Solar PV Modules, Solar Trackers, Energy Storage Systems.	Khavda Solar Project, Gujarat **Capacity:** 393.9 mwp
	3	Adani Solar	Bifacial Solar Panels, Solar Cells & PV Modules.	Kamuthi Solar Power Project, Tamil Nadu **Capacity:** 648 MW
	4	Waaree Energies	Solar PV Panels & Solar Water Pumps	Continuum Green Energy Project, India **Capacity:** 140 MW
Wind	1	Suzlon Energy	Wind Turbines Nacelles & Hubs Rotor Blades	Jaisalmer Wind Park, Rajasthan **Capacity:** 1,064 MW
	2	Siemens Gamesa India	Wind Turbines Nacelles, Blades & Towers	Ayana Renewable Power Project, Karnataka **Capacity:** 302 MW

	3	Inox Wind Ltd	Wind Turbines Towers (Tubular & Lattice) Blades & Nacelles	Kutch Wind Farm, Gujarat Capacity: 200 MW
	4	GE Renewable Energy India	Wind Turbines	O2 Power Wind Project in Maharashtra **Capacity:** 97 MW
Oil & Gas				
	No.	**Key Players**	**Heavy Equipment**	**Key Projects**
	1	KRN	Evaporator coil,Heat exchanger, condenser, Refrigerator	Schneider Electric, Carrier, Eberspächer and many more OEMs as our customers
	2	Anup Engineering	Heat exchanger, Reactors, Pressure vessel, columns and towers	The Anup Engineering and Graham Corporation (USA) have announced a strategic partnership through a manufacturing and supply agreement. Reliance Industries Ltd High-pressure heat exchangers and reactors
	3	Patel Airtemp	Air cooled heat exchanger, Air cooled condenser, Ambient air heater	Air Fin Cooler (AFC) to ONGC, Reliance Industries Limited (RIL), Hindustan Petroleum Corporation Limited (HPCL)

7.3 Insight on Infrastructure: Skids, Major Equipment Used

Modular Skid Market Growth in India in USD Million: CY 2021- CY 2031F



The skids market in India's oil & gas energy sector is experiencing steady growth, driven by increasing exploration and production activities, refinery expansions, and the adoption of modular process systems. Skid-mounted systems, which include pumping, filtration, metering, and gas processing units, are gaining traction due to their cost-effectiveness, faster installation, and operational flexibility. The market is further fuelled by rising investments in LNG infrastructure, offshore drilling, and enhanced oil recovery (EOR) projects. Government initiatives promoting domestic crude production, energy security, and the shift toward natural gas are also supporting market expansion. With advancements in automation, prefabricated modular solutions, and digital integration, the demand for skid-based systems is expected to grow, enhancing efficiency in India's upstream, midstream, and downstream oil & gas operations.

In both the energy (power) and oil & gas sectors in India, infrastructure plays a crucial role in ensuring efficient production, transportation, and distribution. The industry relies on advanced equipment, often mounted on "skids," to streamline operations and enhance mobility, safety, and efficiency.

Skids: Skids are structural steel framework assemblies that support modular process equipment. They allow for easy transportation and integration of equipment. The oil and gas industries use them for steel fabrication and piping.

Skids Systems in the Oil and Gas Industry: Types of Skids used[9]

Chemical Injection Skids:

Chemical injection is a key part of the oil and gas extraction process, involving a system made up of various storage tanks and pressure vessels. These injection systems are custom-designed to meet the specific requirements of clients, catering to a broad range of process applications.

Trend: Energy-efficient chemical injection skids are becoming more popular. These skids are designed with energy-saving features, such as reduced power consumption and optimized chemical injection rates. EPC companies and operators in India are focusing on designing skids with energy-efficient pumps, improved chemical storage management, and optimized injection processes, helping to reduce operational costs over time.

Surge Relief Skids:

Pressure surges occur when there are rapid changes in the flow rate of liquids within pipelines, which can be hazardous. Surge relief skids are crucial in preventing damage, providing safety solutions for hydraulic systems, transmission lines, and oil tanker loading terminals. These skids are designed to meet industry safety standards and regulatory requirements.

Trends:

Customization for Indian Operational Conditions- Surge relief skids are being designed with materials and components that can withstand India's environmental challenges, including extreme temperatures, humidity, and the corrosive effects of saltwater in offshore applications. Custom designs ensure better reliability and durability in these conditions.

Modular and Scalable Designs: Surge relief skids are increasingly being designed with modular and scalable configurations, allowing them to be easily adapted or expanded to meet changing operational needs.

Truck Loading Skids:

Truck loading skids, available in top-loading or bottom-loading configurations, ensure precise transfer operations while adhering to safety regulations. These skids are versatile, capable of loading a variety of products such as gasoline, diesel, methanol, and LPG.

Trends:

Enhanced Safety Features: Truck loading skids are increasingly being designed with advanced safety features such as overfill protection, emergency shutdown systems, leak detection, and spill containment systems to prevent accidents and spills.

Integration with Remote Monitoring and IoT: Truck loading skids are being increasingly integrated with IoT (Internet of Things) devices for remote monitoring and data analytics. IoT integration allows for continuous monitoring of loading skids, providing valuable data on flow rates, temperature, pressure, and other critical parameters.

Modular Skids:

Modular skids contain complete process systems or can be integrated with other skids to form larger, more complex systems. Common types of modular skids include:

- Gas Modular Skid
- Oil Modular Skid
- Power Water Injection Skid

Trends:

As the Indian oil and gas industry grows, companies need equipment that can easily scale with increasing production or adapt to changing operational requirements. Modular skids allow for incremental expansion without the need for major system overhauls.

Use of High-Quality Materials for Harsh Environments: Modular skids in India's oil and gas sector are made with corrosion-resistant materials like stainless steel to withstand harsh environments, including high humidity, extreme temperatures, and saltwater corrosion, ensuring long-term durability, especially in offshore and coastal areas.

[9] https://trenchlesspedia.com/definition/3439/skid#:~:text=Chemical%20injection%20skids.%20Chemical%20injection%20is%20done,over%20a%20wide%20range%20of%20process%20applications.

Modular Skids: Modular engineering solutions, particularly **modular process skids**, are gaining prominence across the **petrochemical, natural gas, and energy sectors** due to their compact, self-contained design. These skids integrate essential components such as equipment, piping, and instrumentation within a pre-engineered frame, making them highly adaptable. Depending on the scale of operations, modular skids can function either as standalone units or as integral parts of larger manufacturing systems. In smaller setups, they can even represent the entire infrastructure, while in larger projects, multiple skids can be combined to form a complete plant.

The **key advantages** of modular skids lie in their **portability, faster installation, and reduced on-site execution time**, making them ideal for time-sensitive or remote projects. Their **cost and material efficiency**, along with a design that supports scalability and robustness, provide a clear edge over conventional stick-built systems. As industries seek more flexible and resource-efficient solutions, modular skids offer a streamlined approach to project execution, especially in environments where space, speed, and precision are critical.

Applications of Modular Skids in Petrochemicals, Natural Gas, and Energy Sectors:

1. Petrochemical Sector

Modular skids play a critical role in supporting the **efficient processing of petrochemical feedstocks** and the **production of derivatives** such as ethylene, propylene, and aromatic compounds. Key applications include:

- **Reactor and distillation skids** for producing intermediates (e.g., olefins, polymers, solvents).
- **Heat exchanger and pump skids** for thermal management and fluid transfer in cracking or reforming units.
- **Filtration and separation skids** for removing impurities or separating products in downstream processing.
- **Chemical dosing skids** used in catalyst injection or for corrosion/scale prevention during refining.

Benefits: Compact footprint for space-constrained brownfield expansions, reduced downtime during maintenance, and standardization across multiple production lines.

2. Energy Sector

In the broader energy domain, especially in power generation and renewable energy integration, modular skids are deployed to streamline **support processes and auxiliary systems**. Applications include:

- **Water treatment and demineralization skids** used in boiler feedwater systems of thermal power plants.
- **Fuel gas conditioning skids** to filter, heat, and regulate gas before combustion in gas turbines or engines.

- **Battery storage and control system skids** in renewable energy plants for power management.
- **Modular cooling systems** (chillers, condensers) for turbine and generator operations.

Benefits: Rapid deployment in remote power plants, ease of transport to off-grid energy projects, and minimal on-site civil works.

3. Natural Gas Sector

Modular skids are extensively used throughout the **natural gas value chain**, from production to distribution. Major applications include:

- **Gas dehydration skids** (e.g., TEG systems) to remove moisture from natural gas streams.
- **Gas sweetening and compression skids** for H_2S and CO_2 removal and pressurization for transport.
- **Metering and regulation skids** at city gas distribution or pipeline custody transfer points.
- **LNG and CNG skids** for small-scale liquefaction, re-gasification, and vehicle refuelling stations.

Benefits: Portability for stranded gas fields or satellite gas hubs, standardized fabrication reducing lead times, and plug-and-play design for faster commissioning.

Overall Value Proposition Across Sectors:

- **Portability** for remote and inaccessible sites.
- **Faster commissioning** compared to stick-built systems.
- **Lower capital and operational costs** through optimized fabrication and minimal site work.
- **Scalability and replicability** across similar projects or locations.

Advantages of Modular Skids over Conventional Process Solutions:

Aspect	Modular Skids	Conventional Solutions
Compact Design Enabling Portability and Quicker Installation	Designed for space optimization with a compact layout; portable and suitable for constrained or remote sites; minimal structural modifications required for installation.	Larger and more dispersed setups; require more on-site space and customized civil structures.
Quick Installation Reducing On-Site Execution Time	Fabricated and tested off-site; allows parallel site preparation; reduces field installation and commissioning time; minimizes startup delays.	Entire process built and assembled on-site; longer construction timelines and more dependencies; higher risk of delays.
Robust Designs Used for Scalability	Modular configuration enables easy scalability; new units can be added in parallel/series; supports process upgrades with minimal disruption.	Scaling involves redesign and site rework; expansion may require downtime and additional permits.
Efficiency in Costs and Materials Used to Manufacture Process Skids	Centralized fabrication reduces material wastage and improves quality control; bulk procurement lowers costs; shorter execution time reduces labor and overhead expenses.	Higher on-site labor and logistics costs; greater material wastage; increased project execution costs due to extended timelines.

Process Skids: Process skids are modular, self-contained systems that consolidate essential process components such as equipment, piping, and instrumentation into a single, transportable frame. These systems are designed to execute specific industrial functions and are widely used to streamline complex processes across sectors such as petrochemicals, oil & gas, energy, pharmaceuticals, and water treatment. By integrating all necessary elements in a compact unit, process skids reduce the complexity and coordination required in traditional on-site installations, enabling faster deployment and improved project control.

The modular nature of process skids offers significant advantages in terms of portability, scalability, and efficiency. They can be fabricated and tested off-site in controlled environments, leading to better quality assurance and minimized construction risks. Once delivered, their plug-and-play setup drastically reduces installation time and on-site labour costs. Additionally, process skids support flexibility in design allowing companies to replicate or scale operations by adding more units as needed. These benefits make process skids a preferred solution in industries where speed, standardization, and cost-effectiveness are critical.

Advantages of Process Skids over Conventional Systems:

Aspect	Process Skids	Conventional Systems
Portability and Quicker Installation	Easily transportable and designed for fast on-site deployment. Installation involves placing the skid and connecting utilities, resulting in faster project completion.	Systems are built component by component on-site, requiring extensive labor, space, and longer installation time.
Reduction of On-Site Weld Joints and Cost of Welding	Major welding and assembly work is completed off-site in controlled conditions, minimizing field welding. This reduces safety risks, time, and welding-related costs.	High number of on-site weld joints increase labor costs, inspection efforts, and potential for rework or safety concerns.
Lower Procurement Costs through Single Transaction	Entire process skid is procured as one integrated package from a single vendor, reducing administrative burden and coordination issues.	Multiple components and systems are procured separately, requiring more vendor management, contracts, and approvals.
Shorter Time Duration to Make Plant Site Ready	While the site is being prepared, skid fabrication can occur in parallel. This concurrent progress shortens overall project timelines and accelerates readiness for operation.	Site must often be fully prepared before major equipment installation can begin, leading to longer lead times.
Pre-Tested and Quality-Controlled Systems	Factory acceptance testing (FAT) ensures the system is fully functional before delivery. This enhances reliability and minimizes start-up issues.	On-site testing is time-consuming and may uncover issues after installation, causing delays.

Major Equipment Used in Oil & Gas EPC [10]

The oil and gas industry are one of the largest and most significant sectors globally. Through the use of advanced equipment, both public and private oil companies are able to construct and maintain refineries where crude oil is processed and converted into valuable products like engine oil and gasoline.

In addition to oil and gas, crude oil yields numerous by-products. While each of these products undergoes specialized processes and equipment to meet specific standards, some of the key by-products include diesel fuel, asphalt, liquefied petroleum gas (LPG), pharmaceutical feedstocks, and wax, among others.

Maintenance Workshop Equipments

- **Pipe Fittings and Flanges**: Pipes and flanges are essential for directing the flow of oil and gas. Pipe fittings connect or change pipe direction, while flanges, secured with bolts and gaskets, serve similar functions.
- **Pressure Gauge**: Pressure gauges monitor equipment like separators and flow lines, helping operators assess pressure levels to make informed decisions.
- **Valve Actuator**: A valve actuator controls fluid flow through valves, allowing manual or automatic operation. High-quality actuators are resistant to pressure and high temperatures.
- **Lathes**: Lathes are versatile workshop tools used for shaping metal through processes like drilling, sanding, and cutting.

Drilling Equipments

- **Drill String and Bit**: Connected pipes that deliver rotation, weight, and fluid to the well, with the bit breaking rock formations.
- **Derrick**: A tall framework over the well, used to push drill pipes into the well.
- **Blowout Preventer (BOP)**: A valve that controls fluid flow and prevents blowouts during drilling.
- **Top Drive**: A motor that moves the drill string and enables deeper drilling, replacing the rotary table.

Wellhead Equipment Used in Oil and Gas

- **Casing Head**: Connects the casing to the wellhead, with flanges and locking bolts to prevent damage from excess pressure.
- **Casing Spool**: The lower part of the wellhead that supports the casing string, BOP, and provides annular outlets during drilling.
- **Tubing Heads**: Located above the casing spool, it holds the tubing and seals the annulus between casing and tubing.

Production Oil and Gas Equipments

- **Pressure Vessel & Distillation Column**: Pressure vessels store oil/gas under high pressure. Distillation columns separate liquid mixtures by heating.
- **Boiler**: Generates steam for distillation and heating by converting water through combustion.
- **Accumulator**: Controls the BOP, storing and transmitting hydraulic components to prevent spills.

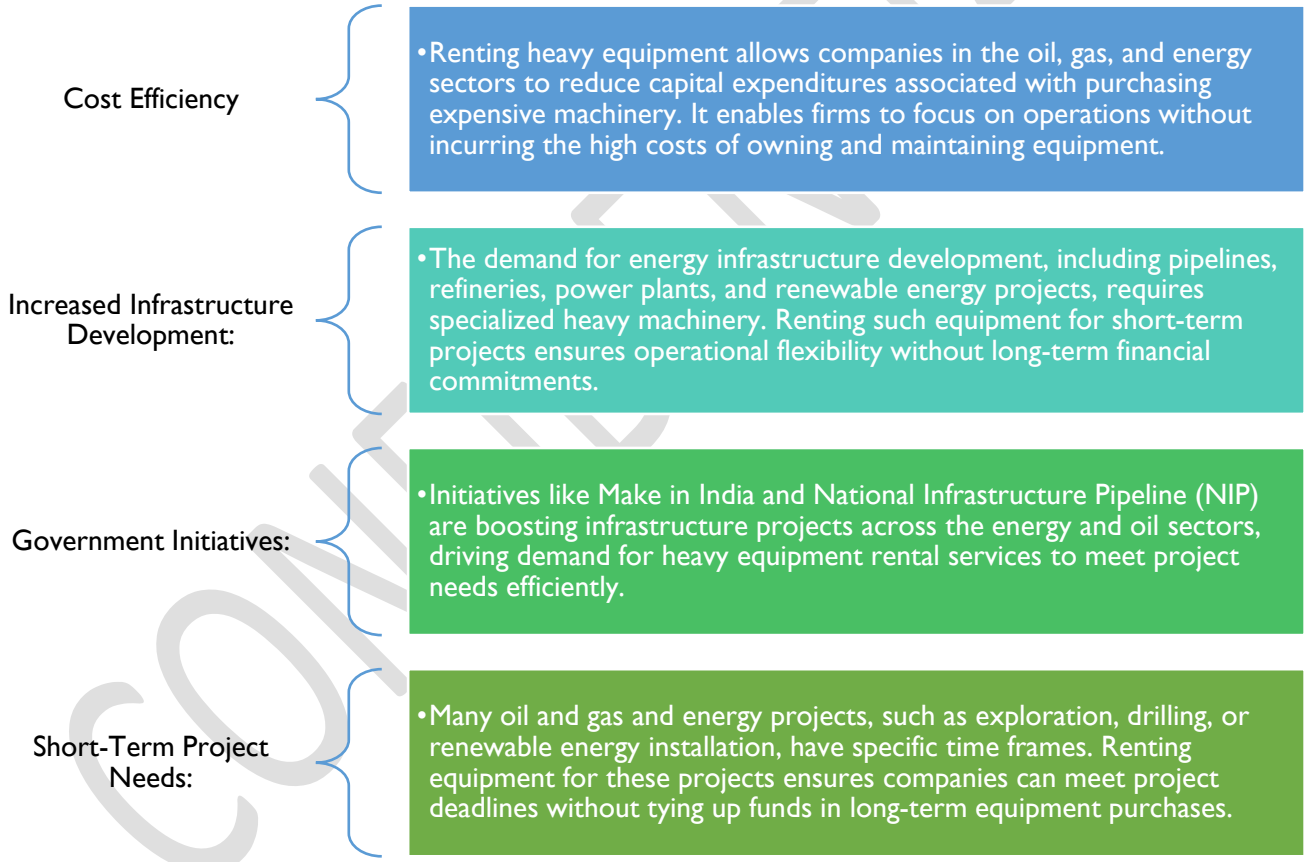
[10] https://www.dombor.com/oil-and-gas-equipment/

7.4 Equipment Rental: Oil & Gas and Energy

7.4.1 Brief Overview on Heavy Equipment Rental Landscape in India

The heavy equipment rental market in India is rapidly growing, fuelled by large infrastructure projects and a shift towards renting over buying. The construction sector dominates demand, while the oil & gas and energy sectors require specialized equipment like cranes and heavy machinery. Rising power demands and government infrastructure investments drive growth, with diesel and gas generators commonly rented for temporary power, especially in remote areas with poor grid access. Renting offers cost efficiency and flexibility, benefiting SMEs by avoiding high upfront and maintenance costs. The market is fragmented, with varied service quality but ongoing innovation. Key challenges include frequent power outages and insufficient grid infrastructure, which need addressing for sustained growth.

Heavy Equipment Rental Landscape in India: Drivers



7.4.2 Key Players: in Equipment Rental

Company	Products
Gainwell Commosales Pvt. Ltd.	Diesel and gas generators, transformers, air-cooled chillers, and mobile lighting towers.
RM Manlift Rental	Access equipment rentals, including crawler cranes, mobile cranes, and forklifts.
Sudhir Power	Industrial equipment rentals, including diesel generators and transformers.
Atlas Copco Specialty Rental	Temporary solutions for air, power, water, and steam requirements, including compressors, generators, and other specialized equipment.
Laxyo Energy Limited	Construction equipment rentals, including earthmoving machinery and road construction equipment. They emphasize supply and timely delivery of equipment for infrastructure projects.

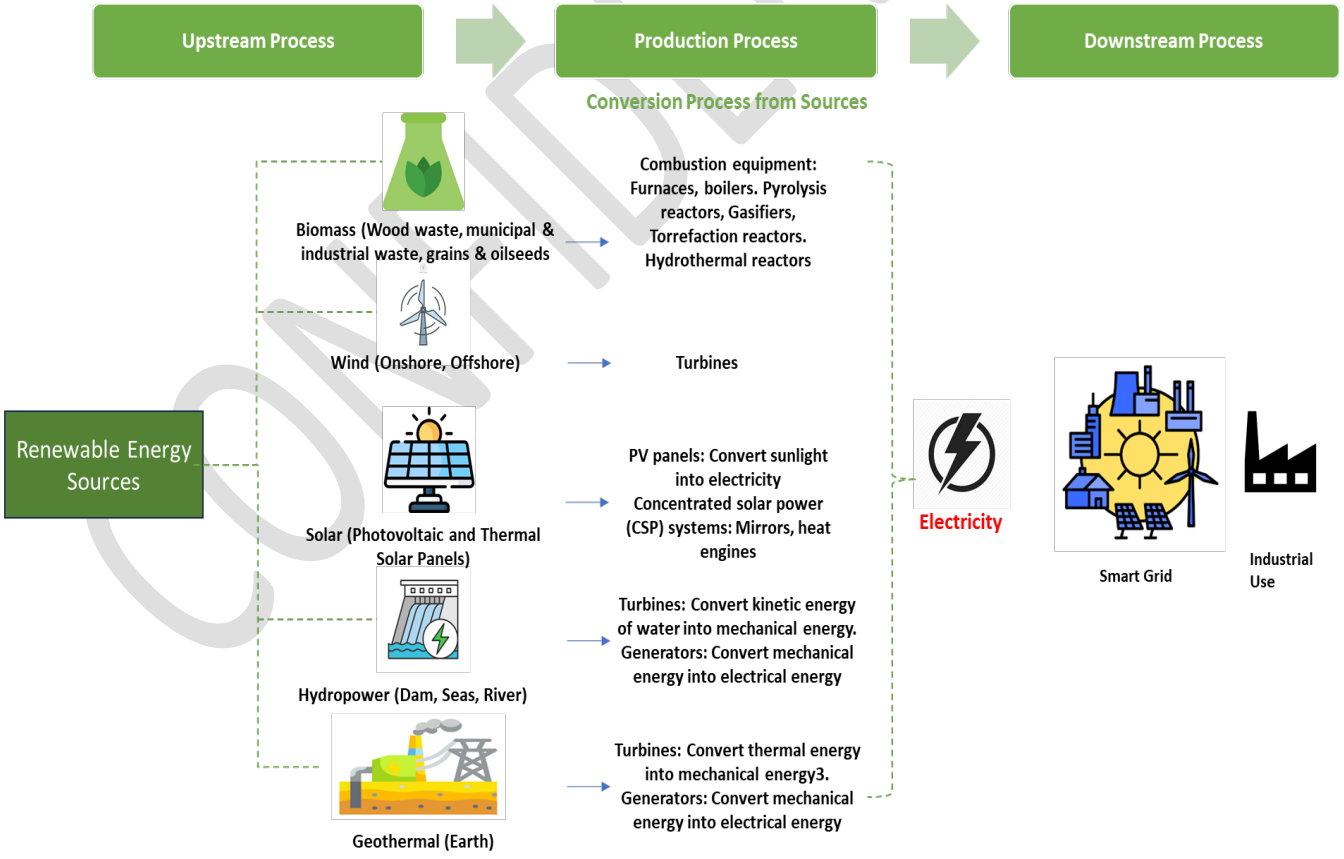
8. Renewable Energy Scenario in India

Renewable energy refers to energy derived from natural resources that are replenished at a rate faster than they are consumed. These sources are sustainable and have a lower environmental impact compared to fossil fuels. Renewable energy is often referred to as green energy or clean energy due to its minimal contribution to greenhouse gas emissions.

India is making significant strides in renewable energy, driven by technological advancements and supportive government policies. The development of high-efficiency solar panels, offshore wind turbines, and energy storage solutions is propelling the transition to clean energy. Government incentives and regulations are fostering a conducive environment for renewable energy adoption, ensuring economic viability and reducing greenhouse gas emissions.

By enhancing energy security and providing social and community benefits, renewable energy projects are creating jobs and improving rural electrification. The integration of renewable energy into the power grid presents challenges, but innovative solutions are being developed to ensure a stable and sustainable energy future for India.

Renewable Energy Value Chain:[11]



[11] https://mark-bridges.medium.com/transforming-the-renewable-energy-value-chain-c4881282a02d
https://gems.engie.com/energy-encyclopedia/what-is-energy-value-chain/
https://www.hennessyfunds.com/insights/energy-investmentidea-valuechain

Upstream Process (Renewable Energy Sources): This stage encompasses the various natural sources of renewable energy.

- **Biomass**: Includes organic materials like wood waste, municipal and industrial waste, grains, and oilseeds.
- **Wind** (Onshore, Offshore): Wind energy is harnessed through wind turbines.
- **Solar** (Photovoltaic and Thermal Solar Panels):
- **Photovoltaic** (PV) panels convert sunlight directly into electricity.
- **Thermal solar power** systems use mirrors to concentrate sunlight to generate heat, which then drives a heat engine to produce electricity.
- **Hydropower** (Dams, Seas, Rivers): The kinetic energy of flowing water is used to turn turbines and generate electricity.

