

Assessment of Biofuels market

TruAlt Bioenergy

Final Report

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1 Macroeconomic overview – Introduction to global & Indian economy

1.1 Review and outlook of Global GDP

Following a prolonged and unprecedented series of shocks, the global economy seems to have stabilized, albeit with steady yet underwhelming growth rates. However, the landscape has shifted as governments worldwide are reordering their policy priorities and uncertainties have surged to new heights.

The euro area's growth is anticipated to decline slightly to 0.8 percent in 2025, before moderately increasing to 1.2 percent in 2026. The key drivers of the subdued growth in 2025 are rising uncertainty and tariffs. Nevertheless, offsetting forces that support the modest pickup in 2026 include stronger consumption driven by rising real wages and a projected fiscal easing in Germany, following significant changes to its fiscal rule, known as the "debt brake." Within the region, Spain's momentum stands in contrast to the sluggish dynamics elsewhere, with a growth projection of 2.5 percent for 2025.

After a marked slowdown in 2024, growth in emerging and developing Asia is expected to decline further to 4.5 percent in 2025 and 4.6 percent in 2026. Emerging and developing Asia, particularly the Association of Southeast Asian Nations (ASEAN) countries, has been among the most affected by the April tariffs. For China, the expected GDP growth in 2025 is 4.0 percent, reflecting the impact of recently implemented tariffs, which offset the stronger carryover from 2024 and fiscal expansion in the budget. The growth in 2026 is also expected to be 4.0 percent, driven by prolonged trade policy uncertainty and the tariffs currently in place. In contrast, India's growth outlook is relatively more stable at 6.2 percent in 2025, supported by private consumption, particularly in rural areas, although there may be some uncertainty due to higher levels of trade tensions and global uncertainty.

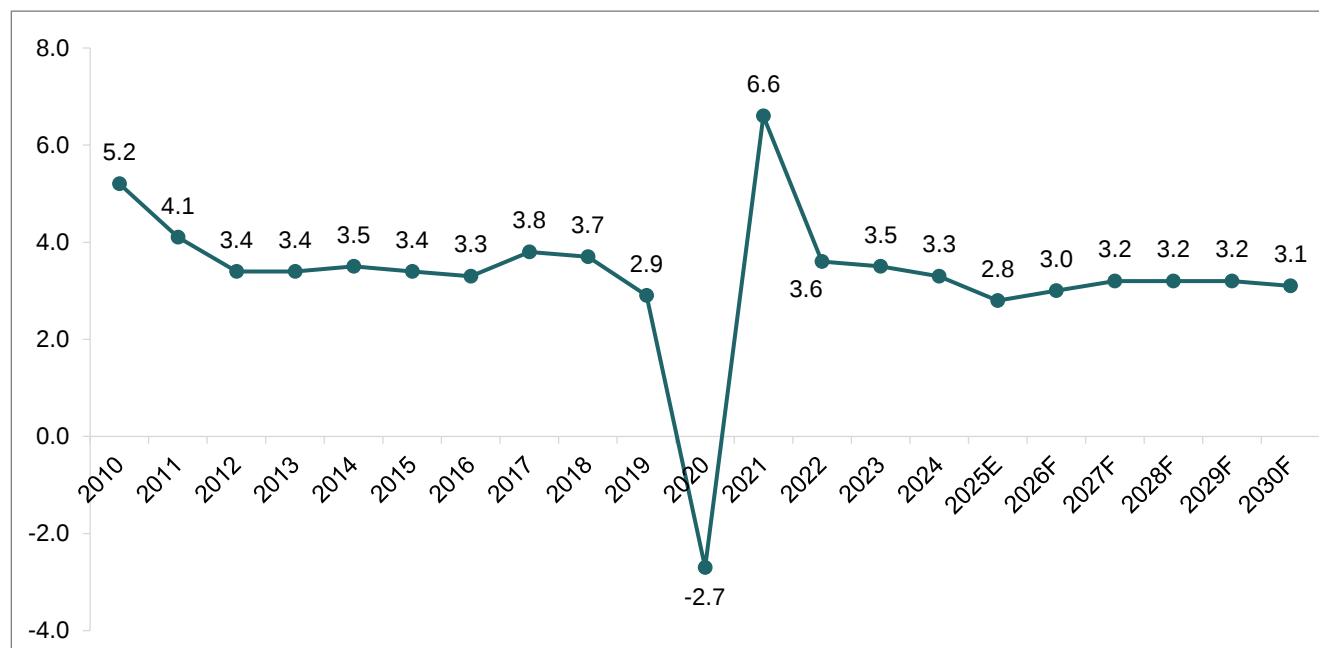
For Latin America and the Caribbean, growth is projected to moderate from 2.4 percent in 2024 to 2.0 percent in 2025, before rebounding to 2.4 percent in 2026. The forecasts are largely due to a significant downgrade to growth in Mexico, by 1.7 percentage points for 2025 and 0.6 percentage point for 2026, reflecting weaker-than-expected activity in late 2024 and early 2025, as well as the impact of tariffs imposed by the United States, associated uncertainty, and geopolitical tensions, and a tightening of financing conditions.