  Geothermal (Earth): Geothermal energy utilizes the heat from the Earth's interior to generate electricity.

Production Process: This stage involves the conversion of the source energy into electricity:

- Biomass: Combustion equipment like furnaces, boilers, and gasifiers are used to convert biomass into heat, which then drives turbines to generate electricity.
- Wind: Wind turbines convert the kinetic energy of wind into mechanical energy, which rotates a generator to produce electricity.
- Solar (PV): PV panels directly convert sunlight into electricity.
- Solar (Thermal): Concentrated solar power (CSP) systems use mirrors to focus sunlight onto a receiver, heating a fluid that drives a turbine to generate electricity.
- Hydropower: Turbines convert the kinetic energy of flowing water into mechanical energy, which is then used to generate electricity.
- Geothermal: Geothermal power plants use the heat from the Earth to produce steam, which drives turbines to generate electricity.

Downstream Process: This stage involves the distribution and utilization of the generated electricity:

- Electricity: The generated electricity is transmitted through power grids to various end-users.
- Smart Grid: Smart grids are advanced electricity grids that use digital technology to improve efficiency, reliability, and sustainability.

Industrial Use: Electricity is used in various industrial applications, powering machinery, processes, and operations.

8.1 Installed Capacity Scenario in India

India has made significant strides in its renewable energy sector, achieving notable milestones and setting ambitious targets for the future. India has been one of the champions globally in adopting renewable energy as part of its energy transition. According to the Central Electricity Authority, India's total renewable energy-based electricity generation capacity has reached **203.15 GW** as of October 2024, highlighting the country's strong commitment to clean energy and sustainable development. This marks a significant increase of 24.2 GW (13.5%) compared to **178.98 GW** in October 2023.

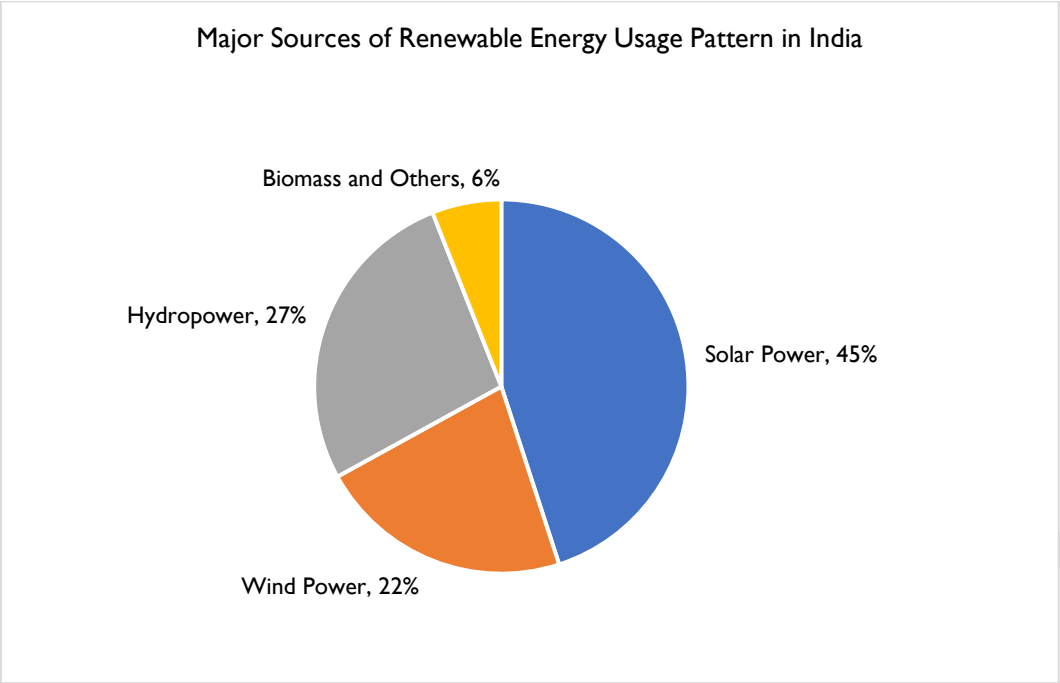
When including nuclear power, India's total non-fossil fuel capacity has risen to 211.36 GW in 2024, up from 186.46 GW in 2023. This growth underscores India's ongoing efforts to diversify its energy mix and reduce dependence on fossil fuels.

Over the years, India has steadily expanded its renewable energy portfolio through large-scale solar parks, wind farms, and hydroelectric projects. These initiatives have not only bolstered energy security but also positioned India as a global leader in clean energy. With 8,180 MW of nuclear capacity contributing to the mix, non-fossil fuel-based power now accounts for nearly 50% of the country's total installed electricity generation capacity, marking a significant step toward a greener and more sustainable future. [12]

As India continues to focus on sustainable development, the Union Budget 2025 has become a much-anticipated opportunity for the renewable energy (RE) industry to strengthen its contribution toward national and global climate goals. With the government's consistent efforts to promote clean energy, the industry has witnessed significant milestones, including surpassing 200 GW of renewable energy capacity. However, achieving the ambitious target of 500 GW by 2030 demands supportive policies, investments, and a collective push across various RE sources.

India's total electricity generation capacity has risen to 452.69 GW, with renewable energy playing a crucial role in the overall power mix. As of October 2024, the country's renewable energy capacity stands at 203.15 GW, making up 46.3% of the total installed capacity. This milestone highlights a significant transformation in India's energy sector, underscoring its increasing dependence on cleaner, non-fossil fuel-based energy sources.

[12] Press Information Bureau

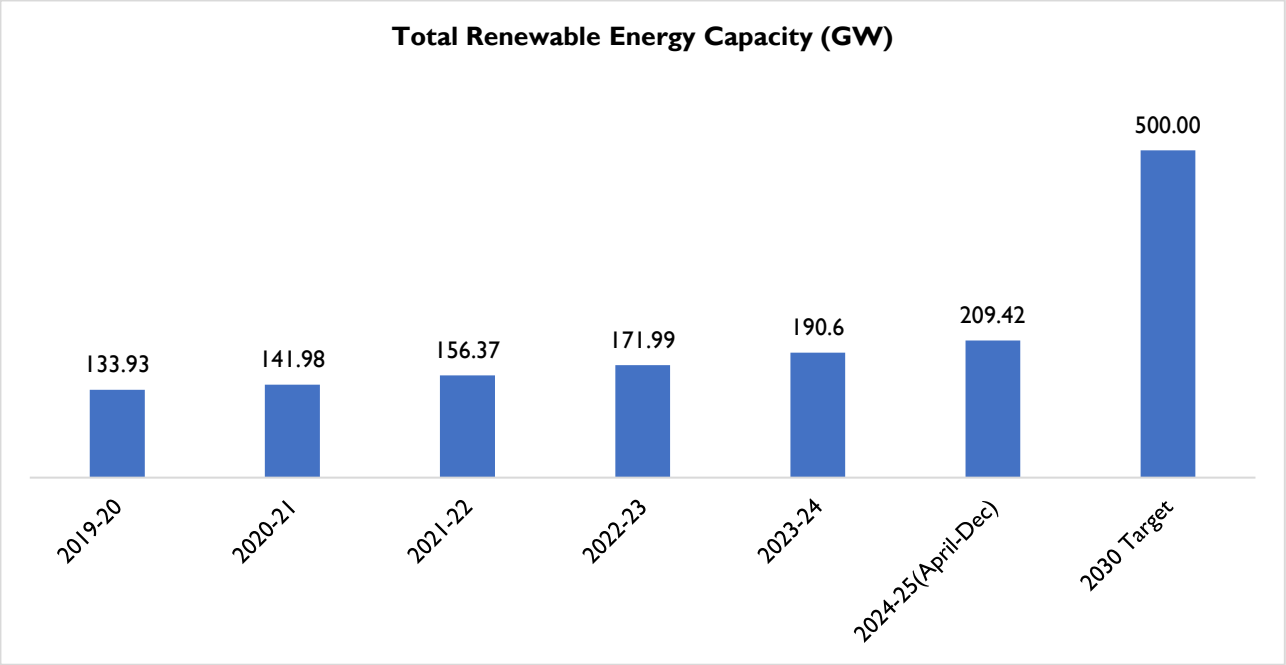


Source: D&B Research

The renewable energy sector has emerged as a cornerstone of India's developmental agenda, reflecting the nation's commitment to sustainability and energy security. The industry, supported by government initiatives, is now focusing on overcoming challenges such as domestic manufacturing, R&D capabilities, affordable financing, and streamlined regulatory frameworks. These areas, along with expanding the green energy infrastructure, have dominated the pre-budget expectations of industry leaders, reflecting a unified call for measures that bolster India's leadership in the global clean energy transition.

8.2 Current Capacity & Growth Trend: India's Renewable Energy

India's renewable energy capacity has been on a steady rise, with a promising outlook for further growth. This expansion is driven by numerous government initiatives aimed at promoting sustainable energy sources. For example, the focus on green hydrogen production is expected to revolutionize the energy landscape by providing a clean and efficient alternative to traditional fossil fuels.



Source: D&B Research

Additionally, government policies are encouraging the development of advanced solar and wind technologies, supporting domestic manufacturing, and improving grid infrastructure to accommodate the increasing share of renewables. Investments in research and development are also fostering innovation in energy storage solutions, enabling more reliable and efficient use of renewable energy.

In FY 2019-20, India's renewable energy capacity stood at 133.93 GW, marking the foundation for its clean energy initiatives. By FY 2020-21, this capacity grew to 141.98 GW, reflecting a year-on-year growth of approximately 6%. FY 2021-22 saw a significant rise to 156.37 GW, representing an annual increase of around 10.2%. In FY 2022-23, capacity further surged to 171.99 GW, showing a growth of 10% from the previous year. By FY 2023-24, the capacity reached 190.6 GW, achieving an annual increase of 10.8%. For FY 2024-25 (April–December), the renewable energy capacity is projected to grow to 209.42 GW, with a notable increase of 9.87% within just three quarters.

Table 10 Major sources of renewable energy in India along with their approximate contributions to the total renewable energy capacity by Oct-2024:

Renewable Energy Source	Installed Capacity (GW)
Solar Power	92.12
Wind Power	47.72
Hydropower	51.99
Biomass and Others	11.32

*GW- Giga Watt

Table 11 Renewable Energy Installed Capacity State wise:

As of March 2024, below are the leading states contributing to the installed capacity of renewable energy. [13]

Type of Installed Capacity	Leading States	Collectively Contributing Percentage from leading states
Renewable Energy Capacity	Gujarat, Rajasthan, Tamil Nadu, Karnataka, and Maharashtra	61%
Solar Power Installation	Rajasthan, Gujarat, Karnataka, Tamil Nadu, and Maharashtra	70.76%
Wind Power Capacity Installation	Gujarat, Tamil Nadu, Karnataka, Maharashtra, Rajasthan, and Andhra Pradesh	93.37%
Bioenergy	Maharashtra, Uttar Pradesh, Karnataka and Tamil Nadu	71.49%
Hydro Installed Capacity	Himachal Pradesh, Uttarakhand, Karnataka, Jammu and Kashmir, Maharashtra and Telangana	57.15%

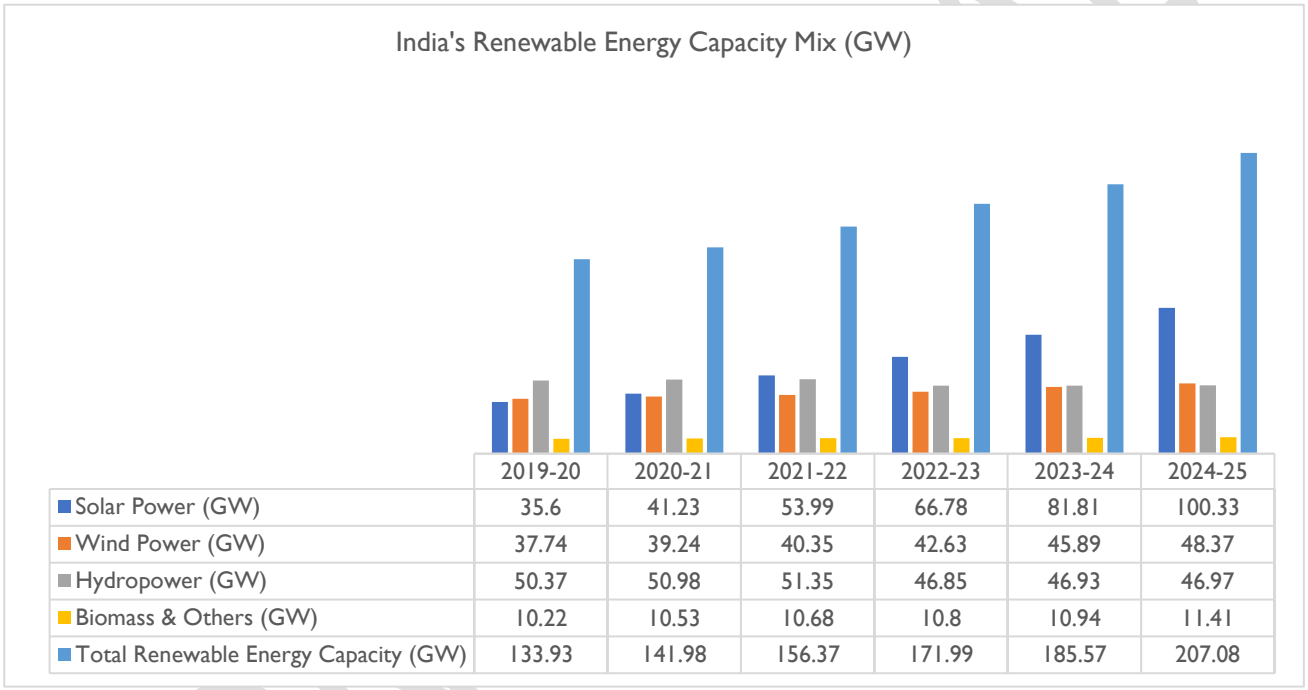
Over the entire period from FY 2019-20 to FY 2024-25, India's renewable energy capacity expanded by 75.49 GW, translating to an impressive overall growth of 56.4%. This steady annual growth rate, averaging around 11.3% per year, reflects the success of policy measures, private-sector investments, and technological advancements in clean energy.

The milestones highlight India's diversified approach, incorporating solar parks, wind farms, hydroelectric projects, and other renewable sources. These efforts have also propelled the share of renewable energy to over 46.3% of the country's total installed electricity capacity, solidifying India's position as a leader in the global clean energy landscape. Looking ahead, India's renewable energy capacity is expected to continue its upward trajectory, driven by ambitious government targets and increasing private-sector investments. The nation aims to achieve 500 GW of non-fossil fuel capacity by 2030, with renewable energy playing a central role. This growth trajectory underscores India's commitment to achieving its climate goals and transitioning to a sustainable, low-carbon energy system.

[13] https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2024/10/2024102951232546 4.pdf

8.3 Capacity Breakup by Source (Solar / Wind / Other)

India's renewable energy generation is supported by a diverse mix of sources, driving the nation's clean energy transition. Solar energy leads the sector, with expansive solar parks and rooftop installations contributing significantly to the energy mix. Wind energy follows closely, with high-potential regions like Tamil Nadu, Gujarat, and Rajasthan playing a pivotal role. Hydropower harnesses the country's vast river systems, encompassing both large and small-scale projects. Biomass energy utilizes agricultural waste, forest residue, and organic matter to generate electricity, adding to the sustainability of the energy landscape. Additionally, emerging sources such as geothermal and tidal energy, though in their early stages, present immense potential for future development. Together, these sources reflect India's commitment to a greener, sustainable energy future.



	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25
Solar Power (GW)	35.6	41.23	53.99	66.78	81.81	100.33
Wind Power (GW)	37.74	39.24	40.35	42.63	45.89	48.37
Hydropower (GW)	50.37	50.98	51.35	46.85	46.93	46.97
Biomass & Others (GW)	10.22	10.53	10.68	10.8	10.94	11.41
Total Renewable Energy Capacity (GW)	133.93	141.98	156.37	171.99	185.57	207.08

8.4 Generation scenario: Renewable Power Generation Scenario in India

Table 12 Renewable Energy Generation during 2023-24:

As of March 2024, below are the leading states contributing to the generation of renewable energy:

Type of Energy Production	Leading States	Collectively Contributing Percentage from the Leading States
Renewable Energy Production	Rajasthan, Gujarat, Karnataka, Himachal Pradesh, and Tamil Nadu	56%
Solar Power	Rajasthan, Karnataka, Gujarat, Tamil Nadu, and Andhra Pradesh	75%
Wind Power	Gujarat, Tamil Nadu, Karnataka, Maharashtra, Rajasthan, and Andhra Pradesh	93%
Bioenergy	Maharashtra, Uttar Pradesh, Karnataka, West Bengal, and Chhattisgarh	74%
Hydro Energy	Himachal Pradesh, Uttarakhand, Karnataka, Jammu and Kashmir, and Sikkim	62.47%

Table 13 Key Renewable Sources Percentage for Leading States in India:

The following table outlines the key renewable energy sources and their respective percentages for the leading states in India based on installed capacity:

State	Total Installed Capacity (GW)	Solar Power (%)	Wind Power (%)	Hydropower (%)	Biomass & Others (%)
Rajasthan	29.98	80%	10%	6%	4%
Gujarat	29.52	60%	30%	5%	5%
Tamil Nadu	23.70	25%	65%	8%	2%
Karnataka	22.37	40%	40%	15%	5%
Maharashtra	17.53	15%	20%	10%	55%.

8.5 Regulatory Landscape: Renewable Energy

India has developed a comprehensive regulatory framework to support the growth of renewable energy (RE). This framework is essential for achieving the country's ambitious targets and addressing the challenges in the sector. Below is a detailed overview of the key components of India's regulatory landscape for renewable energy.

1. National Goals and Policies

- **500 GW Target by 2030**: India aims to achieve **500 GW** of non-fossil fuel-based energy capacity by 2030, reflecting a significant commitment to renewable energy.
- **Net-Zero Emissions by 2070**: The country has set a long-term goal to reach net-zero carbon emissions by 2070, aligning with global climate commitments.

2. Key Regulatory Bodies

- **Ministry of New and Renewable Energy (MNRE)**: The primary government body responsible for formulating policies and implementing programs related to renewable energy.
- **Central Electricity Regulatory Commission (CERC)**: Regulates tariffs and ensures transparency in operations within the electricity sector, including renewable energy projects.
- **State Electricity Regulatory Commissions (SERCs)**: State-level bodies that regulate electricity distribution and tariff setting for renewable energy projects.

3. Incentives and Financial Mechanisms

- **Renewable Purchase Obligations (RPOs)**: Mandates that distribution companies purchase a certain percentage of their total power from renewable sources, ensuring market demand for RE.
- **Waivers on Transmission Charges**: The government provides waivers on interstate transmission system (ISTS) charges for renewable energy projects, enhancing their financial viability.
- **Green Energy Certification**: A framework to certify renewable energy generation, facilitating trading in green certificates to promote investment.

4. Specific Schemes and Initiatives

- **National Green Hydrogen Mission**: Launched to promote the production and utilization of green hydrogen, aiming to decarbonize industries such as steel and transportation.
- **PM-KUSUM Scheme**: Encourages solar power installations in agriculture by providing financial support for solar pumps and grid-connected solar projects.
- **Solar Energy Corporation of India (SECI)**: Facilitates the development of solar parks and supports bidding processes for solar projects.

5. Electricity (Promoting Renewable Energy Through Green Energy Open Access) Rules, 2022

- These rules allow consumers with a contracted demand of 100 kilowatts or more to procure power through green energy open access, promoting flexibility in sourcing renewable energy.

6. Recent Developments

- The draft Green Hydrogen Certification Scheme is expected to be published in 2025, aimed at promoting hydrogen production and its derivatives.
- Pilot projects in the steel sector using hydrogen are underway, indicating a shift towards integrating hydrogen into industrial applications.

The government continues to emphasize research and development (R&D) collaborations with premier institutions to enhance domestic capabilities.

8.6 Growth Forecast: Expected Growth in Renewable Energy Usage Pattern in India

India is poised for significant growth in its renewable energy sector, driven by ambitious targets, government initiatives, and increasing investments. Below is a detailed analysis of the expected growth trends based on the latest information.

1. Current Capacity and Recent Achievements

- **Total Renewable Energy Capacity**: India's total renewable energy capacity stands at approximately **209.44 GW**.
- **Recent Additions**: In 2024 alone, India added a record **24.5 GW** of solar capacity and **3.4 GW** of wind capacity, marking substantial growth compared to previous years.

2. Projected Growth Rates

- **Capacity Additions**: According to projections, India's annual renewable capacity additions are expected to increase significantly:
- From **15 GW in 2023**, the capacity addition is projected to quadruple to **62 GW by 2030**.
- **Solar Power Dominance**: Solar energy is anticipated to be the largest contributor to this growth, with expectations of reaching up to **300 GW** by 2030.

3. Government Targets and Policies

- **500 GW Target by 2030**: The Indian government has set an ambitious target of achieving **500 GW** of non-fossil fuel-based energy capacity by 2030.
- **Net-Zero Commitment**: India aims for net-zero carbon emissions by **2070**, which necessitates a robust expansion of renewable energy sources.

4. Investment Landscape

- **Doubling Investments**: Investments in the renewable energy sector are expected to double to over **USD 32 billion** by the end of 2025.
- **Supportive Policies**: Government incentives, such as tax rebates and subsidies for renewable projects, are driving investments and facilitating growth.

5. Technological Advancements

- **Energy Storage Solutions**: By 2025, significant progress is expected in large-scale battery storage projects that will help stabilize the grid and reduce energy waste.
- **Smart Grids and Electric Vehicles**: The integration of smart grids and electric vehicles is anticipated to enhance the efficiency of renewable energy usage.

6. Regional Contributions

States like Gujarat, Karnataka, Maharashtra, and Tamil Nadu continue to lead in renewable energy installations, accounting for a significant portion of new capacity additions in both solar and wind sectors.

8.7 Key Threats & Challenges: Renewable Energy

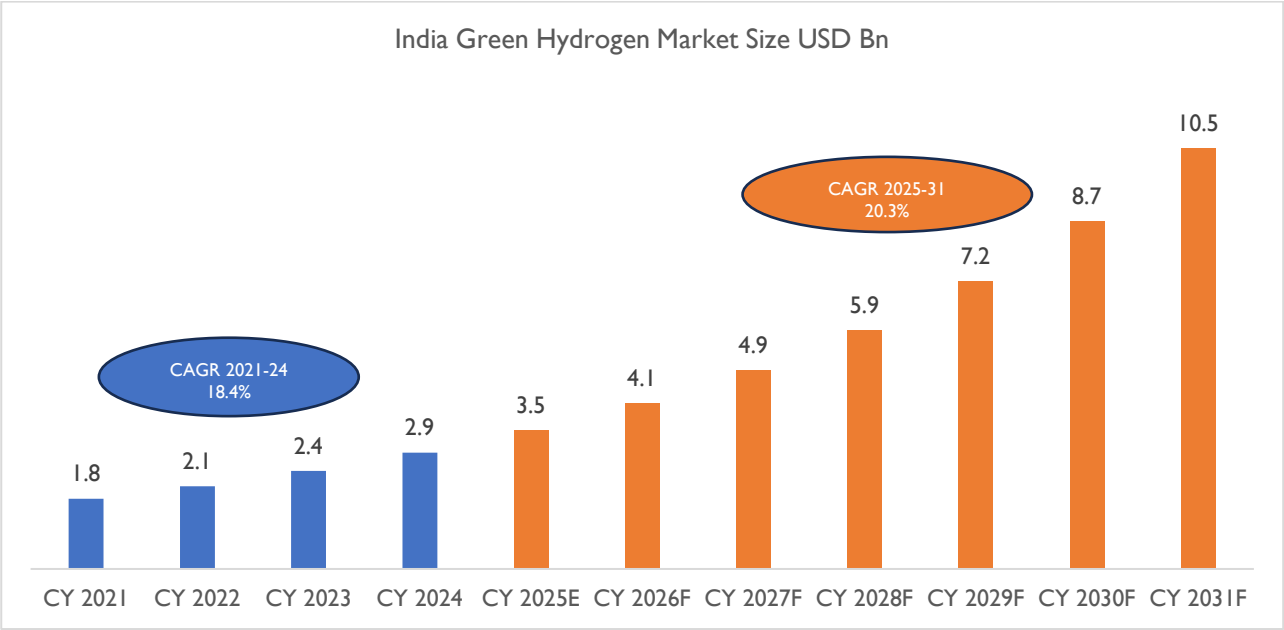
India is making significant strides in renewable energy, yet several challenges and threats persist that could hinder its progress. Renewable energy in India faces several challenges, including grid integration due to the intermittent nature of solar and wind power, and the high cost of energy storage solutions. Land acquisition for large-scale projects and environmental concerns also create hurdles. Financing is difficult due to high initial costs and limited long-term funding options. Regulatory uncertainty, especially with shifting policies and state-level variations, adds complexity.

Additionally, there's a reliance on imported technology and raw materials, and ongoing government support for fossil fuels makes renewables less competitive. A shortage of skilled workers, public resistance, and climate variability further complicate growth in the sector.

Grid Integration Issues	●The existing grid infrastructure is not adequately equipped to handle the variable nature of renewable energy sources like solar and wind. ●Inadequate grid capacity can lead to inefficiencies in energy distribution, increased curtailment of renewable energy generation, and difficulties in balancing supply and demand.
Energy Storage Limitations	●While advancements in battery technology are underway, energy storage solutions remain costly and underdeveloped. ●Without effective storage systems, the intermittency of renewable energy generation poses a significant challenge to reliability and grid stability.
Land Acquisition Issues	●Securing land for large-scale renewable projects can be difficult due to regulatory hurdles, land ownership disputes, and local resistance. ●Delays in land acquisition can stall project timelines and increase costs, affecting overall capacity additions.
Financing Challenges	●Renewable energy projects often require substantial upfront investments, which can be a barrier for developers. ●Although financial instruments like green bonds exist, there is a pressing need for more robust private and international investment to support large-scale projects.
Regulatory Uncertainty	●Frequent changes in policies and regulations can create uncertainty for investors and developers. ●Lack of clarity can deter investment and slow down project development, hindering the growth of the renewable sector.
Technological Barriers	●The nascent technology of green hydrogen production is capital-intensive and requires significant R&D investment. ●Without technological advancements, India may struggle to meet its ambitious targets for green hydrogen adoption.
Inadequate Infrastructure	●Insufficient transmission infrastructure limits the ability to transport renewable energy from production sites to consumption centers. ●This can result in increased transmission losses and reduced efficiency in utilizing generated power.
Payment Delays to Renewable Energy Firms	●Delays in payments from distribution companies to renewable energy producers can create cash flow issues. ●This can undermine the financial viability of renewable projects and deter future investments.
Uneven Rollout of Rooftop Solar	●The implementation of rooftop solar initiatives has been inconsistent across different states. ●This uneven rollout limits the potential contribution of rooftop solar to the overall renewable energy capacity.

While India is on a promising path toward expanding its renewable energy capacity, addressing these challenges is crucial for achieving its ambitious targets. A multifaceted approach involving policy stability, technological innovation, infrastructure development, and financial support will be essential to overcome these hurdles and ensure a sustainable energy future.

9. Green Hydrogen Scenario:



Source: D&B Research

The Green Hydrogen Market in India is projected to experience significant growth from CY 2021 to CY 2031, as depicted in the chart. The market size was USD 1.75 billion in CY 2021 and grew at a Compound Annual Growth Rate (CAGR) of 18.4% between 2021 and 2024, reaching an estimated USD 2.90 billion in CY 2024. The market is expected to accelerate further, with a CAGR of 20.3% from 2025 to 2031, reaching approximately USD 10.49 billion by CY 2031. The rapid expansion highlights increasing investments in renewable energy, government policies promoting green hydrogen production, and growing industrial demand for clean energy solutions. The shift towards decarbonization, energy security, and advancements in electrolyser technology is expected to drive market growth, making India a key player in the global green hydrogen industry.

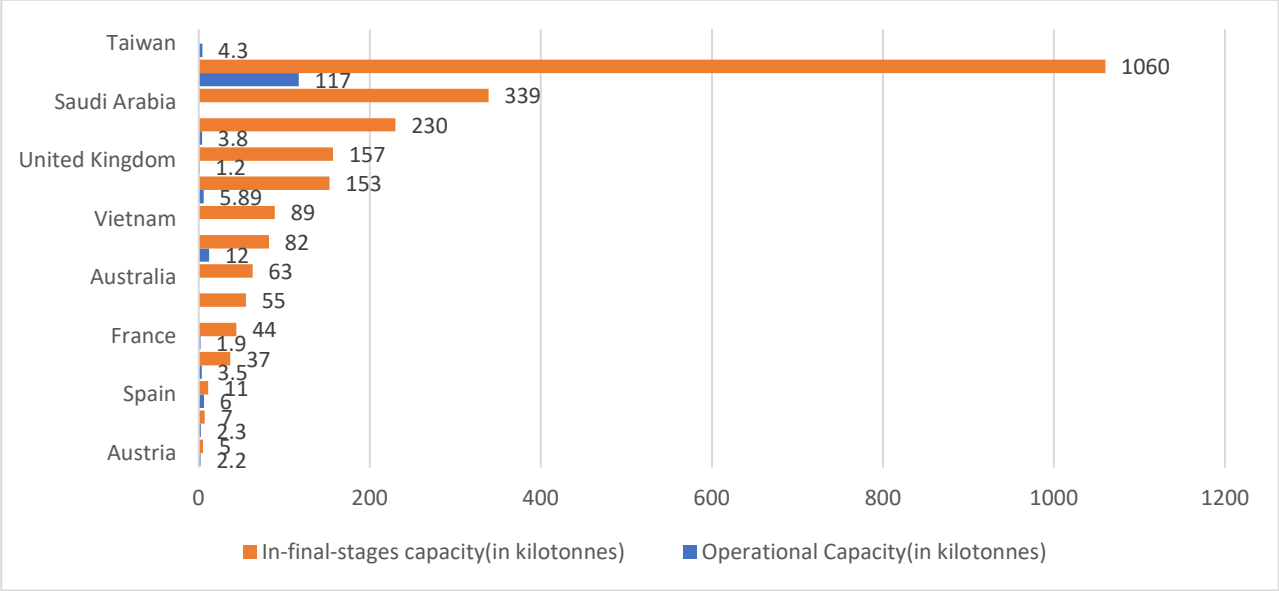
Overview:

The global production of green hydrogen is experiencing rapid growth, driven by stringent emission reduction targets, increasing investments in renewable energy, and the rising demand for clean fuel alternatives. As of 2023, total hydrogen production reached 97 million tonnes (Mt), but less than 1% of this was derived from low-emission sources, highlighting the urgent need for a large-scale transition toward green hydrogen which approximately marks up to 0.60- 0.90 million tonnes.

Regions with abundant and cost-competitive renewable resources, such as Australia, Iberia, and the Middle East, are expected to lead in large-scale green hydrogen production. However, challenges such as renewable power availability, electrolyser technology cost reduction, and large-scale investments remain critical factors for achieving strong adoption. The IEA (International Energy Agency) estimates that replacing grey hydrogen with green hydrogen could potentially save 830 million tonnes of CO_2 annually, significantly contributing to

global decarbonisation goals. Countries like China, Saudi Arabia, the United States, the European Union, and India are investing heavily in green hydrogen infrastructure.

The graph below shows the most ambitious green hydrogen plans country-wide. The value given is Electrolysis-based hydrogen capacity, in kilotons per year.



Source: International Energy Agency (2023) Hydrogen Projects Database

If all under-construction projects become operational, global electrolysis-based hydrogen production could exceed 14,000 kilotons per year by 2030. However, achieving these ambitious goals will require sustained policy support, technological advancements, and significant infrastructure development worldwide.

Global Initiative towards Hydrogen Economy:[14]

~USD10.2tn (Expected global investment by 2050)

~30 Countries Announced National Hydrogen Mission Plan

~250 Cities target Renewable Energy

~USD70b Government support to transition to Hydrogen

~114 Countries have or plan to set targets for cutting emission

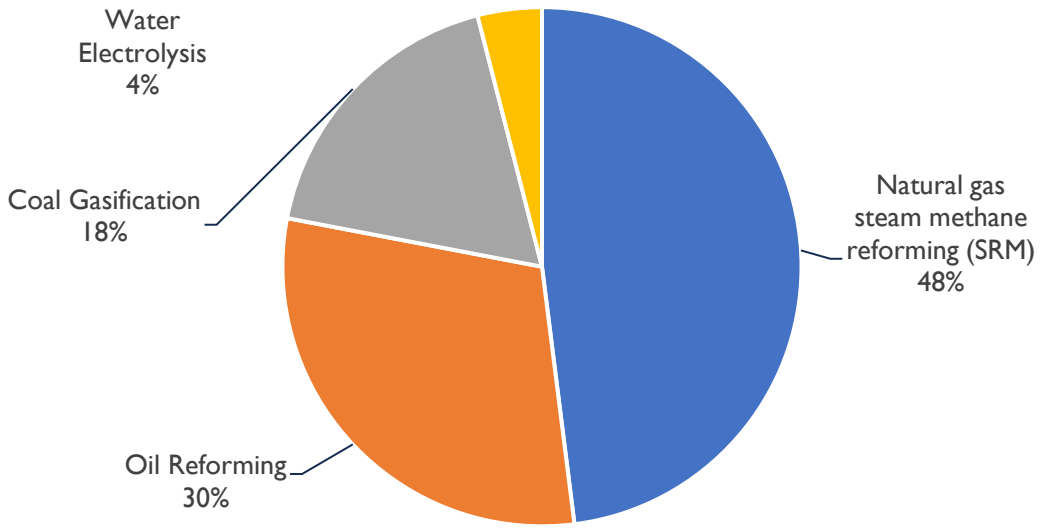
~20 Countries Announced Sales Ban on ICE vehicles

[14] https://static.pib.gov.in/WriteReadData/specificdocs/documents/2024/may/doc202451033630l

What is Grey Hydrogen: Grey hydrogen is hydrogen that's produced from fossil fuels like natural gas or coal, releasing significant amounts of carbon dioxide (CO2) and other greenhouse gases. It's the most common type of hydrogen produced today. The most common method for producing grey hydrogen is steam methane reforming (SMR), which uses heat and steam to break natural gas into hydrogen and CO2.

What is Green Hydrogen: Green hydrogen is hydrogen gas that's produced by splitting water using renewable energy sources like solar, wind, or hydro. It's a carbon-neutral alternative to hydrogen produced from fossil fuels. Green hydrogen reduces greenhouse gas emissions and harmful emissions like carbon dioxide and particulate matter. The most common method for producing Green Hydrogen is Water Electrolysis.

Global hydrogen production:[15]



Major Green Hydrogen Projects Worldwide

Several large-scale green hydrogen projects are underway globally, positioning key countries as leaders in this sector:

1. Saudi Arabia - NEOM Green Hydrogen Project
   - Capacity: 4 GW of solar and wind energy
   - Production: Up to **600 tonnes** of green hydrogen per day (~200 kilotons per year)
   - Status: The world's largest green hydrogen project under construction, a joint venture between ACWA Power, Air Products, and NEOM.
2. China - Xinjiang Green Hydrogen Facility
   - Capacity: **44 kilotons per year**, currently the largest operational green hydrogen plant in the world.

[15] https://static.pib.gov.in/WriteReadData/specificdocs/documents/2024/may/doc202451033630l

- Expansion Plans: China aims to scale up its green hydrogen production for industries like steel and chemicals.

3. European Union - Hydrogen Valley Projects
   - Target: **10 million tonnes** of renewable hydrogen production and **10 million tonnes** of imports by 2030.
   - Key Countries Involved: Germany, France, Spain, Sweden, and the Netherlands.
   - Notable Projects: Sweden's largest electrolyser facility launched in 2023, contributing to the region's green hydrogen supply.
4. United States - Hydrogen Hubs Initiative
   - Policy Support: Backed by the Inflation Reduction Act (2022), which offers the world's most generous clean hydrogen subsidies.
   - Investment Surge: Several green hydrogen projects are in development, benefiting from federal and state-level incentives.
5. India - National Green Hydrogen Mission
   - Target: **5 million tonnes** of green hydrogen production by 2030.
   - Investment: Over USD 70 billion in committed investments from companies like Reliance, Adani, Indian Oil Corporation, and NTPC.
   - Government Initiatives: Large-scale electrolyser manufacturing and hydrogen production subsidies to scale up production.

The production is set to increase rapidly as all of the countries are taking measures for sustainability and getting converted into green hydrogen.

Insight on storage

Key storage options include compressed gas storage, where hydrogen is stored under high pressure in tanks, and liquid hydrogen storage, which involves cryogenic conditions to maintain hydrogen in liquid form. While liquid storage is energy-intensive, it allows for higher energy density. Additionally, chemical storage involves storing hydrogen in compounds that release it when needed, providing flexibility in storage solutions.

For large-scale hydrogen storage, geological formations such as salt caverns and depleted natural gas reservoirs present viable long-term solutions. Salt cavern storage, in particular, enables the storage of excess renewable energy produced during low-demand periods, such as spring, for use in high-demand seasons like summer. This storage approach plays a key role in balancing energy supply and demand. Additionally, efficient transport infrastructure, including pipelines and tube trailers, is essential for distributing hydrogen effectively. This infrastructure supports both domestic consumption and the potential for hydrogen exports, ensuring the successful deployment and scalability of green hydrogen technologies.

Table 14 Notable Projects

Project Name	Capacity	Location	Key Objective
Advanced Clean Energy Storage	300 GWh	Utah, USA	Store surplus renewable energy as green hydrogen and use it for grid stability.
Neom Green Hydrogen Project	-	Neom, Saudi Arabia	Export Green Hydrogen in Ammonia form for easier storage and transport.
Fukushima Hydrogen Energy Research	Large-scale liquid hydrogen facility	Fukushima, Japan	Central to Japan's hydrogen economy goals; supports the country's shift toward a hydrogen-based society.
HyNet	1.3 TWh	Northwest England, UK	Develop hydrogen storage as part of the UK's hydrogen infrastructure plan by 2030.

Insight on electrolyze –[16]

Electrolysers are pivotal in producing green hydrogen by utilizing renewable electricity to split water into hydrogen and oxygen. This process is essential for decarbonizing sectors that are challenging to electrify directly. The International Energy Agency (IEA) provides comprehensive insights into the current state and future prospects of electrolyser technologies.

Current Status and Growth

- Installed Capacity: By end-2023, global electrolyser capacity reached 1.4 GW, projected to grow to 5 GW by 2024. China dominates with nearly 70% of committed capacity. Announced projects may reach 520 GW by 2030, but only 4% have reached FID or are under construction. Fossil-based hydrogen with CCUS shows slightly faster progress, with 14% at FID. Development remains slower than expected, with 6.5 GW reaching FID in the past year, a 12% decline.
- Production and Demand: Electrolyser production capacity doubled in 2023 to 25 GW, but actual production remains low at 2.5 GW. China leads production, accounting for 60%. By 2024, capacity may exceed 40 GW, with projections for 165 GW by 2030, although only 30% of this has secured FID.
- Technological Advancements: Electrolysis is gaining momentum for low-emission hydrogen production, especially with renewables. Significant advancements are required to meet 2050 net-zero targets, with strong growth in China, the EU, and the US driven by supportive policies.
- Future Trends: Hybrid modular systems integrating electrolysers with storage and renewables are gaining traction. Innovations like solid oxide electrolysers (SOECs) aim to enhance efficiency and reduce costs.

[16] IEA-International Energy Agency

Insight on transport infrastructure:

Hydrogen transport and storage infrastructure remain limited, with most production and consumption occurring on-site. Growing demand and new applications highlight the need for dedicated infrastructure to connect production sites with consumption centres.

Pipelines are recognized as the most efficient method for transporting hydrogen over long distances, with capacities of around 200 kilotons per year. The U.S. has approximately 2,600 km of hydrogen pipelines, while Europe operates around 2,000 km. Initiatives like the European Hydrogen Backbone aim to create a pan-European hydrogen infrastructure, with plans for significant investments in national transmission networks, such as the Dutch government's EUR 750 million investment for a 1,400 km hydrogen transmission network.

Under the National Green Hydrogen Mission (NGHM), India aims to develop a comprehensive transport infrastructure for green hydrogen. The mission includes plans to establish bunkering facilities at ports and develop refuelling infrastructure for vehicles powered by green hydrogen. The Indian government has allocated significant funds to support these initiatives, aiming to replace fossil fuels in various sectors including mobility and shipping.

Global partnerships are also being formed to enhance hydrogen transport capabilities. For instance, the India-Middle East-Europe Economic Corridor (IMEC) aims to create an export corridor that connects India with Europe, facilitating the transport of green hydrogen across borders and expanding market opportunities.

9.1 Green Hydrogen Infrastructure in India

India aims for energy independence by 2047 and net-zero emissions by 2070, with green hydrogen as a key driver. Produced via electrolysis using renewable sources or through biomass gasification, green hydrogen offers a clean alternative to fossil fuels. The country is building industrial hubs, storage, transport, and refuelling infrastructure to support its use in sectors like steel, shipping, and ammonia production, and as backup for renewable energy. To further support this transition, the government has set Renewable Purchase Obligation (RPO) targets, mandating an increase in renewable energy usage from 29.91% in 2024–25 to 43.33% by 2029–30, including a separate target for Distributed Renewable Energy. [17]

Year	Wind RPO	HPO	Other RPO	Total RPO
2024-25	3.36%	1.08%	26.37%	29.91%
2025-26	3.36%	1.48%	28.17%	33.01%
2026-27	4.29%	1.80%	29.17%	35.95%
2027-28	5.23%	2.15%	31.43%	38.81%
2028-29	6.61%	2.51%	32.69%	41.36%
2029-30	6.94%	2.82%	33.57%	43.33%

[17] Source: Static.pib.gov.in/WriteReadData/specificdocs/documents/2024/may/doc2024510336301

9.2 National Green Hydrogen Mission

The National Green Hydrogen Mission aims to establish India as a global leader in Green Hydrogen production, utilization, and export, promoting self-reliance through clean energy. It seeks to decarbonize various sectors, reduce fossil fuel imports, and position India at the forefront of Green Hydrogen technology and market growth. India's significant strides in renewable energy and its ambitious goals for energy independence by 2047 and net-zero emissions by 2070 underscore the pivotal role of Green Hydrogen.

The mission, with an initial budget of INR 19,744 crore, will leverage India's renewable resources to become a leading global supplier. Key objectives include promoting R&D, building production capacity, establishing Green Hydrogen hubs, facilitating demand creation, and reducing fossil fuel dependency. The mission emphasizes transitioning from grey to green hydrogen, with a phased implementation strategy focusing on demand creation, electrolyser manufacturing, and achieving cost competitiveness.

Green hydrogen production target	Electrolysis production target	Policy measures in the Hydrogen Mission are expected to reduce
•5 million metric tonnes per annum by 2030	•15 GW by 2030	•USD 1.5 per kg by 2030

Mission Budget: The National Green Hydrogen Mission has an initial financial allocation of **INR 19,744 crore**, covering various key initiatives.

Objective	Budget (INR CR)
SIGHT (Strategic Interventions for Green Hydrogen Transition) Programme	17,490
Research and Development (R&D)	400
Mission Components	388
Pilot Projects	
Low-Carbon Steel Projects	455
Mobility Pilot Projects	496
Shipping Pilot Projects	115

9.3 Green Hydrogen Production Scenario in India

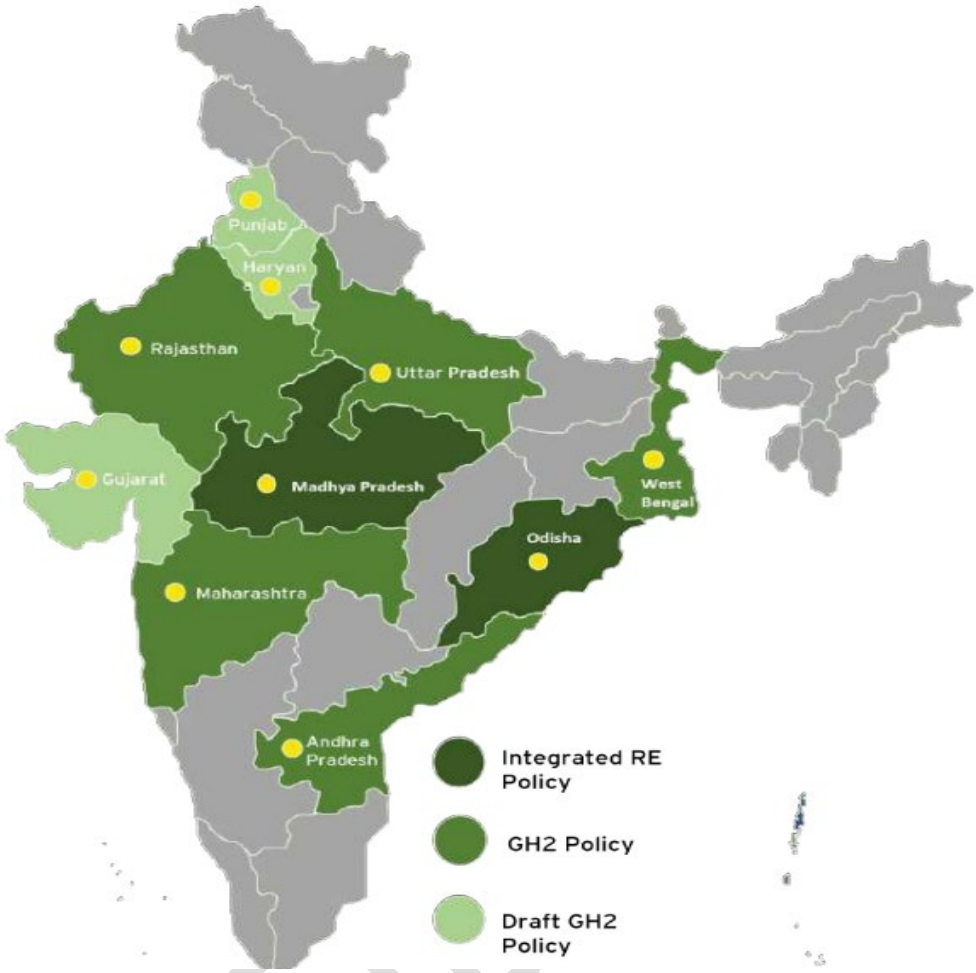
India's green hydrogen sector is expanding, with key companies such as Reliance, Adani, and Hygenco participating, but current production volume remains low. The National Green Hydrogen Mission, launched in January 2023, aims to achieve 5 MMT of annual green hydrogen production by 2030. This initiative is expected to drive significant economic and environmental benefits, including over ₹8 lakh crore in investments, 6 lakh new jobs, a ₹1 lakh crore reduction in fossil fuel imports, and a 50 MMT decrease in annual greenhouse gas emissions. The SIGHT Programme and SECI initiatives support these goals by allocating production and manufacturing capacity and seeking new production facilities.

Key Policy initiated: [18]

Scheme / Programme	Objective	Capacity Allocation	Status
Strategic Interventions for Green Hydrogen Transition (SIGHT) Programme	Provides incentives for electrolyser manufacturing and green hydrogen production	4.12 lakh MTPA hydrogen & 1.5 GW electrolyser manufacturing	Allocated
Green Hydrogen Standards Notification	Defines the carbon intensity of green hydrogen at **2 kg CO_2e per kg of H_2**	-	Implemented (2023)
Renewable Energy Mandates	Green hydrogen production to be powered entirely by **renewable sources**	-	In Progress
Viability Gap Funding (VGF) for Green Ammonia	Supports green hydrogen derivatives (green ammonia, methanol)	-	Proposed

[18] https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2023625&utm_source=chatgpt.com

State Policy Indicator:[19]



Upcoming Green Hydrogen Production Capacity

Company / Developer	Location	Planned Capacity	Status
Indian Oil Corporation (IOCL)	Panipat Refinery	10 KTPA (Initial phase)	Under Development
Reliance Industries (RIL)	Gujarat	100 KTPA	Planned (2030 goal)
NTPC	Odisha, Ladakh	Various pilot projects	Ongoing
ACME Group	Tamil Nadu, Odisha	1.10 MTPA (Green Ammonia)	Planned
Adani New Industries Ltd (ANIL)	Gujarat	1 MTPA (Hydrogen & Ammonia)	Under Development

[19] https://static.pib.gov.in/WriteReadData/specificdocs/documents/2024/may/doc202451033630l

9.4 Key Factors Driving the Demand for Green Hydrogen in India

Growing hydrogen Demand Across Key Industries

- India's hydrogen demand is primarily driven by two industries: crude-oil refineries and fertilizer production. Hydrogen is an essential component in these sectors, particularly in refining processes and ammonia production for fertilizers.

Government Policies and Initiatives

- The Indian government has played a pivotal role in the green hydrogen sector through the National Green Hydrogen Mission, which targets a production of 5 MMTPA of green hydrogen by 2030. This mission outlines strategic policies and incentives to support the growth of the green hydrogen ecosystem, including financial subsidies, regulatory frameworks, and infrastructural support.
- These government efforts are driving in lowering the costs of production and fostering demand for green hydrogen across industries, making it an attractive alternative to traditional hydrogen sources.