Growth in emerging and developing Europe is projected to slow down considerably, from 3.4 percent in 2024 to 2.1 percent in 2025 and 2026. This reflects a sharp drop in growth in Russia from 4.1 percent in 2024 to 1.5 percent in 2025 and to 0.9 percent in 2026, as private consumption and investment decelerate amid reduced tightness in the labor market and slower wage growth.

According to the International Monetary Fund, the global economy is expected to grow by 2.8 percent in 2025 due to increasing trade tensions, policy uncertainty, and the resulting negative economic impacts. Emerging economies and advanced countries are estimated to grow by 3.7 percent and 1.4 percent, respectively, in 2023. The trade conflict has led to increased uncertainty, which has weighed on business confidence, reduced investment, and disrupted global supply chains, thereby slowing economic activity worldwide. For Türkiye, growth is projected to bottom out in 2025 at 2.7 percent and accelerate to 3.2 percent in 2026, owing to recent pivots in monetary policy. The Middle East and Central Asia is projected to come out of several years of subdued growth, with the rate accelerating from an estimated 2.4 percent in 2024 to 3.0 percent in 2025 and to 3.5 percent in 2026, as the effects of disruptions to oil production and shipping dissipate and the impact of ongoing conflicts lessens.

The world continues to watch as geopolitical uncertainties create a challenging environment for growth, however, economies like India have continued to grow through the uncertainty with robust private demand and efficient navigation of policy and global relations through these unpredictable circumstances.

Figure 1: Real GDP Growth (%) 2010-2030F



Note: E-Estimated, F-Forecast

Source: International Monetary Fund (IMF) World Economic Outlook April 2025

1.2 Review and outlook of Global GDP in Key Economies

Table 1: Real GDP growth comparison among India vs Advanced and emerging economies

Year	World	India	United States	China	Europe	Japan	Advanced Economies	Emerging markets and developing economies
2010	5.2	8.5	2.7	10.6	2.5	4.1	3.1	7.2
2011	4.1	5.2	1.6	9.5	2.3	0.0	1.8	6.1
2012	3.4	5.5	2.3	7.8	0.3	1.4	1.2	5.3
2013	3.4	6.4	2.1	7.8	0.5	2.0	1.5	4.9
2014	3.5	7.4	2.5	7.5	1.6	0.3	2.1	4.7
2015	3.4	8	2.9	7.0	1.6	1.6	2.4	4.3
2016	3.3	8.3	1.8	6.8	1.7	0.8	1.8	4.4
2017	3.8	6.8	2.5	6.9	2.8	1.7	2.6	4.8
2018	3.7	6.5	3.0	6.8	2.3	0.6	2.3	4.7
2019	2.9	3.9	2.6	6.1	2.0	-0.4	1.9	3.7
2020	-2.7	-5.8	-2.2	2.3	-5.4	-4.2	-4.0	-1.7
2021	6.6	9.7	6.1	8.6	6.4	2.7	6.0	7.0
2022	3.6	7.6	2.5	3.1	2.4	0.9	2.9	4.1
2023	3.5	9.2	2.9	5.4	1.3	1.5	1.7	4.7
2024	3.3	6.5	2.8	5.0	1.7	0.1	1.8	4.3
2025E	2.8	6.2	1.8	4.0	1.3	0.6	1.4	3.7
2026F	3	6.3	1.7	4.0	1.5	0.6	1.5	3.9
2027F	3.2	6.5	2.0	4.2	1.6	0.6	1.7	4.2
2028F	3.2	6.5	2.1	4.1	1.6	0.6	1.7	4.1
2029F	3.2	6.5	2.1	3.7	1.5	0.5	1.7	4.1