Renewable Energy Potential for Green Hydrogen Production

- India's renewable energy potential is a key driver in green hydrogen production. The country has an estimated 748 GW of solar energy potential, of which only about 9% is currently harnessed, with 70 GW of installed capacity. In addition to solar, India has access to significant wind and hydro energy resources.
- The country's vast renewable energy potential positions it well to produce green hydrogen via electrolysis, where water is split into hydrogen and oxygen using electricity from renewable sources. Rapid scaling of renewable energy capacity will be essential to meet the hydrogen production targets set by the government.

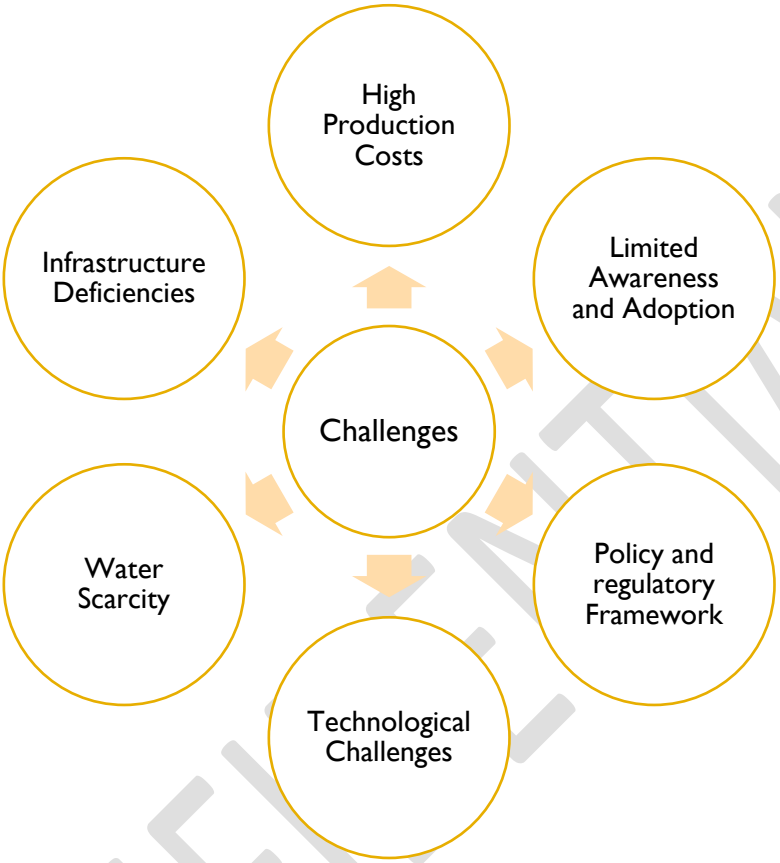
Global Environmental and Sustainability Trends

- As the world becomes more committed to reducing carbon emissions, green hydrogen is increasingly recognized as a key solution to replace fossil fuel-based energy sources, particularly in industries that are difficult to electrify. Green hydrogen production emits no CO2, unlike grey hydrogen, which is produced from natural gas and releases significant amounts of CO2.
- International markets are starting to show strong demand for green hydrogen, as countries adopt stricter emissions regulations. This global momentum presents India with a unique opportunity to align itself with international sustainability efforts, driving both domestic demand and export potential for green hydrogen.

Technological Advancements & Cost Reduction	• A major challenge for green hydrogen production has been its high cost compared to grey hydrogen. However, technological advancements in electrolyzer efficiency and renewable energy generation are expected to reduce the production cost of green hydrogen. India aims to reduce the cost of green hydrogen to $2/kg, which would make it competitive with grey hydrogen. • This price parity will be crucial in driving widespread adoption in industries such as steel, cement, and chemical manufacturing, which are major consumers of hydrogen. As technology continues to evolve, the cost of producing and delivering green hydrogen is expected to decrease, making it more accessible to industries.
Market Dynamics and Global Supply Chain	• The global market for green hydrogen is becoming more interconnected as countries implement decarbonization strategies. This trend creates an opportunity for India to position itself as a competitive player in the global hydrogen supply chain. Green hydrogen is expected to become a globally traded commodity, and India's hydrogen production capabilities can cater to both domestic and international markets. • Exporting green hydrogen to countries with high decarbonization targets, such as those in Europe and Japan, will provide additional demand for India's hydrogen. Therefore, aligning India's green hydrogen production with international standards and trade regulations will boost its attractiveness in the global market.
Industrial Readiness and Adoption	• While green hydrogen presents a promising solution for decarbonizing various industries, the readiness of Indian industries to adopt it is still in early stages. Industries such as steel, cement, and chemicals are exploring ways to integrate green hydrogen into their processes to reduce emissions. However, significant challenges remain, such as the need for infrastructure development and adaptation of existing processes to accommodate green hydrogen. Capacity building, both in terms of technology and skills, will be necessary to transition these industries to greener practices.
Cost of Delivery and Infrastructure Development	• One of the key constraints in the expansion of green hydrogen in India is the cost of delivery and the lack of necessary infrastructure. Developing the infrastructure for the transportation and storage of green hydrogen, including pipelines, storage tanks, and refueling stations, will be essential to ensure the smooth delivery of hydrogen to end-users. • The cost of logistics and distribution plays a significant role in the overall cost structure of green hydrogen, and reducing these costs will be vital for widespread adoption. Government support in developing the required infrastructure will also be a critical factor in ensuring green hydrogen can be effectively distributed across industries.

9.5 Key Threats & Challenges Facing the Sector

India's ambition to become a leader in green hydrogen production is met with several significant challenges that need to be addressed to achieve its goals effectively. The following outlines the key threats and challenges:



1. **High Production Costs**
    a) Cost Disparity: The production cost of green hydrogen is substantially higher than that of traditional hydrogen derived from fossil fuels. Currently, green hydrogen costs between USD 5.30 and USD 6.70 per kilogram, compared to USD 1.90 to USD 2.40 for grey or blue hydrogen. This high cost is primarily due to the expensive electrolysis process, which requires substantial amounts of renewable energy.
    b) Weighted Average Cost of Capital (WACC): In emerging markets like India, a high WACC increases financing costs, further elevating the production costs of green hydrogen.

2. **Infrastructure Deficiencies**
    a) Lack of Storage and Distribution Facilities: India currently lacks the necessary infrastructure for the production, storage, and distribution of green hydrogen, including pipelines and refuelling stations. This absence hampers the scalability and accessibility of green hydrogen solutions.
    b) Investment Needs: Significant investment in infrastructure development is required to support the growth of green hydrogen production and distribution networks.

3. **Water Scarcity**
    a) Resource Intensive Production: Green hydrogen production is water-intensive, raising concerns in a country where many regions face severe water scarcity. Ensuring a sustainable water supply for hydrogen production is critical.

4. **Technological Challenges**
    a) Emerging Technology: The technology for efficient green hydrogen production through electrolysis is still developing. Challenges include improving the efficiency of electrolysers and reducing their costs, which currently range from USD 500 to USD 1,800 per kW depending on the technology used.
    b) Limited R&D Investment: There is a need for increased research and development to enhance existing technologies and create new methods that are less resource intensive.

5. **Policy and Regulatory Framework**
    a) Lack of Comprehensive Policies: Unlike other countries with established hydrogen policies, India lacks integrated frameworks that foster market confidence and encourage private sector investment.
    b) Need for Incentives: Effective incentive schemes are necessary to attract investments in green hydrogen projects, including subsidies and tax benefits for companies involved in this sector.

6. **Limited Awareness and Adoption**
    a) Public Understanding: There is limited awareness about green hydrogen among the general public and businesses, which affects its adoption.
    b) Incentives for Transition: Without sufficient incentives or clear benefits communicated to stakeholders, the transition to green hydrogen technologies may be slow.

9.6 Overview of Investments Announced in Green Hydrogen Production in India

Investment Landscape: India has attracted substantial investments in green hydrogen and electrolyser manufacturing, with commitments totalling around INR 6,05,800 crore. Major companies involved include:

Reliance Industries

- Investing INR 86,500 crore over three years to transition from grey to green hydrogen by 2025. The company has been awarded subsidies under the Strategic Interventions for Green Hydrogen Transition (SIGHT) program for manufacturing 300 MW of alkaline electrolysers per year and producing 90,000 tonnes of green hydrogen annually

Adani Group

- In partnership with French energy major TotalEnergies, Adani plans to invest INR 4,32,735 crore in India's green hydrogen market over the next decade, targeting 3 million tonnes of clean gas production by 2032.

Welspun Group

- Proposing an investment of INR 40,000 crore to establish a green hydrogen or ammonia plant in Bulandshahr, Uttar Pradesh.

Hygenco Green Energies

- Planning to set up a 0.2 million-tonne green hydrogen facility in Prayagraj, Uttar Pradesh, with an investment of INR16,000 crore

ReNew India

- ReNew has demonstrated its dedication to sustainable energy by making a significant investment of INR 26,400 crore towards a green hydrogen project in Karnataka, aiming to achieve a production capacity of 0.22 MTPA.

Acme Cleantech

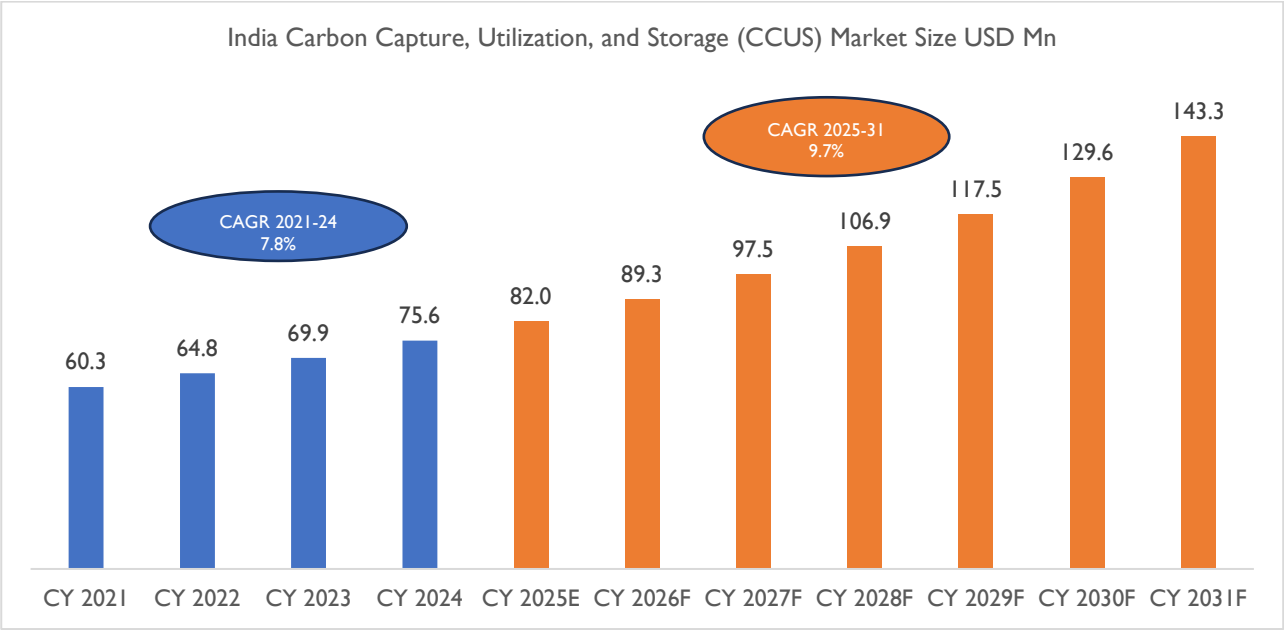
- Acme Cleantech revealed an impressive investment of INR 27,000 crore to establish a green hydrogen production facility in India with a capacity of 1.10 MTPA

Capacity Expansion Plans: In 2024, a capacity of 4.12 lakh tonnes per annum (LTPA) was awarded to ten companies with a total subsidy of INR 3,055 crore. An additional 7.8 LTPA of production capacity is expected to be awarded in 2025, alongside ongoing tenders for 4.5 LTPA for green hydrogen and 7.39 LTPA for green ammonia.

Government Support and Regulations: The Indian government is focusing on regulatory frameworks to ensure the growth of the green hydrogen sector. Green Hydrogen Certification Scheme: A draft scheme has been released for public comments, aiming to establish standards for certifying green hydrogen production. In 2025, new standards will be published covering various aspects of green hydrogen production, storage, transportation, and applications across sectors like aviation and railways.

Financial Allocations in the Union Budget: National Green Hydrogen Fund: An allocation of ₹600 crore to National Green Hydrogen Fund has been made in Union Budget 2024-25 to support the mission's initiatives. Increased funding has been allocated for renewable energy projects, including solar power initiatives that support the broader goals of the NGHM.

10. Carbon Capture, Utilization & Storage (CCUS) in India



Source: D&B Research

The Carbon Capture, Utilization, and Storage (CCUS) market in India is projected to witness steady growth from CY 2021 to CY 2031, driven by rising initiatives for decarbonization, industrial emission reduction, and sustainable energy solutions. The market size was USD 60.3 million in CY 2021, growing at a CAGR of 7.8% between 2021 and 2024, reaching USD 75.6 million in CY 2024. Post-2024, the market is expected to expand at a higher CAGR of 9.7% from 2025 to 2031, reaching USD 143.3 million by CY 2031. This growth is fuelled by increasing government policies, industrial adoption of carbon capture technologies, and advancements in CO_2 utilization for enhanced oil recovery, chemical production, and sustainable fuels. The rising focus on net-zero commitments and carbon credit markets is expected to further accelerate investments in India's CCUS sector, positioning it as a crucial component in the country's clean energy transition.

Overview:

Carbon Capture, Utilization, and Storage (CCUS) is a technology designed to reduce greenhouse gas (GHG) emissions by capturing carbon dioxide (CO_2) from industrial and power sector sources before it enters the atmosphere. The captured CO_2 can either be stored permanently in deep geological formations such as depleted oil and gas reservoirs or repurposed for various industrial applications.

Globally, power and industry contribute about 50% of total GHG emissions, making CCUS a crucial tool for decarbonization. The technology enables manufacturers to capture carbon at the point of emission such as chimneys of power plants and industrial facilities using chemical processes. The captured CO_2 can be utilized in producing synthetic fuels (methanol and methane), plastics, pharmaceuticals, fire extinguishers, soda ash, food and beverages, construction materials, and agricultural applications.

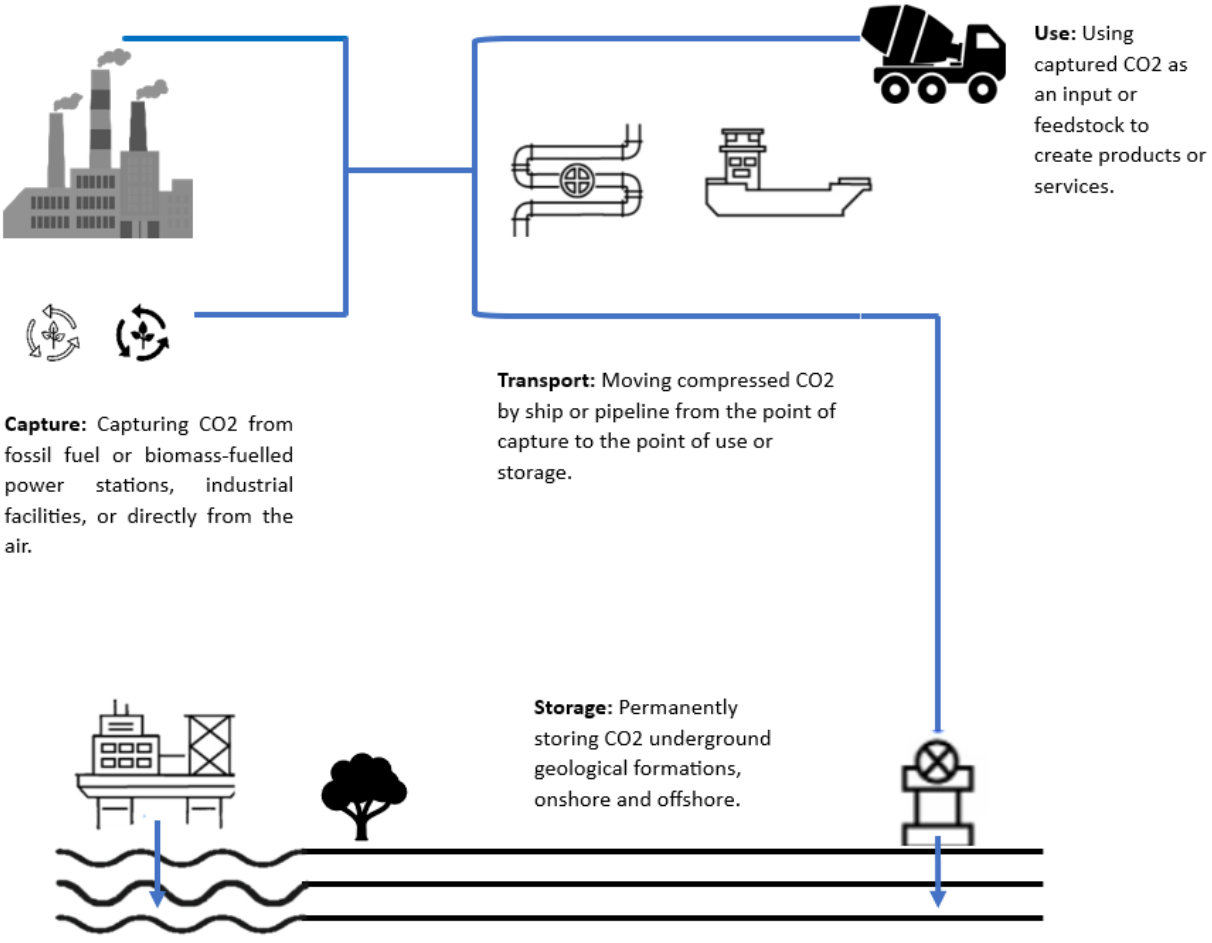
Beyond conventional methods, innovative CCUS solutions include artificial photosynthesis using bio-solar leaves and phytoplankton-based technologies that mimic natural carbon absorption. Additionally, CCUS plays

a key role in producing low-carbon hydrogen, which can further support the decarbonization of sectors such as heavy industry, transportation, and shipping. It also offers a means of removing CO_2 from the air, helping balance emissions that are difficult to eliminate. Although CCUS has historically fallen short of expectations, recent years have seen growing momentum, with over 700 projects in various stages of development across the CCUS value chain. However, despite this progress, deployment remains far below what is required to meet Net Zero Scenario targets, necessitating accelerated investment and expansion.

CO2 can be captured from various sources, including the air, and transported by pipeline or ship for utilization or permanent storage. Different terminology is often used when discussing CCUS technologies. In this report:

- Carbon Capture and Storage (CCS): This involves capturing CO2 and permanently storing it.
- Carbon Capture and Utilization (CCU) or CO2 Use: This refers to capturing CO2 for use in the production of fuels and chemicals.
- Carbon Capture, Utilization, and Storage (CCUS): This encompasses both CCS and CCU, including scenarios where CO2 is used and stored, such as in Enhanced Oil Recovery (EOR) or in building materials, where the use results in some or all of the CO2 being permanently stored.

Process of Carbon Capture, Utilization and Storage:



10.1 Global Scenario: CCUS Infrastructure

As of early 2025, the global infrastructure for Carbon Capture, Utilization, and Storage (CCUS) is experiencing significant growth, yet it remains far behind the ambitious targets set for 2045. Currently, there are around 45 commercial facilities with a total annual capture capacity of more than 50 Mt CO2, applying carbon capture, utilization, and storage (CCUS) to industrial processes, fuel transformation, and power generation. Although CCUS deployment has lagged behind expectations in the past, momentum has significantly increased in recent years, with over 700 projects now in various stages of development across the CCUS value chain.

In 2023 alone, announced capture capacity for 2030 increased by 35%, while announced storage capacity rose by 70%. This means that by 2030, the total amount of CO2 that could be captured annually is projected to reach approximately 435 million tonnes (Mt), with announced storage capacity expected to be around 615 Mt of CO2 per year. While this positive momentum is encouraging, it still represents only about 40% of the capture capacity and 60% of the storage capacity needed to achieve the Net Zero Emissions by 2050 (NZE) Scenario, which requires capturing and storing around 1 Gt of CO2 per year. This represents a substantial increase, as the number of CCUS facilities has grown significantly in recent years, with a 102% year-on-year increase in project numbers reported in 2023.

The current infrastructure primarily consists of operational projects such as the Boundary Dam Project in Canada and the Petra Nova Project in Texas, which have demonstrated the feasibility of large-scale carbon capture. However, these projects collectively capture only a fraction of the CO2 emissions needed to meet future targets. The International Energy Agency (IEA) has noted that while momentum is building behind CCUS technologies, actual final investment decisions are lagging behind the required pace to achieve significant capacity increases.

Table 15 Below are the table of existing major CCUS projects in operation.

Some of these facilities have been operational since the 1970s and 1980s, starting with natural gas processing plants in the Val Verde area of Texas, which began capturing CO2 and supplying it to local oil producers for Enhanced Oil Recovery (EOR) operations.:[20]

Country	Project	Operation date	Source of CO_2	CO_2 capture capacity (Mt/year)	Primary storage type
United States (US)	Terrell natural gas plants (formerly Val Verde)	1972	Natural gas processing	0.5	EOR
US	Enid fertiliser	1982	Fertiliser production	0.7	EOR
US	Shute Creek gas processing facility	1986	Natural gas processing	7.0	EOR

[20] https://www.iea.org/reports/ccus-in-clean-energy-transitions/a-new-era-for-ccus

Norway	Sleipner CO_2 storage project	1996	Natural gas processing	1.0	Dedicated
US/Canada	Great Plains Synfuels (Weyburn/Midale)	2000	Synthetic natural gas	3.0	EOR
Norway	Snohvit CO_2 storage project	2008	Natural gas processing	0.7	Dedicated
US	Century plant	2010	Natural gas processing	8.4	EOR
US	Air Products steam methane reformer	2013	Hydrogen production	1.0	EOR
US	Lost Cabin Gas Plant	2013	Natural gas processing	0.9	EOR
US	Coffeyville Gasification	2013	Fertiliser production	1.0	EOR
Brazil	Petrobras Santos Basin pre-salt oilfield CCS	2013	Natural gas processing	3.0	EOR
Canada	Boundary Dam CCS	2014	Power generation (coal)	1.0	EOR
Saudi Arabia	Uthmaniyah CO_2-EOR demonstration	2015	Natural gas processing	0.8	EOR
Canada	Quest	2015	Hydrogen production	1.0	Dedicated
United Arab Emirates	Abu Dhabi CCS	2016	Iron and steel production	0.8	EOR
US	Petra Nova	2017	Power generation (coal)	1.4	EOR
US	Illinois Industrial	2017	Ethanol production	1.0	Dedicated
China	Jilin oilfield CO_2-EOR	2018	Natural gas processing	0.6	EOR
Australia	Gorgon Carbon Dioxide Injection	2019	Natural gas processing	3.4-4.0	Dedicated
Canada	Alberta Carbon Trunk Line (ACTL) with Agrium CO_2 stream	2020	Fertiliser production	0.3-0.6	EOR
Canada	ACTL with Northwest	2020	Hydrogen production	1.2-1.4	EOR

	Sturgeon Refinery CO_2 stream				
United States (US)	Terrell natural gas plants (formerly Val Verde)	1972	Natural gas processing	0.5	EOR
US	Enid fertiliser	1982	Fertiliser production	0.7	EOR

*EOR- Enhanced Oil Recovery

As of now, approximately 25 megatons (Mt) of CO2 are captured annually in the United States and Europe combined. This figure is starkly contrasted with the ambitious target set by the International Energy Agency (IEA), which estimates that around 6,000 Mt of CO2 must be captured and stored each year by 2050 to align with the goals of the Paris Agreement. This target represents about 16% of current global emissions, highlighting the scale of infrastructure development needed to achieve meaningful reductions in greenhouse gas emissions.[21]

Currently, the operational CCUS capacity is limited, with only about 40 Mtpa globally. Despite a growing number of projects approximately 392 in various stages of development the actual capture volumes remain low compared to what is necessary. The IEA's assertion that about 6,000 Mt must be captured annually underscores the urgency for scaling up CCUS technologies and infrastructure significantly.

While countries are planning to expand the CCUS plants and establishing the new government initiatives there are some several challenges, including high economic costs that often exceed potential financial benefits, complex permitting processes that delay projects, and the need for effective coordination among multiple stakeholders. Additionally, significant gaps in infrastructure development, policy uncertainty, and public scepticism about CO2 storage safety hinder progress. While advancements in technology are ongoing, many methods remain in early development stages, requiring further research and innovation to enhance efficiency and reduce costs. Addressing these challenges is essential for maximizing CCUS's potential in achieving climate goals.

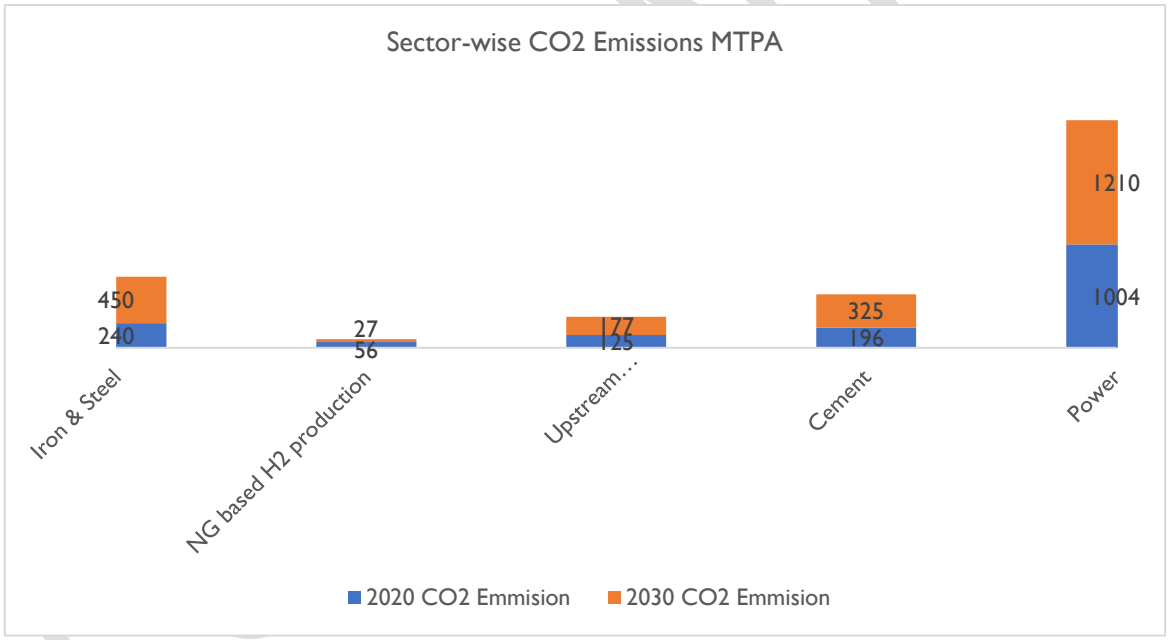
[21] https://think.ing.com/articles/carbon-capture-storage-outlook-2025-gaining-ground-despite-challenges/

10.2 India CCUS Scenario

India is the world's third-largest emitter of CO2, following China and the US, with estimated annual emissions of about **2.6 gigatonnes**. The Government of India has committed to reducing CO2 emissions by 50% by 2050 and achieving net zero by 2070. One of the key success stories in India's clean energy transition has been the growth of renewable power capacity. However, the power sector only contributes to about one-third of the total CO2 emissions, which will continue to decline as renewables increasingly replace fossil fuel-based power generation.

The growing industrial economy in India emits nearly another third of the aggregate emissions, which are hard to abate and will continue to increase unless new technologies and carbon abatement mechanisms are deployed. While India plans to phase down the use of coal over time, the country will remain dependent on fossil energy sources like coal for a long time to support the industry and provide affordable and reliable baseload power. Therefore, India's decarbonization pathway must also include technologies that will reduce emissions from hard-to-abate industrial sectors and residual baseload power generation.

Sector-wise CO2 Emissions in India:



Source: NITI Ayog

Carbon Capture Utilization and Storage (CCUS) plays a critical role in decarbonizing the industrial sector, which is challenging to electrify and abate due to the use of fossil fuels as both a source of energy and within the process itself. CCUS is also essential for decarbonizing the power sector, given India's current reliance on coal for over 70% of its electricity needs. Even if India substantially greens the grid and meets the target of 500 GW installed capacity of renewables by 2030, there will still be a need to meet baseload power demand from fossil fuels (most likely coal) or other dispatchable sources, due to the intermittency and non-dispatchable nature of solar and wind power.

Direct Air Capture (DAC), which directly captures dilute CO2 (415 ppm) from the air, may also emerge as a form of carbon capture with wide applicability, as it is independent of the source and concentration of the emission stream. However, DAC is still in its early stages, and the economics (present cost estimated to range between INR 34,000-70,000 per tonne of CO2) and scale of operations are yet to be established.

For effective large-scale adoption of CCUS, it's essential to have a clear strategy for the permanent geological storage of captured CO2, beyond converting it to value-added products. Currently, geological sequestration is the only commercial option available at the gigatonne scale for CO2 disposition.

Options for geological storage include Enhanced Oil Recovery (EOR), Enhanced Coal Bed Methane Recovery (ECBMR), and permanent storage in saline aquifers and basalt formations. However, India has limited geological data on pore space availability, especially for saline aquifers and basalt storage. In contrast, data availability for EOR and ECBMR is better due to prior hydrocarbon exploration activities. The British Geological Society and IIT Bombay estimate that India has significant CO2 storage potential, ranging from 400 to 600 gigatonnes.

CO2 Storage options:

Storage in Deep Saline Aquifers

Captured CO2 can be permanently stored in deep saline aquifers, which are large porous rock formations containing unusable saltwater. Unlike EOR and ECBMR, injecting CO2 into these aquifers offers no economic benefit but has the potential to store vast quantities of CO2. Supercritical CO2 can be injected into saline aquifers, where it rises to the impermeable caprock and is trapped (structural trapping). Some CO2 displaces the existing fluid in the pore spaces (residual trapping), while some dissolves in the brine (solubility trapping). Over time, CO2 can also react with minerals to form solid carbonates (mineral trapping).

Storage in Basalts

Recent geological studies have explored the CO2 storage potential of basaltic rocks, which contain divalent cations of calcium, magnesium, and iron. These elements react with dissolved CO2 to form stable carbonate minerals, offering a long-term sequestration solution. Basalt rocks have faster reaction kinetics compared to saline aquifers due to the abundance of these oxides. Additionally, the widespread presence of basalts on Earth's surface has sparked interest in CO2 storage research. Researchers estimate the global CO2 storage capacity of basalts to be between 8,000 and 41,000 gigatonnes (Gt).

Table 16 Region-wise Storage Clusters in India:

Total Theoretical Storage Capacity of India = 395 - 614 Gt CO2

Region	Saline aquifer	ECBMR	EOR	Basalt	Total (GT CO2)	Region-wise estimated CO2 emission volumes (2030-2050) (GT)
Southern Region	75.2	0.3	0.8	0	76.3	9.01
Northern Region	7.34	0	0.31	0	7.65	7.21
Eastern Region	67.2	2.4	0	10.98	80.5	10.13
North-Eastern Region	46.5	0	0.7	0	47.2	0.22
Western Region	80.8	0.9	2.3	304.9	388.9	16.58
Total	**277**	**3.6**	**4.1**	**315**	**498**	-

Source: Carbon Capture Utilization and Storage (CCUS) – Policy Framework and Deployment Mechanism in India

*GT- Giga Tons

This indicates significant potential for establishing regional CCUS clusters across five regions in India: North, South, East, West, and North-East. Sequestration in deep saline aquifers emerges as the most promising option in all these regions. However, the theoretical storage capacity for the northern sedimentary basins is currently low due to insufficient data. Nevertheless, as more exploratory activities targeting CO2 storage are conducted, the storage potential in the northern region is expected to rise.

10.3 Regulatory Landscape: CCUS in India

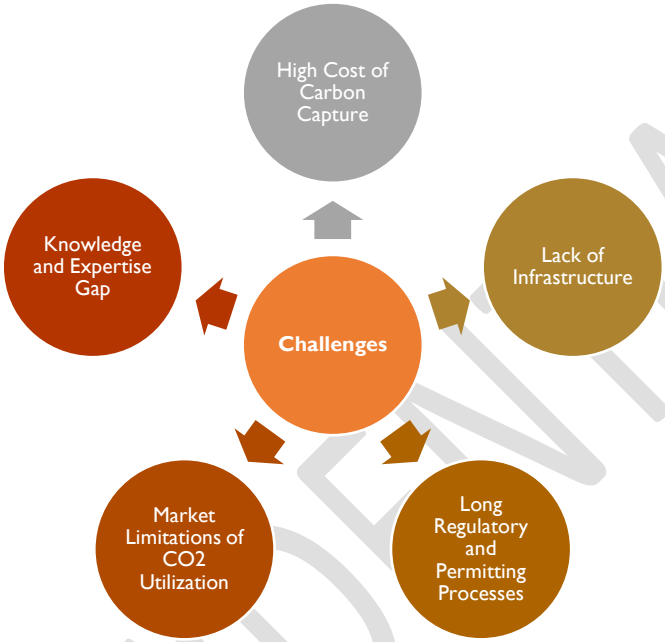
India is developing a robust regulatory and financial framework to promote Carbon Capture, Utilization, and Storage (CCUS) for reducing greenhouse gas emissions and advancing sustainable development.

- **Policy Framework**: NITI Aayog's CCUS policy highlights key interventions such as carbon credits, early-stage financing, regional CCUS hubs, and preferential procurement of low-carbon products to drive adoption, particularly in hard-to-decarbonize sectors.
- **Task Force Initiatives**: The Ministry of Petroleum and Natural Gas has formed the "Upstream for CCS/CCUS" (UFCC) task force to chart CCUS implementation in oil and gas. It also partnered with IIT Bombay to boost R&D efforts.
- **Financial Incentives**:
    - **Viability Gap Funding (VGF)** for economically unviable CCUS projects.
    - **Carbon Pricing Mechanism** to encourage industrial adoption.

- **Carbon Credit Trading** for monetizing captured CO_2.
- **Tax Incentives** and proposed **Carbon Capture Finance Corporation (CCFC)** to provide financial support, backed by clean energy taxes and bonds.

- **Storage Potential**: India has an estimated CO_2 storage capacity of 500–1,000 gigatons, enabling large-scale CCUS deployment.

10.4 Key Threats & Challenges



High Cost of Carbon Capture: Carbon capture accounts for over 70% of total CCUS costs due to energy-intensive processes and expensive materials. The energy penalty further reduces plant efficiency, making large-scale adoption economically unfeasible without subsidies or technological breakthroughs.

Lack of Infrastructure: Adequate CO_2 pipelines, storage, and transport systems are limited, especially near industrial sites. This creates a "chicken-and-egg" dilemma between investing in capture systems and infrastructure. Shared hubs and public-private partnerships could help bridge the gap.

Complex Regulatory Processes: Lengthy, multi-agency approval procedures such as coordination between MoEFCC, MoPNG, and state governments in India delay projects and deter investors. Clear, streamlined regulations are needed for national and international CCUS deployment.

Limited CO_2 Utilization Market: The market for CO_2-based products is underdeveloped, making storage the main but economically non-viable option. Policy support and incentives are essential to drive innovation and create demand for CO_2 utilization.

Knowledge and Expertise Gap: CCUS demands specialized skills in capture, transport, and storage. A shortage of trained professionals and limited knowledge sharing hinder progress. Investment in training, academia-industry collaboration, and CCUS centres of excellence is vital to build capacity.

10.5 Overview of Investments Announced in CCUS In India

Several investments have been announced in the CCUS sector, involving contributions from the government, private firms, and public-private partnerships. These investments aim to accelerate the deployment of carbon capture technologies, infrastructure development, and industrial decarbonization efforts. The collaborative approach is expected to drive innovation, attract global expertise, and enhance India's transition toward a low-carbon economy.

India is making substantial investments in Carbon Capture, Utilization, and Storage (CCUS) to support its ambitious decarbonization goals, with NITI Aayog playing a pivotal role in formulating policies and frameworks to facilitate large-scale adoption. The Indian government, through its planning body NITI Aayog, has proposed a dedicated CCUS policy that focuses on industry clusters, employment generation, and financial incentives, aiming to create a robust ecosystem for CCUS deployment. As part of this vision, India is projected to require an investment of approximately INR 8,500 crore- INR 13,000 crore by 2050 to develop CCUS infrastructure, which will be able to capture 750 MMT implement cutting-edge capture technologies, and establish necessary mechanisms for CO2 transportation, storage, and utilization.

This significant financial commitment aligns with India's broader strategy to reduce emissions by 50% by 2050 and achieve net-zero by 2070. The policy under development, expected to be finalized by the end of 2024, will provide clear guidelines on capture standards, economic incentives, and regulatory frameworks to drive CCUS adoption. The investment will particularly target high-emission industries such as steel, cement, petrochemicals, fertilizers, and oil and gas, which are crucial for India's economy but contribute significantly to CO2 emissions. Additionally, India's Ministry of Science and Technology, in collaboration with the Asia CCUS Network, is actively working on research and deployment strategies to enhance CCUS implementation across the region.

The commercial viability of CCUS is also a key focus area, with opportunities for converting CO2 into value-added products like building materials (concrete and aggregates), chemicals (methanol and ethanol), polymers, and enhanced oil recovery solutions. To support this, NITI Aayog's policy will include incentives for industries adopting CCUS, helping to attract private sector investments and international collaborations. Given this push, U.S. companies and technology providers specializing in CCUS solutions have significant opportunities to enter the Indian market, partnering with Indian stakeholders to deploy advanced carbon capture technologies and contribute to India's decarbonization efforts.

Table 17 CCUS Financial Mechanism: Assumptions/Considerations for CCUS Financing Analysis:

	Parameters	Remarks
Current CO2 emissions from industries & power sector	1600 mtpa	NA
CAGR of CO2 emissions	4% till 2030 2% from 2031-40 1% from 2041-50	NA
Capturable CO2	85% of emissions	NA
Current coal consumption	1050 mtpa	NA
CAGR of coal consumption	2% till 2035, no increase after that	NA
Clean energy cess	400 Rs. /tonne	Existing rate of Rs. 400/tonne, to be effective from 1 April 2026
Subsidy for storage	4.1k Rs. /tonne till 2040 3.0k Rs. /tonne till 2050	Based on the average CCUS cost for industries and power
Subsidy for EOR usage	3.0k Rs. /tonne till 2040 2.4k Rs. /tonne till 2050	Based on the average CCUS cost for industries and power, adjusted for benefits from EOR
Subsidy for utilization for value-added products	2.3k Rs. /tonne	Based on average CCUS cost for industries and power, adjusted for benefits from value-added product
Return on corpus/bond re-investment	9%	NA

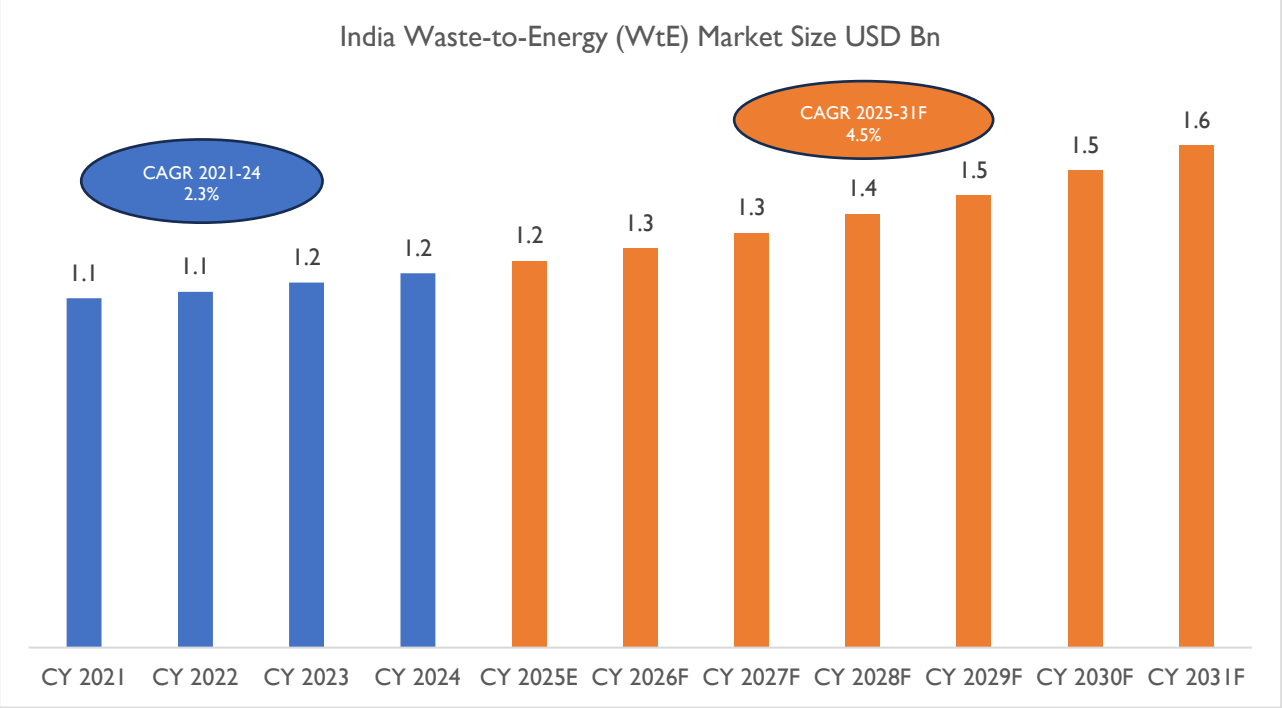
Source: NITI Ayog

Table 18 CCUS Funding through Clean Energy Cess and CCUS Funding with Bonds and Government Budgetary Support:

Year	Fund. Req., TH CR	Fund available TH CR	Surplus/Shortfall TH CR	Bond with Return TH CR	Gross Budgetary Support (GBS)TH CR
2023	-	23	23	-	-
2030	15	169	154	-	15 (0.2% of GBS)
2040	89	603	514	36	53 (0.4% of GBS)
2050	210	225	15	107	103 (0.5% of GBS)

- **Oil India Limited (OIL):** Investing INR1,000 crore in CCUS as part of a INR 25,000 crore clean energy plan to achieve net-zero by 2040. Projects include green hydrogen, solar, wind, and biogas.
- **NALCO:** Commissioned a CO_2 sequestration pilot plant in Odisha; plans to scale up for long-term sustainability.
- **BHEL:** Exploring CCUS technologies to reduce emissions in heavy engineering and power sectors.
- **APGENCO:** Collaborating on CCUS for emission reduction from thermal power plants.
- **Reliance Industries:** Developing CCS for deployment in refineries and petrochemical units; targets net-zero by 2035.
- **Dalmia Cement:** Building a 500,000 TPA carbon capture plant in Tamil Nadu with UK-based CCSL to become carbon-negative by 2040.
- **Tata Steel:** Commissioned a 5 TPD carbon capture plant at its Jamshedpur facility the first in India's steel sector.
- **IOCL & ONGC:** Partnering to capture CO_2 at Koyali refinery for injection into the Gandhar field for enhanced oil recovery.
- **Tuticorin Alkali Chemicals:** Operates India's first unsubsidized industrial CCU plant (60,000 TPA), using CO_2 to produce soda ash.
- **NTPC:** Developing a CO_2-to-methanol plant at Vindhyachal with CCSL and Green Power International.

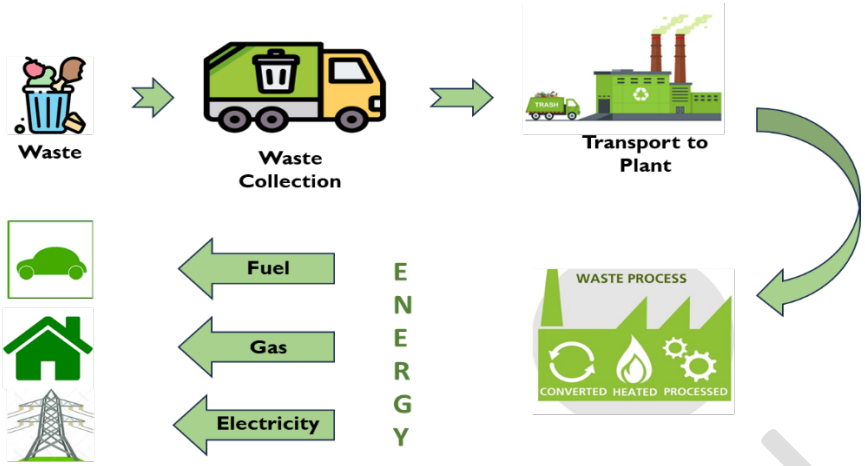
11. Waste to Energy Sector



The Waste-to-Energy (WtE) market in India is projected to grow steadily from CY 2021 to CY 2031, driven by increasing waste management initiatives, rising energy demands, and government policies promoting renewable energy generation from waste. The market size stood at USD 1.12 billion in CY 2021 and grew at a CAGR of 2.3% between 2021 and 2024, reaching USD 1.20 billion in CY 2024. The growth rate is expected to accelerate post-2024, with a projected CAGR of 4.5% from 2025 to 2031, reaching approximately USD 1.61 billion by CY 2031. This expansion is fuelled by urbanization, increased municipal solid waste generation, technological advancements in waste processing, and government incentives for clean energy projects. The rising emphasis on sustainability, circular economy principles, and reducing landfill dependency is expected to further drive investments in India's WtE sector, positioning it as a key contributor to the country's renewable energy mix.

Overview: The Waste-to-Energy (WtE) sector focuses on converting various types of waste materials into usable energy, such as electricity, heat, or biofuels. It plays a crucial role in waste management, energy production, and reducing environmental pollution. [22]

[22] https://www.ecomena.org/wte-pathways/



The Waste to Energy (WTE) process involves converting waste materials into usable energy. Here's an overview of the steps:

Waste Collection: Waste is gathered from households, businesses, and industrial sources.

Transport to Plant: The collected waste is transported to a dedicated waste-to-energy facility.

Waste Processing: The waste is sorted and processed, typically by heating it in a controlled environment (incineration or gasification). This process breaks down organic materials and converts them into energy.

Energy Production:

- **Fuel for Vehicles**: Some processed waste is converted into biofuels that can be used to power vehicles.
- **Gas for Households**: Organic waste can be converted into biogas, which is then distributed for use in households for cooking and heating.
- **Electricity for Power Stations**: The heat generated from the waste is used to produce steam, which drives turbines to generate electricity, supplying power to the grid.

Classification of Waste for Energy Conversion

- **Municipal Solid Waste (MSW) –** Includes household and commercial waste such as food scraps, paper, plastics, and textiles. Suitable for incineration, gasification, anaerobic digestion.
- **Industrial Waste –** Includes chemical, manufacturing, and process waste like sludge, plastic residues, and hazardous materials. Suitable for pyrolysis, gasification, and plasma arc technology.
- **Agricultural Waste –** Crop residues, husks, bagasse, and animal manure. Used for biogas production, bioethanol fermentation, and biomass combustion.
- **Biomedical Waste –** Includes hospital and pharmaceutical waste, often incinerated or processed via plasma arc gasification to ensure safe disposal.
- **Plastic & Rubber Waste** – Non-recyclable plastics, tires, and synthetic materials are converted into pyrolysis oil, syngas, or solid fuel.
- **E-Waste –** Contains electronic components with combustible plastics and metals, processed through gasification or incineration.

- **Sewage & Organic Waste –** Wastewater sludge and organic residues are treated using anaerobic digestion or microbial fuel cells to generate biogas and electricity.

Importance of Waste-to-Energy (WtE)

- **Reduces Landfill Waste** – Minimizes the volume of municipal solid waste (MSW) and prevents land pollution.
- **Generates Renewable Energy** – Produces electricity, heat, or biofuels as an alternative to fossil fuels.
- **Lowers Greenhouse Gas Emissions** – Captures methane from decomposing waste, reducing its impact on climate change.
- **Supports Circular Economy** – Converts waste into a valuable resource, promoting sustainability.
- **Reduces Dependence on Fossil Fuels** – Provides an additional source of clean energy for power generation.
- **Efficient Waste Management** – Helps manage growing urban waste in a sustainable way.
- **Reduces Air & Water Pollution** – Proper waste treatment prevents hazardous emissions and contamination

Challenges Of Waste-to-Energy (WtE)

- **High Capital & Operational Costs –** Expensive infrastructure, technology, and maintenance increase project costs.
- **Air Pollution & Emissions –** Incineration and gasification can release pollutants (dioxins, CO_2, NOx) if not properly controlled.
- **Waste Segregation Issues** – Inefficient sorting reduces the efficiency of energy recovery and may damage equipment.
- **Public Opposition & Perception –** Concerns over environmental and health risks often lead to resistance from communities.
- **Regulatory & Policy Challenges –** Strict environmental regulations and inconsistent policies can delay projects.
- **Energy Efficiency Concerns –** Some WtE processes have lower energy efficiency compared to conventional power plants.

Competition with Recycling – Diverting waste for energy may reduce recycling rates, conflicting with sustainability goals.

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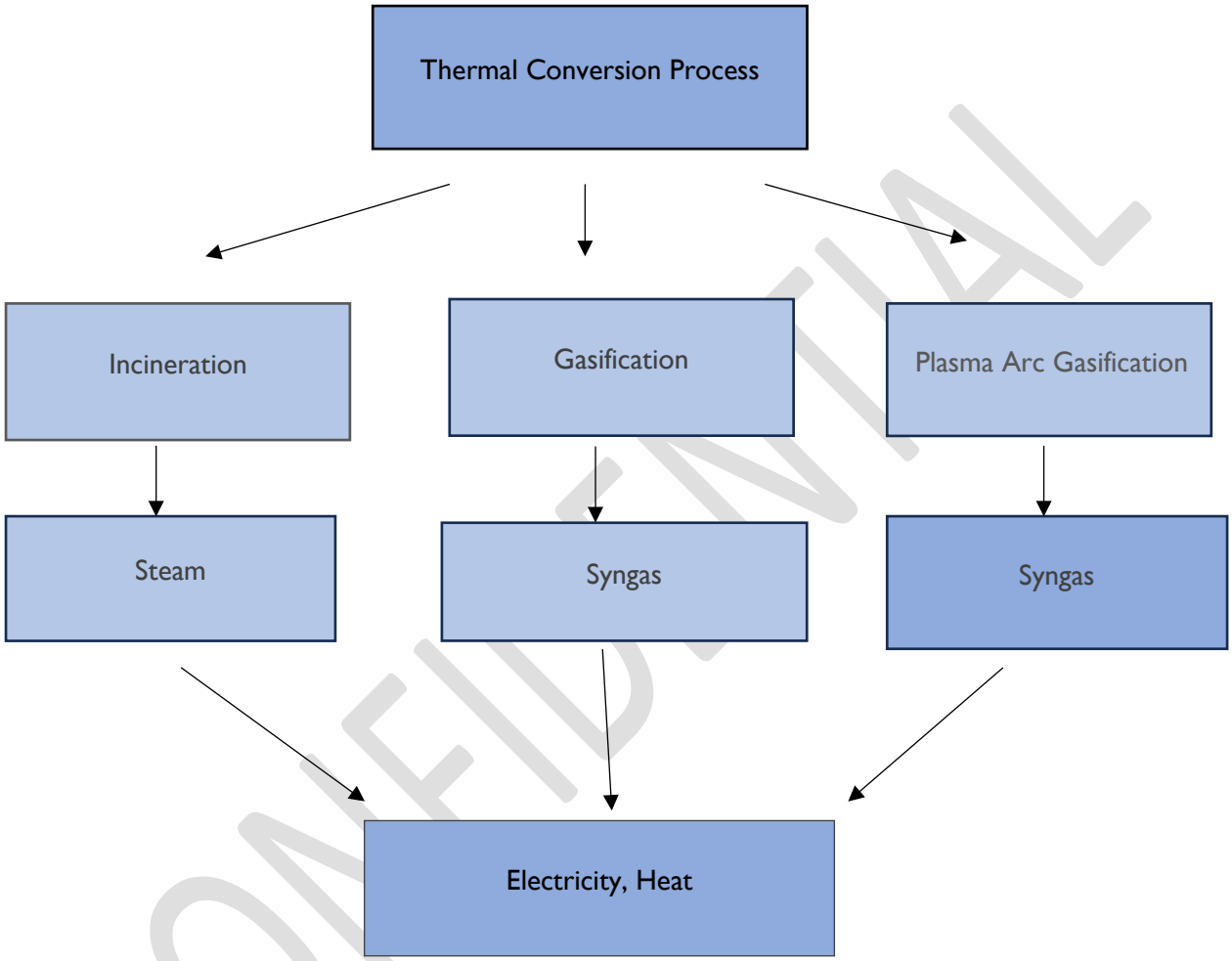
11.1 Waste to Energy Conversion:

Thermal Conversion Methods

Thermal processes use heat to convert waste into energy (electricity, heat, or fuels). These processes reduce waste volume and generate useful byproducts. The main types include:



These processes use heat to break down waste into usable energy.

Method	Process Description	Common Waste Sources	Energy Output
Incineration	Direct combustion of waste at high temperatures.	Municipal Solid Waste (MSW), industrial waste, hazardous waste.	Electricity, heat
Plasma Arc Gasification	Uses a plasma torch (up to 5000°C) to convert waste into syngas and slag.	Medical waste, plastics, electronic waste	Syngas (H_2, CO), vitrified slag
Torrefaction	Mild pyrolysis in low-oxygen at 200-300°C to produce bio-coal.	Biomass, wood chips, agricultural waste	Bio-coal, biochar

Thermo-Chemical Conversion Methods: These methods involve chemical reactions at high temperatures to extract energy.

Method	Process Description	Common Waste Sources	Energy Output
Pyrolysis	Heating waste in the absence of oxygen to produce bio-oil, syngas, and char.	Plastic waste, tires, biomass	Bio-oil, syngas, biochar
Gasification	Converts organic waste into syngas (H_2, CO) using controlled oxygen supply.	MSW, biomass, coal, agricultural waste	Syngas, electricity, fuels
Hydrothermal Carbonization (HTC)	Converts wet biomass into hydrochar using high pressure and moderate temperature.	Food waste, sewage sludge	Hydrochar, bio-crude

Example: Japan extensively uses gasification plants to convert MSW into syngas for electricity.

Bio-Chemical Conversion Methods: These processes use microorganisms to break down organic waste into energy-rich compounds.

Method	Process Description	Common Waste Sources	Energy Output
Anaerobic Digestion	Bacteria break down organic matter in oxygen-free conditions to produce biogas.	Food waste, manure, wastewater sludge	Biogas (CH_4, CO_2), bio-fertilizer
Fermentation	Microbes convert organic sugars into bioethanol.	Sugarcane, corn, agricultural residues	Bioethanol, CO_2
Composting for Biothermal Energy	Controlled microbial degradation of organic waste generates heat.	Green waste, food scraps	Heat energy

Electrochemical Conversion Methods: These methods directly convert chemical energy from waste into electricity using electrochemical reactions.

Method	Process Description	Common Waste Sources	Energy Output
Microbial Fuel Cells (MFCs)	Uses bacteria to break down organic matter and generate electricity.	Wastewater, organic waste	Direct electricity, hydrogen
Electrolysis of Organic Waste	Electrochemical breakdown of organic waste into H_2 and oxygen.	Wastewater, organic waste	Hydrogen gas (for fuel cells)

11.2 India Scenario: Waste to Energy Generation Potential in India

Every year, about 62 million tonnes of municipal solid waste (MSW) and 38 billion litters of sewage are generated in the urban areas of India. In addition, large quantities of solid and liquid wastes are generated by industries. **It is estimated that the amount of waste generated in India will increase at a per capita rate of approximately 1-1.33% annually**. The current rate of solid waste generation in India stands at 0.34 kg per person per day, and it is projected to increase to 0.7kg per person per day by the year 2025.

Table 19 Summary of the sector wise covering urban and industrial sectors mainly for energy potential for India is given as below:

S N	Sectors	Energy potential – MW
1	Urban Solid Waste	1247
2	Urban Liquid waste	375
3	Paper (liquid waste)	254
4	Processing and preserving of meat (liquid waste)	182
5	Processing and preserving of meat (solid waste)	13
6	Processing and preserving of fish, crustaceans and molluscs (liquid waste)	17
7	Vegetable Processing (solid waste)	3

8	Vegetable Raw (solid waste)	579
9	Fruit Processing (solid waste)	8
10	Fruit Raw (solid waste)	203
11	Palm Oil (solid waste)	2
12	Milk Processing/Dairy Products (liquid waste)	24
13	Maize Starch (liquid waste)	47
14	Tapioca Starch (liquid waste)	36
15	Tapioca Starch (solid waste)	15
16	Sugar (liquid waste)	49
17	Sugar press mud (solid waste)	200
18	Distillery (liquid waste)	781
19	Wine Industry	NA
20	Slaughterhouse (solid waste)	48
21	Slaughterhouse (liquid waste)	263
22	Cattle farm (solid waste)	862
23	Poultry (solid waste)	462
24	Chicory (solid waste)	1
25	Tanneries (liquid waste)	9
26	Tanneries (solid waste)	10
Total (MWeq)		**5690**

The total estimated energy generation potential from urban and industrial organic waste in India is approximately 5690 MW.

Estimated Capacity for Waste-to-Energy [23]

- **Total Potential:** According to NITI Aayog, India has the potential to generate approximately 5,690 MW of energy from various waste sources, including urban solid waste, agricultural residues, and industrial waste. This capacity represents a substantial opportunity for energy generation while addressing waste management challenges.

- **Current Installed Capacity**: As of 2023-2024, the total installed capacity for waste-to-energy in India was around 620 MW, which accounts for only about 0.1% of the total energy generated in the country. This indicates a significant gap between potential and actual utilization.

- **Waste Generation Insights:** India produces about 62 million tonnes of MSW annually, with projections reaching 165 million tonnes by 2030. The average calorific value of this waste ranges from 1,411 to 2,150 kcal/kg, making it suitable for energy recovery.

- **Industrial Waste:** Significant energy potential exists in industrial sectors, including paper, sugar, distilleries, and food processing industries.

- **Government Initiatives:** The MNRE's Waste to Energy Programme aims to support the establishment of projects generating biogas, bio-CNG, power, and producer or syngas from urban, industrial, and agricultural wastes. This program offers financial assistance to project developers to promote WtE projects across the country.

[23] https://mnre.gov.in/en/waste-to-energy-overview/

https://indianexpress.com/article/upsc-current-affairs/upsc-essentials/harnessing-waste-to-energy-for-sustainable-growth-in-india-9612101/

11.3 Cumulative Achievement in Waste to Energy Generation in India

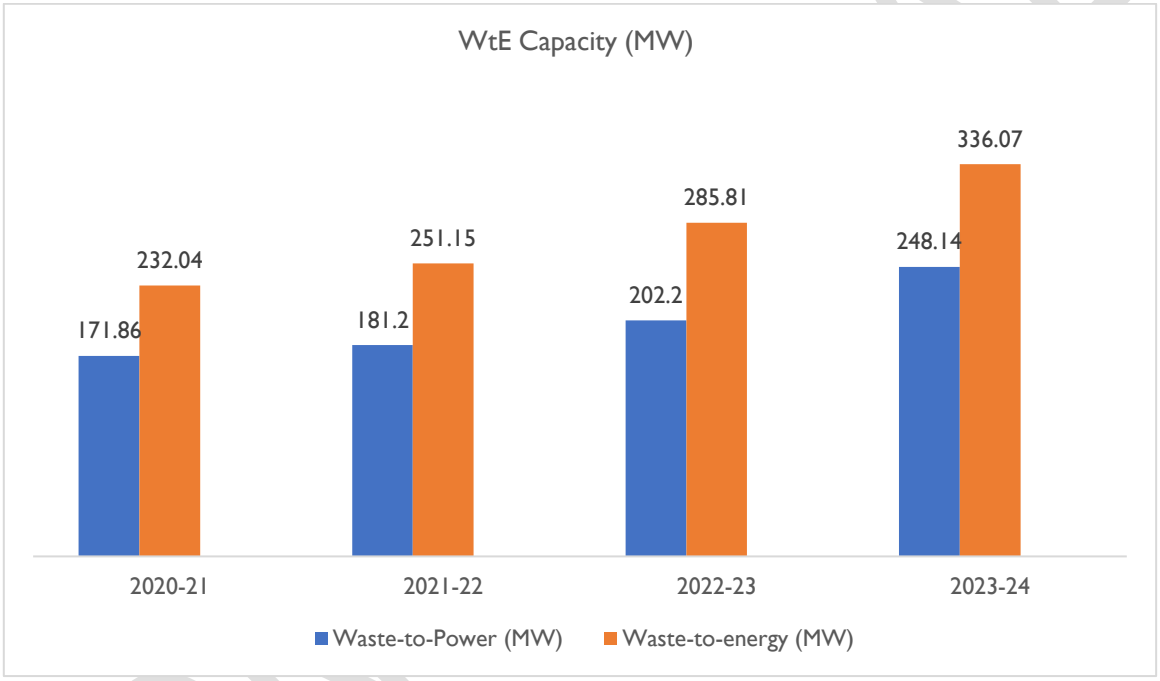
India has been making steady progress in **the waste-to-energy (WtE)** sector, focusing on converting municipal solid waste (MSW) and industrial waste into electricity, biogas, and other forms of renewable energy.

Current Installed Capacity (As of December 2024)

- Waste-to-Power Plants (Grid-Connected): 249.74 MW
- Waste-to-Energy (Off-grid & Captive Use): 370.20 MW

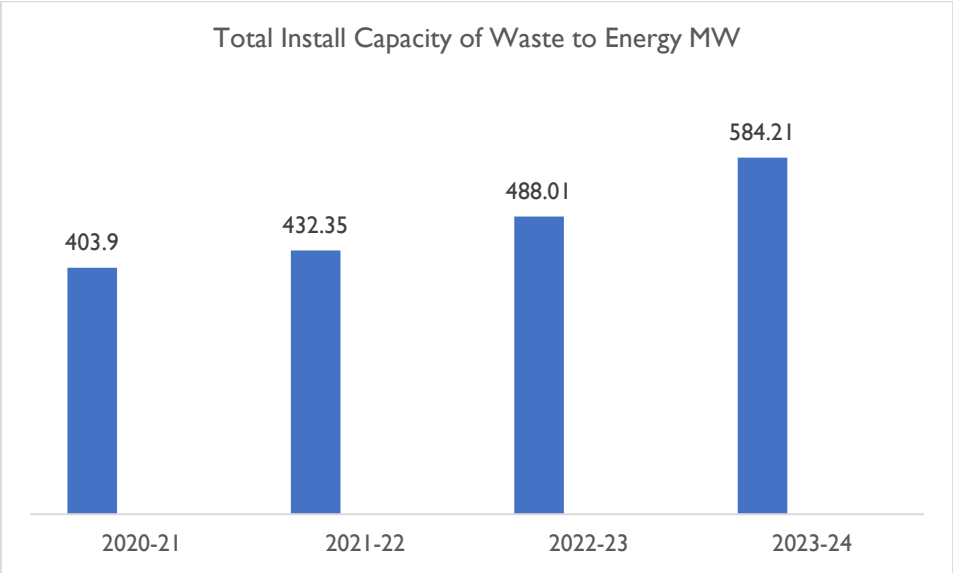
  Total Cumulative Capacity: 620 MW

Over the past years, India's waste-to-energy (WtE) capacity has experienced gradual growth.



Source: D&B Research

Both Waste-to-Power and Waste-to-Energy capacities show a continuous increase over the years. This suggests an expansion of waste-to-energy projects, greater investments, or increased waste utilization efficiency. The **growth rate accelerates over the years**, indicating increasing adoption of waste-to-power technology. Similar to **waste-to-power**, the growth in waste-to-energy capacity accelerates annually, showing **rising efficiency and investment in waste-based energy production**



Source: D&B Research

The total installed capacity has consistently increased every year. This suggests higher investments, improved technology, and increased adoption of waste-to-energy projects. The accelerating annual growth rates suggest an increasing adoption of installed capacity over time. If the growth trend continues, waste-to-energy will become a key contributor to renewable energy production and sustainable waste management.

11.4 Key Demand Drivers: Waste to Energy Sector in India

Some of the Key demand drivers: [24]

Rapid Urbanization & Growing Waste Generation	• India generates ~62 million tons of MSW annually, with only 20% properly processed. • By 2030, MSW generation will double, pushing urban bodies to adopt WtE for landfill reduction.
Rising Energy Demand & Power Shortages	• With growing power demand, WtE provides a renewable alternative to reduce fossil fuel dependency. • WtE supports decentralized energy generation, ensuring stable power supply in cities.
Supportive Government Policies & Incentives	• Programs like Swachh Bharat Mission and National Bio-Energy Mission promote WtE adoption. • MNRE provides subsidies, tax benefits, and PPP models to attract private investments.
Environmental & Climate Concerns	• WtE reduces methane emissions from landfills and minimizes air, water, and soil pollution. • It aligns with India's Net Zero 2070 target by supporting cleaner waste management solutions.

Future Outlook: India has an estimated WtE potential of 5,690 MW, but only 620 MW is currently

[24] https://swachhbharatmission.ddws.gov.in/, https://mnre.gov.in/en/

installed. With growing waste volumes, increasing energy demand, and strong government backing, the sector is set for significant expansion in the coming years.

11.5 Regulatory Landscape Governing Waste to Energy Landscape in India

India's waste-to-energy (WtE) sector operates within a comprehensive regulatory framework designed to promote sustainable waste management and energy recovery. In India, the regulatory landscape governing waste-to-energy is primarily managed by the **Ministry of New and Renewable Energy (MNRE).**

MNRE promotes waste-to-energy technologies by offering incentives and financial support, while also being guided by the broader environmental regulations set by the Ministry of Environment, Forest and Climate Change (MoEFCC), including rules regarding waste management and emission standard.

Solid Waste Management (SWM) Rules, 2016 Established by the Ministry of Environment, Forest and Climate Change, these rules mandate:

- **Waste Segregation at Source:** Households must separate waste into biodegradable, dry, and hazardous categories.
- **Utilization of Non-Recyclable Waste:** Waste with a calorific value of 1,500 kcal/kg or higher should be directed towards energy recovery processes, such as refuse-derived fuel (RDF) or co-processing in cement or thermal power plants, rather than landfilling.

Waste to Energy Programme by the Ministry of New and Renewable Energy (MNRE): The MNRE promotes various technologies for energy recovery from waste, including biogas, bio-CNG, and electricity generation from municipal solid waste, agricultural residues, and industrial effluents. **The program offers:**

Central Financial Assistance (CFA): Financial incentives are provided based on project performance, with the commissioning period set at 24 months for WtE plants.

Performance-Based Incentives: The percentage of eligible CFA is linked to the plant's Plant Load Factor (PLF), encouraging efficient operations.

Guidelines for Implementation of Waste to Energy Programme (2021-2026): These guidelines outline the framework for WtE project implementation, specifying eligible waste types, technological options, and financial assistance mechanisms. They emphasize:

- **Eligible Waste Streams:** Municipal solid waste, refuse-derived fuel, and segregated combustible fractions are identified as suitable for energy recovery.
- **Technological Options:** Technologies such as incineration, gasification, and pyrolysis are recommended for processing waste into energy.

11.6 Insight on Major Waste to Energy Plants

Table 20 Details of operational waste to energy plants:

Sr. No.	Plant Name	Location	Conversion Method	Capacity	Electricity Generated (MW)	Additional Information
1	Ghazipur Waste-to-Energy Plant	Ghazipur, Delhi	Incineration	1,300	12	Helps reduce landfill burden and generates electricity.
2	Narela-Bawana Waste-to-Energy Plant	Narela-Bawana, Delhi	Incineration	2,400	24	Addresses Delhi's waste management and supplies energy to the grid.
3	Okhla Waste-to-Energy Plant	Okhla, Delhi	Incineration	2,000	21	Reduces waste volume and landfill dependency in Delhi.
4	Tehkhand Waste-to-Energy Plant	Tehkhand, Delhi	Incineration	2,000	20	Supports clean energy initiatives and waste management in Delhi.
5	Hyderabad Waste-to-Energy Plant	Hyderabad, Telangana	Incineration	2,000	20	Part of the city's strategy to reduce landfill usage and generate power.
6	Pimpri-Chinchwad Waste-to-Energy Plant	Pimpri-Chinchwad, Maharashtra	Incineration	700	14	Helps manage waste in Maharashtra and reduces landfill stress.

Moving Forward

With waste-to-energy technology crucial for sustainable urban development, the government is focusing on expanding such projects to manage municipal solid waste more effectively while contributing to the renewable energy mix.

12. Competitive Landscape

The competitive landscape in India's energy and oil & gas sector is influenced by several key factors, including government policies, technological advancements, and the growing emphasis on renewable energy. These factors are not only shaping the way energy is produced and consumed in India but are also creating a dynamic and evolving environment for businesses operating in this sector. Companies in the energy and oil & gas space are required to adapt quickly to these changing conditions to remain competitive.

In response to these dynamics, companies like Deep Industries, Anup Engineering, Sterling & Wilson, and PatelsAirtemp are actively innovating in energy efficiency, renewable energy, and specialized manufacturing to maintain their competitive position. Deep Industries Ltd. is focusing on natural gas compression, drilling, and well testing services, while also investing in renewable energy projects. Anup Engineering Ltd., with its strong presence in manufacturing heat exchangers and pressure vessels, continues to serve the energy sector with high-quality, customized equipment solutions. Sterling & Wilson Renewable Energy Ltd. has expanded its offerings in solar energy solutions, capitalizing on the country's growing solar power demand. Meanwhile, PatelsAirtemp has focused on providing energy-efficient HVAC solutions for industrial and energy sectors, contributing to the adoption of green technologies.

As India continues to emphasize sustainable growth, these companies must not only adapt to the global energy shift but also meet the changing domestic demand trends. The energy sector in India is undergoing a transformation, and companies that can navigate these changes by focusing on innovation, sustainability, and regulatory compliance will be better positioned for long-term success. The future of India's energy landscape will likely see increased integration of renewable energy solutions, smart technologies, and green infrastructure, pushing companies to continuously evolve and maintain their competitive advantage.

12.1 Analysis of Key Factors Shaping Competition in the Sector

- **Government Policies**: India's transition to renewable energy is driven by ambitious targets set in the National Action Plan on Climate Change and various government initiatives like the International Solar Alliance. While fossil fuels still play a significant role, the government encourages diversification and private sector participation through policies like NELP and HELP. Price regulation and subsidies also influence the market dynamics.

- **Technological Advancements**: Advancements in renewable energy technologies (solar, wind), smart grids, and energy storage are driving competition. In the oil & gas sector, digitalization, automation, and technologies like seismic imaging and fracking are improving efficiency and productivity, allowing for better management of resources and reducing operational costs.

- **Market Demand**: India's growing industrialization and urbanization lead to higher energy consumption. The adoption of electric vehicles and government schemes like the Saubhagya Yojana are reshaping demand, influencing both the traditional energy and renewable energy markets.

- **Environmental Concerns**: There's a strong push towards sustainability, with companies focusing on clean energy solutions like solar, wind, and carbon capture technologies. Corporate social responsibility initiatives are also a priority as companies strive to reduce their environmental impact.

- **Global Energy Price Fluctuations**: Volatile global oil prices, influenced by geopolitical tensions and shifts in demand, impact India's energy costs. These fluctuations affect profitability and can lead to inflationary pressures in the economy.

- **Intense Competition**: The energy sector in India is highly competitive, with both domestic companies like Reliance Industries, IOC, and NTPC, and international players like Shell and BP, vying for market share. Additionally, renewable energy companies like ReNew Power and Adani Green are intensifying competition in the green energy segment. Companies are responding by investing in R&D and forming strategic partnerships.

12.2 Players Profiling

12.2.1 Deep Industries Ltd.

Company Overview

Founded: 2006

Headquarters: Ahmedabad

Locations: 42 Plants and 3 Offices Across India

Employee Count: 1,646

Deep Industries Ltd. operates primarily in the oil & gas and energy sectors, offering specialized services and products related to drilling, well services, and industrial equipment. The company's headquarters are located in Ahmedabad, Gujarat, and it has manufacturing and service facilities in this region. These facilities support operations for oilfield exploration and production, with the company also providing equipment for drilling rigs, gas compressors, and other related services.The company has a solid presence in the upstream oil and gas segment and focuses on improving operational efficiency through investments in technology and infrastructure. The facilities are equipped with advanced machinery that ensures optimal productivity and safety in its operations.

Product/Services Offered:

- **Upstream Services**:

➢ Drilling and Workover Services:

  - Slim Hole Coring Rig especially for CBM field, which can go up to depth of 1500 metre.
  - Air Drilling Rig
  - Onshore Workover Rigs of varied capacity (from 150 HP TO 1000 HP)
  - Onshore Drilling Rigs of varied capacity (from 350 HP to 1500 HP)
  - Casing retrieval
  - Well stimulation
  - Planning, designing and executing of well service programs for critical wells
  - Rehabilitation of sick / abandoned oil and gas wells
  - Multi zone completions.
  - Fishing
  - Milling
  - P/O & R/I of Tubing's
  - Cement Plug Drilling
  - Scrapping,
  - Conversion to S/Rod Completion
  - Logging & Perforation
  - Coil Tubing

- Gas Lift Valve (GLV)

➢ Integrated Project management Services:

- Workover / Drilling / Coring Rig Services
- Liner Hanger, Completion & Work over Services.
- Gas Compressors Services
- Air Compressor
- Mud Engineering Services
- Mud Logging Services
- Mud Logging Services
- Well Testing Services
- Operation and Maintenance of Services
- Cementing Services
- Hydro Fracturing & Coil Tubing
- Diesel Pumping Unit
- Laying Gas Pipelines
- Transportation of Equipment
- Crane Services
- Installation of Sucker Rod Pumps and Maintenance
- Steaming Unit Services
- Drilling Water Supply
- Accommodation Services
- Canteen Services
- Fuel Supply
- Diesel Tanker Supply
- Crude Tanker Supply
- Separators

• **Midstream Services**:

➢ Drilling and Workover Services:

- Well Head Compression
- Gas gathering
- Gas storage facilities
- Gas processing
- Pipeline Booster stations
- CNG
- Injection
- Gas lift
- Onshore / Offshore
- Pipeline testing / evacuation

- Air Injection
- Seismic air / Drilling air / Plant air
- Vapour / Flare Gas Recovery

➢ **Gas Dehydration, Conditioning & Processing: Experienced EPC Services Provider and providing:**

- FEED, Detailed Designing
- Installation & Commissioning Oil and Gas Conditioning & Processing
- Surface facilities
- Gas Processing Units
- Scrubbers, Nitrogen rejection system
- Gas Gathering Stations & Gas Collecting Stations
- Overground & underground Pipeline network

- **Key Strengths:**

❖ The company offers a broad range of services across various sectors, serving a diverse client base, which helps maintain stability amid market fluctuations and changing demands.

❖ By utilizing fully mobile units, the company is able to transport its resources efficiently to different locations within the country, adapting to customer needs in a timely manner.

❖ Through its subsidiary, the company is exploring sustainable offshore opportunities, with promising prospects that may lead to significant growth in the future.

❖ The company's strong liquidity and resource base enable it to manage expansion needs effectively. It maintains a balanced approach to liquidity and debt, which contributes to its solid financial position.

❖ With the rising demand for gas compression services, the company is well-positioned to capitalize on the increasing trend of outsourcing this specialized service.

❖ Deep Industries brings expertise in providing value-added services, which helps clients improve their revenue generation and profitability, while offering a diverse range of services within its portfolio.

Recent Developments:

❖ Acquisitions: In 2023, Deep Industries, through its subsidiary, acquired a significant equity stake in Dolphin Offshore Enterprises (India) Limited and Breitling Drilling Private Limited.

12.2.2 The Anup Engineering Ltd.

Company Overview

Founded: 1669

Headquarters: Ahmedabad

Locations: No of Plants- 2 (Kheda and Ahmedabad, Gujarat) and No of Offices- 3 in India

Presence: National (No. of States) 29 and International (No. of Countries) 34

Employee Count: 750

Anup Engineering Ltd. is an established company in the Indian industrial sector, specializing in the manufacturing of engineered products, particularly pressure vessels, heat exchangers, and related equipment. Founded in 1969, the company has built a reputation for producing reliable products that meet industry standards. Anup Engineering operates its manufacturing facility in Ahmedabad, Gujarat, where it designs and manufactures products for industries such as oil & gas, chemical, petrochemical, and power generation.

The company offers a diverse range of products, including heat exchangers, pressure vessels, columns, reactors, air coolers, and custom-built equipment. These products are designed to meet specific requirements of clients in various industrial environments.

Anup Engineering focuses on research, development, and the use of advanced technologies to address market needs. The company maintains a commitment to global quality standards to meet the varied demands of its clients.

Product/Services Offered:

- **Static Process Equipment**:
  - Heat Exchanger E550
  - Reactors
  - Pressure Vessels
  - Columns & Towers
  - Custom Fabrication
- **Technology Products**:
  - Helix changer
  - EMBaffle Heat Exchanger
  - Polymerization Reactor
- **Engineering Services**:
  - Thermal & Hydraulic Design (Preliminary)
  - Thermal & Hydraulic Design (Detailed)
  - Flow-induced Vibration Analysis (X-vib)
  - Mechanical Design (Concise)
  - Mechanical Design (Detailed)
  - FEA Analysis of process equipment/structural

- Fatigue Analysis (Thermal Transient & Cyclic Loading)
- 3-D Modelling
- Drawing- General arrangement
- Drawing- Detailed manufacturing

Key Strengths:

- Reputed Clientele: Anup has a strong and reputed client base, including ThyssenKrupp Industrial Solutions (India) Private Limited, Air Products USA, Toyo Japan, Saipem, Linde Germany, and Technip France. This indicates their credibility and reliability in serving major industry players.
- In-house Engineering Capabilities: The company has an agile and flexible team with strong in-house engineering capabilities. They have invested in the latest design software and built technically competent teams of engineers across functions.
- Innovation and Space Exploration: Anup has supplied components for many space expeditions, demonstrating their ability to manufacture critical and precise components for advanced applications. They were also one of the first fabricators approved by ISRO for such supplies.
- Location Advantage: Company's facility in Ahmedabad is well-connected to major national highways and seaports in Western India, including Mundra, Kandla, and Mumbai, located 400 km, 350 km, and 550 km away, respectively. The logistics team manages the timely movement of equipment to client sites globally.
- Strong Customer Base: The company has a strong customer base that includes Reliance, Petronas, Nayra, IOCL, Air Products, HPCL, PetroPeru, and more than 50 customers in India and across the globe.

12.2.3 Patels Airtemp (India) Ltd.

Company Overview

Founded: 1973

Headquarters: Ahmedabad, Gujarat, India

Locations: Plant (Rakanpur Works 1 and Dudhai Works 2) and No of Offices- 3

Employee Count: 187

Patels Airtemp (India) Ltd. is a manufacturer and supplier of HVAC (Heating, Ventilation, and Air Conditioning) solutions and industrial air conditioning products. Founded in 1983, the company is based in Ahmedabad, Gujarat. Patels Airtemp provides a range of products and services, including custom-designed HVAC systems, air conditioning systems for various industries, and related equipment.

The company focuses on designing, manufacturing, and servicing air conditioning and refrigeration systems for sectors such as oil and gas, healthcare, hospitality, and commercial industries. Its products include precision air conditioning, central air conditioning, and HVAC systems tailored to meet specific client needs. With a manufacturing infrastructure and a skilled team, Patels Airtemp is known for offering reliable and energy-efficient products.

The company also provides end-to-end solutions, including installation, maintenance, and after-sales support. Patels Airtemp works to integrate advanced technologies into its products and services while ensuring compliance with industry standards and environmental guidelines. The company has expanded its presence in both domestic and international markets, contributing to various projects.

Key Customers: CPCL, NRL, HP

Product/Services Offered:

- Heat Exchangers
- Air Cooled Condensers
- Pressure Vessels
- Ambient Air Vaporizers
- Steam Coil Air Pre-heaters & Heaters
- Ambient Air Heater

Key Strengths:

- The company serves a diverse customer base across industries such as oil and gas, petrochemical, power, chemical, fertilizer, pharmaceuticals, cement, and textiles.
- The company has established supply network with the delivery of over 10,500 equipment units to a diverse customer base.

- ❖ The company distributes its products across various regions, catering to customers within India as well as in overseas markets.
- ❖ Patels Airtemp (India) Ltd. is ISO 9001:2015 certified for quality management and follows ASME, TEMA, API, IS, and DIN design codes. It operates with strict quality checks in its manufacturing facilities.

12.2.4 Lloyds Engineering Works Ltd

Company Profile: Lloyds Engineering Works Ltd is an engineering company that specializes in providing a range of services in the field of mechanical and electrical engineering. The company offers solutions for the construction, installation, and maintenance of industrial plants, machinery, and equipment. It serves various industries, including oil and gas, power, infrastructure, and manufacturing, with a focus on delivering quality services through a skilled workforce and technical expertise. Lloyds Engineering Works Ltd is involved in both domestic and international projects, managing each phase from design to execution while ensuring compliance with industry standards.

EPC Services Offered to the Energy Sector:

Engineering Services:

- ➢ **Front-End Engineering Design** (FEED): Detailed design and planning for energy, oil, and gas infrastructure, ensuring feasibility and cost optimization.
- ➢ **Detailed Engineering**: Comprehensive engineering design for mechanical, electrical, and instrumentation systems in oil & gas and energy sectors.
- ➢ **System Integration**: Integration of complex systems for automation, control, and monitoring to optimize operational efficiency.

Procurement Services:

- ➢ **Material Procurement**: Sourcing and procuring high-quality materials such as pipelines, valves, pumps, compressors, and electrical components.
- ➢ **Equipment Supply**: Providing critical equipment for oil & gas facilities, refineries, and energy plants.
- ➢ **Vendor Management**: Managing relationships with suppliers and ensuring timely delivery of quality materials and equipment.

Construction and Installation:

- ➢ **Pipeline Installation**: Design and installation of pipelines for oil, gas, and water transport systems, including laying, welding, and testing.
- ➢ **Tank and Vessel Construction**: Installation of storage tanks, pressure vessels, and other storage solutions for oil and gas storage and refining.
- ➢ **Mechanical & Electrical Installation**: Installation of mechanical and electrical systems, including power distribution, instrumentation, and control systems.

- **Civil and Structural Works**: Foundation works, building structures, and site development for energy and oil & gas plants.

Turnkey Project Execution:

- **Complete Project Management**: Handling the entire lifecycle of EPC projects, from planning and design to procurement, construction, and commissioning.
- **Customized Solutions**: Tailoring project execution to meet client-specific requirements and operational needs.

Products Offered:

- Processed Columns
- Pressure Vessels/Reactors
- Heat Exchanger
- Waste Heat Recovery Boilers
- Skid Mounted Dryers for Air, Liquid and Gas
- Steel Plant Equipment & Machinery
- Steering Geers & Stabilizers

Clients:

GAIL	BPCL	CPCL	EIL
EUROPEM	Haldia Petrochemical	HPCL	IOCL
Nayra Energy	Petrofac	Petron Engineering	Reliance Industries Ltd.
South Asia LPG Company Pvt. Ltd.	TechnipFMC	Total Energies	Ratnagiri Gas and Power Pvt Ltd.

Financial KPI (Selected KPI Indicators for Profiled Players, for the Last 3 Years)

All Values In Million	Oswal Energies Limited			Anup Engineering			Deep Industries Ltd		
	FY 2023	FY 2024	FY 2025	FY 2023	FY 2024	FY 2025	FY 2023	FY 2024	FY 2025
Total Income	1604.30	2626.87	4126.60	4125.80	5594.40	7379.20	3525.85	4626.25	6084.58
Revenue from Operations	1600.12	2560.37	4108.74	4113.38	5503.84	7327.86	3413.36	4269.93	5761.30
Operating Revenue Growth	77.64%	60.01%	60.47%	42.71%	33.80%	33.14%	6.13%	25.09%	34.93%
EBITDA	97.82	373.79	909.51	827.05	1267.51	1652.24	1305.46	1594.00	2314.66
EBITDA Margin	6.11%	14.60%	22.14%	20.10%	23.03%	22.55%	38.25%	37.33%	40.18%
EBIT	85.45	352.22	884.56	701.64	1092.86	1414.05	1009.46	1250.31	1902.94
EBIT Margin	5.34%	13.76%	21.53%	17.06%	19.86%	19.30%	29.57%	29.28%	33.03%
PAT	53.40	300.77	657.95	514.30	1034.75	1183.03	1252.99	1251.59	-787.62
PAT Margin	3.33%	11.45%	15.94%	12.47%	18.50%	16.03%	35.54%	27.05%	-12.94%
Return on Capital Employed	22.61%	63.90%	82.42%	16.21%	21.43%	23.78%	7.76%	8.22%	10.49%
Return on Equity	22.11%	71.81%	73.27%	12.38%	21.42%	20.75%	10.02%	8.90%	-4.83%
Total Asset Turnover Ratio	1.55	1.54	1.52	0.70	0.76	0.84	0.24	0.24	0.24
Fixed Asset Turnover Ratio	20.94	22.33	34.04	1.64	1.83	2.20	0.60	0.59	0.43
Net Working Capital Days	97	49	115	210	196	203	197	225	271
Net Debt	-9.10	71.55	147.83	17.44	-20.01	137.60	270.76	1030.67	1540.99
Net Debt to EBITDA	-0.09	0.19	0.16	0.02	-0.02	0.08	0.21	0.64	0.67
Net Debt to Equity	-0.03	0.13	0.12	0.00	0.00	0.02	0.02	0.07	0.08
Order Book Value	2487.90	4898.10	8341.50	5300.00	8542.00	7700.00	10,000.00	12100.00	29,600.00

All Values In Million	Patels Airtemp (India) Ltd.			Lloyds Engineering Works Limited		
	FY 2023	FY 2024	FY 2025	FY 2023	FY 2024	FY 2025
Total Income	2828.04	3728.82	3893.66	3184.06	6316.76	8699.00
Revenue from Operations	2814.79	3707.62	3878.16	3126.10	6242.36	8457.41
Operating Revenue Growth	-7.17%	31.72%	4.60%	524.01%	99.69%	35.48%
EBITDA	310.70	350.13	355.88	522.47	1009.97	1351.72
EBITDA Margin	10.72%	9.44%	9.18%	16.71%	16.18%	15.98%
EBIT	260.61	309.49	316.65	498.65	969.51	1255.10
EBIT Margin	9.26%	8.35%	8.16%	15.95%	15.53%	14.84%
PAT	111.69	147.61	165.10	368.23	798.38	1080.03
PAT Margin	3.95%	3.96%	4.24%	11.56%	12.64%	12.42%
Return on Capital Employed	12.30%	13.44%	13.12%	25.19%	27.17%	21.30%
Return on Equity	9.30%	10.84%	11.00%	22.28%	26.32%	20.39%
Total Asset Turnover Ratio	0.87	1.01	1.14	1.11	1.33	1.08
Fixed Asset Turnover Ratio	6.09	8.15	8.75	8.37	8.60	6.66
Net Working Capital Days	268	233	228	145	127	111
Net Debt	843.43	881.01	623.53	383.25	-644.08	-775.87
Net Debt to EBITDA	2.80	2.51	1.75	0.73	-0.64	-0.57
Net Debt to Equity	0.65	0.62	0.40	0.20	-0.16	-0.12
Order Book value	4900.00 (Till Aug)	3120.00 (Till Aug)	NA	6829.42	9043.19	13153.80

Note: For Anup Engineering and Lloyds Engineering Works Limited, standalone financial statements are considered, while for all other companies, consolidated statements are used.

However, Anup Engineering has consolidated figures available for FY 2022, FY 2023, and FY 2025 these have been used accordingly. For FY 2024, only standalone figures are used, as consolidated data is not available for that year and for Lloyds Engineering Works Limited for FY 2025, consolidated figures are considered.

	Parameter	Formula
1	Total Revenue	Total Income includes Revenue from Operations and Other income.
2	Revenue From Operations	Revenue from operations means the revenue from operations as appearing in the restated statement of profit & loss for the relevant year/period.
3	EBITDA	PBT + Finance Cost + Depreciation
4	EBITDA Margin	EBITDA/Revenue from Operations
5	PAT Margin	PAT / Revenue from operation + Other Income
6	Return on Capital Employed	EBIT/Average Capital Employed
7	Return on Equity	PAT/Average Total Capital Employed
8	Total Asset Turnover Ratio	Revenue from Operations/Average Total Asset
9	Fixed Asset Turnover Ratio	Revenue from Operations/Average Fixed Asset
10	Net Working Capital Days	Inventory Days +Receivable Days-Payable Days
11	Net Debt	Short Term Borrowing +Long Term Borrowing-Cash and Cash Equivalent-Bank Balance Other than Cash and Cash Equivalent
12	Net Debt to EBITDA	EBITDA/Net Debt
13	Net Debt to Equity	Shareholder Equity/Net Debt

12.3 Some Other Major Players

12.3.1 Engineers India Limited (EIL)

Company Profile: Engineers India Limited (EIL) is a prominent global engineering consultancy and project management firm. The company primarily specializes in delivering engineering consultancy and EPC (Engineering, Procurement, and Construction) services to the oil and gas, as well as petrochemical sectors. Leveraging its robust technical expertise and established success, EIL has expanded its operations into various other sectors, including infrastructure, water and waste management, solar and nuclear energy, and fertilizers.

Engineers India Limited (EIL) offers comprehensive services for offshore projects, encompassing the design and implementation of wellhead platforms, process platforms, gas compression platforms, water injection platforms, gas lift platforms, and submarine pipelines.

EPC Services Offered by EIL in the Energy Sector:

Thermal Power Plants: EIL designs and executes thermal power plants including Rankine, Simple Cycle, Combined Cycle, and Co-generation Cycle.

- Key Services: Implements thermal power plants powered by solid, liquid, and gas fuels using diverse cycles.
- Example: Consultancy services for Balance of Plant (BOP) packages in large power plants across India.

Nuclear Power: Expanding operations to pursue strategic consultancy opportunities in the nuclear power sector, specializing in Balance of Plant (BOP) engineering.

- Key Services: Strategic Consultancy for nuclear power projects and Balance of Plant (BOP) Engineering and design
- Example: Provided Engineering Services for the Balance of Plant (BOP) to Nuclear Power Corporation of India Ltd. (NPCIL) and Secured EPCM consultancy services contract from Nuclear Fuel Complex, Hyderabad.

Solar Power: EIL offers EPC solutions for solar power sector, leveraging opportunities created by the Jawaharlal Nehru National Solar Mission Policy.

- Key Services: Engineering consultancy and EPC services for solar power projects and Technology development for photovoltaic power plants.
- Example: Delivered technical services for the Power Block of Reliance ADAG's 125MW solar thermal project in Rajasthan, India's largest solar project.

Upstream (Exploration & Production): EIL offers EPC services for offshore platforms, covering wellhead, process, gas compression, water injection, and gas lift platforms.

- Key Services: Process platform engineering and Gas lift platform construction.

- Example: Successfully completed projects for over 213 offshore platforms, including 40 process platforms.

Midstream (Transportation & Storage): EIL constructs pipelines and terminals & storage.

- Key Services: Pipeline construction and terminals & storage.

Example: Contributed to Dabhol-Bangalore Pipeline, Dhamra-Haldia Pipeline Project and Crude Oil & Petroleum Product Storage Terminals.

Downstream (Refining & Petrochemicals): EIL offers EPC services refineries, including greenfield and brownfield projects.

- Key Services: Refinery construction, greenfield and brownfield projects.
- Example: Contributed to ONGC Petro Additions Limited (OPaL), BPCL's Refinery and Petrochemical Project and Petronet LNG Petrochemical Complex.

Key Developments:

- ❖ EIL secured orders worth ₹4,681 crore in the first five months of FY25, exceeding the total orders of ₹3,406 crore received in FY24. As of August 31, 2024, the company's total order book stood at approximately ₹11,350 crore.
- ❖ EIL expanded its global presence by commissioning the Dangote Refinery & Petrochemical Project in Nigeria, the world's largest single-train refinery, while making steady progress on the Mongol Refinery project in Mongolia.
- ❖ The company has developed more than 40 process technologies for oil and gas processing, refineries, and the petrochemical, with 34 active patents as of March 31, 2023.

12.3.2 NPCC Engineering Private Limited (NEL)

Company Profile: NPCC Engineering Private Limited (NEL), established in February 2007, is a wholly owned subsidiary of NPCC Abu Dhabi, headquartered in Mumbai, India. It specializes in providing Design & Engineering Services for Onshore and Offshore Oil & Gas industries across India and the GCC region.

Over the years, NEL has expanded significantly, acquiring ANEWA Engineering Private Limited in Hyderabad in August 2015, increasing its total engineering capacity to 1000+ employees. With expertise in multiple disciplines, including Process & Safety, Mechanical, Structural, Civil, Subsea Pipeline, Piping, Electrical, Instrumentation, and Project Management, NEL has successfully executed medium and large-scale complex engineering projects. Strategically located in Kanjurmarg (East), Mumbai, NEL maintains seamless global connectivity with clients, reinforcing its position as a trusted engineering partner in the Oil & Gas sector.

EPC Services Offered by NEL in the Energy Sector:

Thermal Power Plants: NEL specializes in the EPC of coal, gas, and oil-fired power plants. The company provides engineering and integration of Boiler, Turbine, and Generator (BTG) islands.

- Key Services: Balance of Plant (BoP) systems, including cooling towers, fuel handling, and water treatment.
- Example: EPC execution of a 660 MW supercritical coal-based power plant and Retrofitting of pollution control systems in existing thermal power stations.

Nuclear Power: NEL provides EPC services for nuclear power infrastructure, including reactor containment, auxiliary systems, radiation shielding, and waste management.

- Key Services: It integrates **turbine island components** with reactor systems to enhance efficiency and ensure compliance with **nuclear safety standards.**
- Example: Engineering and construction of a pressurized heavy water reactor (PHWR) auxiliary systems.

Solar Power: NEL provides turnkey EPC solutions for utility-scale solar photovoltaic (PV) and concentrated solar power (CSP) plants.

- Key Services: Design and installation of solar modules, inverters, and balance of system (BoS) components and Solar thermal integration for industrial applications.
- Example: Development of a 100 MW solar PV plant with grid connectivity, Hybrid solar-wind energy plant for remote area electrification and Rooftop solar EPC project for industrial and commercial buildings.

Upstream (Exploration & Production): NEL delivers EPC services for oil & gas facilities, including wellhead platforms, risers, FPSO integration, and subsea pipeline design, ensuring safe and efficient hydrocarbon extraction.

- Key Services: Engineering and construction of offshore and onshore production facilities and Floating Production Storage and Offloading (FPSO) system integration
- Example: Cross-country gas pipeline EPC project for a national gas grid, Development of a crude oil tank farm with automated monitoring systems and EPC of an LNG receiving and regasification terminal.

Midstream (Transportation & Storage): NEL offers EPC services for crude oil and gas pipelines, including compressor stations, LNG terminals, tank farms, SPR infrastructure, and gas processing plants for NGL extraction and fractionation.

- Key Services: Design and construction of crude oil and natural gas pipelines and Compressor and pumping station engineering.
- Example: Cross-country gas pipeline EPC project for a national gas grid, Development of a crude oil tank farm with automated monitoring systems and EPC of an LNG receiving and regasification terminal.

Downstream (Refining & Petrochemicals): NEL provides EPC solutions for refineries, petrochemical, and fertilizer plants, specializing in process unit engineering, storage tank farms, terminal automation, and sustainable emission control technologies.

- Key Services: EPC of refineries, petrochemical, and fertilizer plants and Crude distillation, catalytic cracking, and hydro processing unit engineering.
- Example: Expansion of a petroleum refinery with hydrocracking and desulfurization units, EPC execution of a polypropylene production plant and Design and construction of an ammonia-urea fertilizer plant.

Key Developments:

- ❖ Acquired a majority stake in ANEWA Engineering Pvt. Ltd. (Hyderabad) in 2015, enhancing engineering capacity and expertise.
- ❖ Adopted advanced engineering software such as E3D, SP3D, Aspen HYSYS, CAESAR II, TEKLA, and STAAD Pro for cutting-edge design and analysis.
- ❖ Integrated energy-efficient and emission control technologies in EPC solutions for refineries, petrochemical, and fertilizer plants.
- ❖ Successfully delivered engineering solutions for offshore platforms, subsea pipelines, LNG terminals, refineries, and petrochemical plants.

Clients:

Abu Dhabi National Oil Company (ADNOC)	BG Exploration and Production India Limited	Dolphin Offshore Enterprises India Limited	Saudi Aramco
National Petroleum Construction Company (NPCC)	Oil and Natural Gas Corporation Limited (ONGC)	Afcons Infrastructure Limited	Mustang Wood Group
Valentine Maritime Limited	Gujarat Chemical Port Limited	Consolidated Contractors Company (CCC)	Qatar Petroleum Development
Reliance Industries Limited (RIL)	Abu Dhabi Marine	Larsen & Toubro (L&T)	

12.3.3 KEC International Limited

Company Overview:

Incorporated in 2005, KEC International Limited is headquartered in Mumbai, and operates as the flagship engineering, procurement, and construction (EPC) entity of the RPG Group. As a major EPC player with annual revenues around USD 2.4 billion, KEC provides comprehensive infrastructure services, including transmission towers, power transmission and distribution systems, railway electrification and signaling, civil construction, cables, and smart infrastructure. KEC delivers turnkey infrastructure solutions in more than 110 countries, with its tower manufacturing, cable, railway, and civil facilities supporting projects across power, transportation, and urban development sectors.

Key Products & Services Offered:

- Power Transmission & Distribution
- Railways
- Civil
- Renewables Businesses
- Oil & Gas Pipelines
- Cables

Services: Turnkey EPC Solutions, Engineering & Design, Manufacturing, Tower Testing, Quality

Key Customer Segments Served:

- Power Transmission & Distribution
- Civil
- Transportation
- Renewables
- Oil & Gas Pipelines and Cables

Key strengths:

- Well-diversified across businesses and geographies
- Strong project management and execution capabilities and Well-integrated global supply chain
- Preferred contractor for ahead of schedule delivery of projects
- Capabilities to execute projects in difficult terrains and conditions
- Unparalleled manufacturing, engineering and design capabilities
- Backward integration of operations - Transmission & Distribution, Railways, and Renewables

12.3.4 Kalpataru Projects International Limited

Company Overview:

Established in 1981, Kalpataru Projects International Limited (KPIL) is headquartered at Mumbai, with its registered office in Gandhinagar, Gujarat. KPIL is a publicly listed engineering, procurement, and construction (EPC) company engaged in multiple infrastructure sectors, including power transmission and distribution, buildings and factories, water supply and irrigation, railways, oil and gas pipelines, urban mobility (flyovers and metro rail), highways, and airports. Since its foundation, KPIL has executed over USD 14 billion worth of orders and has an active global footprint in more than 75 countries, with over 300 projects currently underway in more than 30 countries. The company operates dedicated operations and design facilities such as a high-voltage tower R&D centre in Gandhinagar and has expanded through strategic acquisitions including Linjemontage in Sweden and Fasttel in Brazil.

Key Products & Services Offered:

- Power T&D
- Building & Factories
- Water
- Railways
- Urban Infrastructure
- OIL & GAS
- Manufacturing Plants
- Biomass Plants

Key Customer Segments Served:

- Utility & Power Companies
- Municipalities & Water Authorities
- Urban Development Agencies
- Oil & Gas Companies
- Infrastructure Manufacturers
- Renewable Energy Sector

Key strengths:

- **Diversified Infrastructure Portfolio:** KPIL operates across multiple infrastructure segments including power transmission, buildings, water, railways, oil & gas, urban mobility, and highways.

- **Global Presence:** The company has executed projects in over 75 countries, with ongoing operations in more than 30 countries worldwide.
- **In-house Design & Manufacturing:** KPIL maintains dedicated design centers and transmission tower manufacturing facilities with galvanizing and painting capabilities.
- **Sustainability Commitment:** The company has set clear goals including achieving carbon neutrality by 2040 and water neutrality by 2032.
- **Strategic Acquisitions:** KPIL has expanded globally through acquisitions like Linjemontage (Sweden) and Fasttel (Brazil), strengthening its international footprint.

12.4 Oswal Energies Limited

Company Overview

Founded: 2013

Headquarter: Ahmedabad, Gujarat

Locations: Plant-Ola, Gujrat, No of Offices- 1, Projects in 2 countries

Presence: PAN India and International (No. of Countries) 9

Employee Count: 205-300

Oswal Energies Limited (formerly Oswal Infrastructure Limited), incorporated on January 28, 2013, is a public limited company headquartered in Ahmedabad, Gujarat, India. The company specializes in providing Engineering, Procurement, and Construction (EPC) services, primarily within the upstream and midstream segments of the hydrocarbon industry. Over the years, Oswal has developed a strong execution track record through various critical projects in the oil and gas sector, including well hook-ups and the development of new well pads in fields such as Mangala, Aishwarya, and Bhagyam. It has also executed central processing facilities at Bhaskar Field and Raag-01, as well as produced water treatment and injection facilities at Raag-03. In the midstream space, the company has laid cross-country pipelines and contributed to city gas distribution projects for clients like Gujarat Gas Limited and Sabarmati Gas Limited.

The company operates in a competitive landscape and faces competition from several established players in the oil and gas EPC segment, including Anup Engineering, Deep Industries Ltd, Patels Airtemp (India) Ltd., Lloyds Engineering Works Limited, among others. These companies also offer comparable EPC and process equipment solutions across similar segments, with capabilities in modular fabrication, gas processing, and midstream infrastructure. While the competitive intensity is notable, Oswal differentiates itself through its integrated project delivery model, agile execution approach, and growing expertise in both brownfield and greenfield projects across diversified geographies.

Building on its technical capabilities and proven project delivery expertise, Oswal Energies is now strategically diversifying into emerging areas of the energy sector. This includes ventures into hydrogen production, waste-to-energy solutions, thermal energy storage systems, and modular process units for refinery and petrochemical applications. These initiatives reflect the company's commitment to innovation and its alignment with global energy transition goals.

Oswal is also leveraging favourable government policies and strong public sector support, particularly in areas such as renewable and green energy. With national priorities shifting toward decarbonization and energy diversification, opportunities in green hydrogen and waste-to-energy projects driven by circular economy principles are gaining significant policy and investment momentum. By proactively aligning its strategy with these developments, Oswal Energies aims to establish itself as a key player in India's clean energy transformation. Its focus on sustainable infrastructure and advanced energy solutions positions the company to deliver integrated EPC services across both conventional and next-generation energy domains.

Key Customers: ExxonMobil, ONGC, Cairn India, Reliance, BPCL, and IOCL

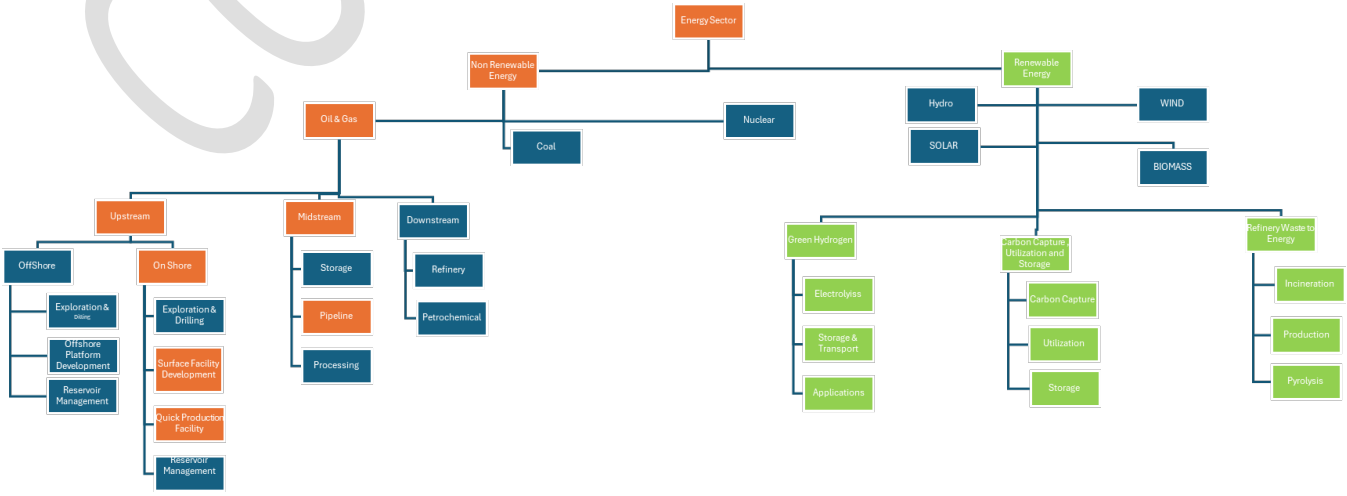
Product/Services Offered:

- **Oil / gas pipeline:** Oswal Energies Limited provides contracting services for Oil & Gas and City Gas Distribution network projects, ensuring smooth execution. Their pipeline project services include conceptual planning, feasibility studies, route surveys, telecommunications, and project management, covering design, engineering, procurement, and construction supervision**.**
- **Glycol Dehydration Unit:** They offer Dehydration Units of various capacities to meet client requirements, including modular units. Certain liquids can absorb water from gas, but only a few are suitable for commercial processes**.**
- **Clean Energy:** Using Plasma Enhanced Gasification System (PEGS) technology, they convert various waste streams into energy products such as power, methanol, ethanol, and hydrogen. This process handles municipal, industrial, biomedical, and hazardous wastes without generating landfill waste or pollution.

Key Strengths:

- Develops green hydrogen through electrolysis using renewable energy sources such as wind and solar. This process splits water molecules to produce hydrogen and oxygen.
- The company has a presence in multiple countries, including Canada, the USA, Nigeria, Egypt, Italy, Oman, Qatar, the UAE, and the Netherlands. Engages in projects and partnerships across these regions.
- Works on waste-to-energy projects by converting different waste streams into energy products. This process helps manage waste while generating resources like power, methanol, ethanol, and hydrogen.
- The company uses advanced systems for oil and gas processing, modular process skids, and industrial applications.

Value Chain Analysis: Oswal Energies Limited



	Current Business		Future Business		No Business

Non-Renewable Energy Segment (Current Business): Oswal Energies Limited operates in the non-renewable energy sector, with a strategic focus on the **exploration, production, transportation, and processing of oil and natural gas**. In the **upstream segment**, the company engages in onshore extraction activities, beginning with geological surveys and extending to the drilling of wells. It develops essential surface infrastructure such as **wellheads, separators, and gathering pipelines** to facilitate efficient resource extraction. Oswal emphasizes the deployment of **quick production facilities**, enabling accelerated recovery from oil fields and reduced time-to-market.

In the **midstream segment**, Oswal Energies invests in a robust network of **pipelines and storage systems** to ensure the safe and efficient transportation of crude oil and natural gas. This includes the development of **natural gas processing plants**, where impurities are removed and natural gas liquids are separated from raw gas, enhancing fuel quality and commercial value. Through the integration of advanced technologies and environmentally compliant infrastructure, the company ensures **cost-effective, reliable, and scalable delivery** of energy resources across domestic and regional markets.

Renewable Energy Segment (Future Business): Oswal Energies Limited is focusing on renewable energy for its future business, with key investments in green hydrogen, carbon capture, utilization and storage (CCUS), and refinery waste-to-energy technologies. The company aims to produce green hydrogen through electrolysis using renewable energy, develop efficient storage and transport solutions, and explore its diverse applications in power, transportation, and industry. In CCUS, Oswal Energies is working on capturing CO2 emissions, utilizing them in products like chemicals, and ensuring secure storage to mitigate climate change.

Additionally, the company is exploring refinery waste-to-energy solutions, including incineration, pyrolysis, and waste-to-power production, to reduce waste and generate clean energy. These initiatives support Oswal Energies' commitment to sustainability and a low-carbon future.

Table 21 Financial overview

Oswal Energies Limited (INR Crores)	FY 2022	FY 2023	FY 2024	FY 2025
Operating Revenue	929.90	1604.30	2626.87	4126.6
Finance Cost	10.66	15.23	19.00	16.89
EBITDA	41.71	97.83	373.79	909.51
PAT	42.58	54.40	300.77	657.95
Net Worth	214.20	268.65	569.05	1227.00
Long Term Borrowing	2.27	4.00	0.00	4.40
Return on Assets	105.76%	71.14%	262.33%	545.02%

Table 22 Company Position:

Particular	FY 2024	FY 2025
Overall EPC (INR Cr)	2,07,153.42	2,17,780.25
Oswal Energies Ltd. (EPC Segment Revenue in INR Cr)	161.98	296.44
Share of Oswal Energies Ltd. In India's Overall EPC Market	0.08%	0.14%

In FY 2024, the overall EPC market in India was valued at INR 2,07,153.42 Crore, while Oswal Energies Ltd.'s EPC segment revenue was INR 161.98 Crore, representing a market share of 0.08%. Moving to FY 2025, the overall EPC market experienced growth, reaching INR 2,17,780.25 Crore. Oswal Energies Ltd. also saw a significant increase in its EPC segment revenue to INR 296.44 Crore. This growth allowed the company to increase its share in India's overall EPC market to 0.14% in FY 2025.

Expertise in EPC for Oil & Gas Sector

Oswal Energies Limited has demonstrated its engineering and execution capabilities in the Oil & Gas sector by delivering complex EPC projects across upstream and midstream operations. With a strong presence across key hydrocarbon basins in India, the company has undertaken multi-disciplinary EPC assignments involving well hook-ups, surface facility development, and produced water management systems. Over recent years, Oswal has successfully executed integrated projects that involved the end-to-end development of production facilities from procurement and installation to testing, commissioning, and start-up under Live Site and brownfield conditions. These projects, awarded between 2021 and 2024, reflect the company's ability to work under stringent safety, quality, and environmental standards while ensuring adherence to aggressive timelines.

The company applies a comprehensive project execution model that encompasses detailed engineering, procurement, logistics, health and safety compliance, and quality control. Its ability to deploy resources efficiently in challenging terrains has enabled successful delivery of projects that include high-pressure systems, modular dehydration facilities, separation units, and water reinjection infrastructure.

Each project has been executed while maintaining process continuity and minimizing downtime for the client. With a structured approach to automation, modular engineering, and integration of instrumentation systems, Oswal Energies continues to meet the technical and timeline requirements of its clients. Its experience in brownfield modification, rapid deployment strategies, and adherence to industry norms supports its role in delivering scalable oil and gas infrastructure solutions.

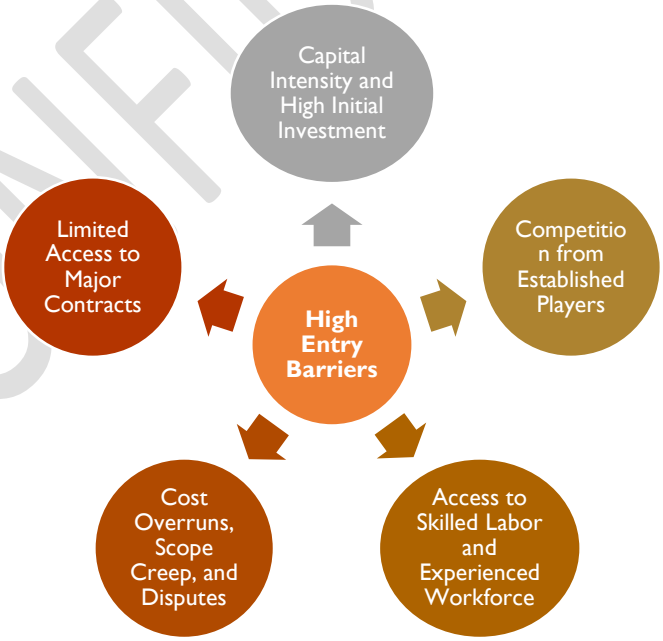
Table 23 Key EPC Projects Executed by Oswal Energies Limited:

Sr. No.	Client	Project Type	Scope of Work	Location	Contract Date	Status
A. EPC PROJECTS - OIL & GAS						
1	Vedanta Limited (Division Cairn Oil & Gas)	Procurement and construction of well hook-up and surface facility infrastructure development	RFSU, Project Management, Construction Management, Logistic Management, Site Management, stakeholder management, HSE and Quality Management etc. and making wells ready to flow including execution of applicable hook-ups & tie-ins with the existing & proposed facilities complete in all respects in accordance with ITT document and Contract.	Barmer, Rajasthan, India	13-05-2024	ONGOING
2	Vedanta Limited (Division Cairn Oil & Gas)	Provision of EPC Works for Integrated Surface Facility Development - MWP 1 & 19 Project (Phase 2-LSF ASP Upgradation)	Acid Neutralisation Package on MWP-01 and MWP-19, LSF Oil water Separation upgradation and integration (MWP-01 and MWP-12), LSF Produced Water Treatment upgradation and Integration on MWP-01 and MWP-12, Associated utilities and infrastructure on MWP-01, MWP-12 and W19.	Gurugram, Haryana, India	16-01-2024	ONGOING
3	Vedanta Limited (Division Cairn Oil & Gas)	Provision of EPC Service for well hookup at RDG Field to support mining operation	It is proposed to develop and hookup new infill wells from existing well pads 3 (Three) New Wells at Pad RP-05. 2 New wells at Pad Rp-07. Supply and Installation of operating platforms with Staircases, cellar pits coves for new and existing cellar pits.	Gurugram, Haryana, India	10-02-2024	ONGOING
4	Oil & Natural Gas Corporation Ltd.	Creation of Surface Facilities for High Pressure Air Injection (HPAI) at NAWAGAM of Ahmedabad asset on LSTK basis	Supply, installation, Testing and Commissioning of Packaged Items, Tanks Vessels, Pits, Pumps, Material Handling and Safety Systems, Electrical	Ahmedabad, Gujrat, India	24-08-2023	ONGOING

		with 3 months O&M	and Instrumentation and Civil Works.			
5	Vedanta Limited (Division Cairn Oil & Gas)	Development Of Surface Facility And Well Hook Up Services For Abh 11	Provision of well hook-up services for ABH 11 wells at Aiswharya Field in Barmer, Rajasthan.	Gurugram, Haryana, India	24-03-2023	ONGOING
6	Oil and Natural Gas Corporation Ltd.	Replacement of Cold Box for LPG-1 & LPG-units and Brazed Aluminium Plate-Fin Heat Exchanger (BAHX) E-1511B of C2-C3	Replacement Of Cold Box For Lpg-1 & Lpg-Ii Units And Brazed Aluminium Plate Find Heat Exchanger (Bahx) E-1511b Of C2-C3 On Lstk Basis.	Uran, Dist. Raigad, Maharashtra, India	15-05-2023	2025
7	Halliburton Offshore Services Inc.	Surface Facility Work for Integrated Field Plan Execution Services in Satellite Fields in RJ-ON-90/1 Block, Barmer, Rajasthan (End Client-Vedanta Limited-Div. Cairn Oil and Gas)	Provision of Surface facilities for RAAG-01, RAAG 03 and GSV fields in Satellite fields including Design, Engineering, Manufacturing, Supply Installation and Commissioning work comprising Civil Mechanical, Electrical, Instrumentation & Automation work.	Barmer, Rajasthan, India	25-10-2021	2023
8	Vedanta Limited (Div. Cairn Oil And Gas)	Provision of Integrated Development Surface Facility Works at Mangala Fields in RJ-ON-90/1 Block, Barmer, Rajasthan, India	Supply, installation, Testing and Commissioning including Civil, Mechanical, Electrical, Instrumentation and Automation work for 14 Producer well and 9 Injector Well Hook-up.	Gurgaon, Haryana, India	14-11-2021	2023
9	Vedanta Limited (Div. Cairn Oil And Gas)	Provision of Well Hook-up Services for RDG Field Within RJ-ON-90/1 Block to Support the Petroleum Operations.	Design, Engineering, Supply, installation, Testing and Commissioning including Civil, Mechanical, Electrical, Instrumentation and Automation work for 3 Producer well Hook-ups in RDG fields.	Gurgaon, Haryana, India	19-07-2021	2022
10	Sun Petrochemicals Pvt. Ltd.	Central Processing Facility Bhaskar Field	Laying of Collector Pipeline (6" x 18.133 km) and Export Pipeline (6" x 10.56 km) with hook-up of 7 nos. Producing well hook up along with Design, Engineering, Manufacturing, Supply, Installation and Commissioning of different process	Khambhat, Gujrat, India	16-01-2020	2021

			equipment and Package for Central processing facilities.			
B. EPC PROJECTS - CROSS COUNTRY PIPELINE						
1	Bharat Petroleum Corporation Limited (Merged With Bgrl)	City Gas Distribution at Geographical Area of Jajpur & Kendujhar in the state of Odisha For M/S BGRL	Laying & Construction of underground steel pipeline network & associated works at Jajpur & Kendujjhar GA (Odisha) 12"/10"/4" NB Dia Pipeline X 34 KM.	Jajpur & Kendujhar, Odisha, India	23-12-2021	ONGOING
2	Gujrat Gas Limited	City Gas Distribution Project	Laying, Testing and Commissioning of steel pipeline construction and associated work for palghar district and Thane rural GA (approx length 50 km).	Thane, Maharashtra, India	06-08-2018	2020
C. EPC PROJECTS - OTHER THAN OIL & GAS INDUSTRY						
1	Bharat Aluminium Company Limited	FTP (Potline & Bake Oven) Civil Services and Mechanical erection contact package	FTP Pot-line & Bake-Oven Civil Services and Mechanical Erection work for 414 KTPA Smelter Expansion Project.	Korba, Chhattisgarh, India	12-05-2023	ONGOING

High Entry Barriers for Mid-Sized EPC:



- **Capital Intensity and High Initial Investment**: The oil and gas sector demand significant upfront capital investment for infrastructure, machinery, and project execution. Mid-sized EPC companies may struggle to raise the necessary funds to compete with large, well-established players who have deep pockets. Companies like Larsen & Toubro and BHEL dominate large-scale projects due to their financial strength. For instance, L&T's involvement in the Cochin Refinery Expansion Project (Rs. 5,000 crores)

required substantial financial resources, making it difficult for smaller players to secure similar large-scale projects.

- **Competition from Established Players**: Large, well-established EPC companies dominate the market and are preferred by major oil and gas operators due to their proven expertise, financial stability, and capacity to handle large projects. Mid-sized EPC firms face fierce competition from these dominant players, making it hard to win significant contracts. TechnipFMC, Larsen & Toubro, and Saipem dominate major oil and gas infrastructure projects like the Reliance Jamnagar Refinery and ONGC's Krishna Godavari Basin. Smaller firms may find it difficult to compete in such large-scale project bids due to the strong brand presence and extensive resources of these established players.
- **Access to Skilled Labor and Experienced Workforce**: The oil and gas industry requires a highly skilled workforce, including engineers, technicians, and project managers with specific expertise in offshore drilling, pipeline construction, and refinery operations. Large EPC firms typically have access to a pool of trained professionals, while mid-sized companies may face difficulty recruiting and retaining such talent. Companies like Petrofac and Jacobs Engineering benefit from a global network of skilled personnel who can deploy for specialized tasks such as offshore platform construction or pipeline welding. Mid-sized EPCs may face challenges in sourcing experienced professionals, limiting their ability to deliver high-quality work on complex projects.
- **Limited Access to Major Contracts**: Large-scale projects in oil and gas, such as refineries, petrochemical plants, or offshore platforms, are typically awarded to the top-tier EPC contractors due to their proven track record and financial stability. Mid-sized EPCs find it challenging to gain access to these large contracts, especially in competitive bidding environments. Major oil and gas projects like the ONGC KG Basin Development or BPCL Kochi Refinery are awarded to large, experienced contractors. Smaller firms often miss out on these opportunities due to their inability to meet the scale and scope of such projects.
- **Cost Overruns, Scope Creep, and Disputes**: Mid-size EPC companies face significant challenges in managing cost overruns due to incomplete project scopes during the FEED stage, aggressive L1 bidding, and unexpected change orders during project execution. The involvement of multiple stakeholders increases the potential for disputes, making effective dispute resolution and securing long-term funding crucial for successful project delivery.
- **Changing Government Regulations and Policies**: The Indian oil and gas sector is heavily regulated by multiple agencies, including the Ministry of Petroleum and Natural Gas (MoPNG), Directorate General of Civil Aviation (DGCA), and various environmental bodies. Mid-sized EPC companies may struggle to navigate these complex regulations, obtain permits, and ensure compliance, especially in projects involving sensitive environmental concerns. The ONGC Mumbai High Field Redevelopment Project required strict adherence to environmental and regulatory guidelines, as well as approvals from multiple government agencies. Companies like L&T, with their extensive experience, have dedicated legal and compliance teams to manage such approvals, whereas smaller EPC firms may find this process cumbersome and time-consuming.

Significant Difficulties in Switching Vendors in Oil & Gas EPC Industry:

High Switching Cost of Changing Vendors

- The costs associated with switching vendors in the EPC industry can be substantial, involving not just financial resources but also significant time, effort, and administrative work. These costs may include re-negotiating contracts, setting up new logistics, retraining personnel, and even potential delays in project execution. This can be especially burdensome for large, complex projects.

  Example: If a vendor is responsible for supplying specialized equipment or materials, such as pipelines or compressors, switching to a new vendor may require re-sourcing or re-designing certain aspects of the project, resulting in delays and additional costs.

Long-Term Relationships and Trust

- Oil & gas projects typically involve long-term relationships between EPC contractors and vendors. Trust and reliability are built over years of collaboration, which can make switching vendors challenging. Vendors with an established track record are often preferred due to their familiarity with the specific requirements of the project. Switching to a new vendor may introduce risks related to the quality of work, timelines, and potential delays

Compatibility with Existing Systems and Processes

- Different vendors often use distinct methodologies, technologies, and systems for project execution. Compatibility issues can arise when trying to integrate a new vendor into an existing project, especially in terms of software, project management systems, or quality control processes. Mismatched systems and processes can lead to inefficiencies, errors, or delays. There may also be additional effort required for the new vendor to get up to speed with the existing systems in place, such as procurement or supply chain management.
- In a large oil refinery project, a vendor who is deeply integrated into the supply chain and project management system may be difficult to replace without creating disruptions in the workflow or complicating coordination across teams.

Contractual and Legal Challenges

- Switching vendors often involves complex legal and contractual issues, especially when long-term contracts are involved. These agreements typically include clauses related to penalties for early termination, exclusivity, and performance guarantees. Legal hurdles such as renegotiating terms, paying penalties, or resolving disputes can add significant complexity to switching vendors. Additionally, switching may lead to legal challenges if a vendor claims breach of contract or non-compliance