Year	World	India	United States	China	Europe	Japan	Advanced Economies	Emerging markets and developing economies
2030F	3.1	6.5	2.1	3.4	1.5	0.5	1.7	4.0

Note: E: Estimated, F: Forecast

Source: International Monetary Fund (IMF) World Economic Outlook April 2025

United States

The real GDP growth has shown varied trends, reflecting fluctuations in economic activity. Pre-pandemic, growth remained steady between 1.8-3.0% from 2014 to 2019, reflecting mature economic expansion. The COVID-19 pandemic caused a sharp -2.2% contraction in 2020, followed by an exceptional 6.1% rebound in 2021 due to stimulus measures and economic reopening. The economy then normalized with 2.5%, 2.9% and 2.8% growth in 2022, 2023 and 2024 respectively, slightly above pre-pandemic averages.

Looking forward, the US economy is expected to grow by 1.8% in 2025 due to the uncertainty of the tariff imposed by US and other countries. The tariff policies have started impacting US consumers as major companies like Walmart, Mattel has announced price increase. Tariffs on Chinese goods and imported cars are pushing business to pass rising costs onto consumers. The new administration in the country has imposed a 10% baseline tariff on most imports and a 30% duty on Chinese goods, with some categories, such as steel and aluminium, facing even steeper rates. The tariffs are expected to impact the economic growth in 2026, real GDP is expected to grow by 1.7%. Over the longer term IMF expects the real GDP to stabilise at 2.1%.

Europe

Between 2014 and 2019, Europe experienced modest and stable growth, ranging from 1.6% to 2.8%, with the peak in 2017 reflecting post-Eurozone crisis recovery. In 2020, the region witnessed a sharp economic contraction of -5.4% due to the COVID-19 pandemic, which led to widespread lockdowns, supply chain disruptions, and reduced economic activity. This was followed by a strong rebound in 2021 with a growth rate of 6.4%, driven by vaccine rollouts, relaxation of restrictions, and stimulus measures. However, from 2022 to 2024, growth moderated to levels between 1.3% and 2.4%, reflecting lingering inflation, energy supply disruptions related to the Russia-Ukraine war, and the effects of monetary tightening.

Looking ahead, the period from 2025 to 2030 is expected to be marked by low but steady growth, ranging between 1.3% and 1.6%, as Europe grapples with several structural challenges. These include an aging population, subdued productivity growth, and tightening labour markets. The continent's green transition and decarbonization efforts, while vital for long-term sustainability, may create short-term fiscal pressures. Additionally, Europe's heavy reliance on exports makes it sensitive to global economic shifts, particularly in major markets like the US and China.

China

China's economy has undergone significant transformation since 2014, with growth gradually declining from 7.5% to 6.1% by 2019. The COVID-19 pandemic caused a sharp drop to 2.3% in 2020, though China uniquely maintained positive growth while other major economies contracted. A recovery to 8.6% in 2021 was followed by volatility, with growth falling to 3.1% in 2022 before rebounding to 5.4% in 2023. In 2024, the GDP grew by 5.0% driven by robust manufacturing and high export demand. In first quarter of 2025, the country's GDP outstripped expectation with growth of 5.4%, underpinned by solid consumption and industrial output, but economists suggests momentum could shift sharply lower as US tariffs pose the biggest risk to the country's economic growth. US has imposed 30% tariffs on Chinese goods, heightening the tension between two economies. On the other hand, China's real estate is facing challenges, the value of the housing sold dropped by a quarter and the average prices of these houses also has plunged.

China is currently confronting dual significant challenges: domestically, the continuing deterioration of its property market, while internationally, it navigates an exceptionally severe trade conflict with US.

Japan

Between 2014 and 2019, Japan experienced moderate and fluctuating growth, ranging from 0.3% in 2014 to a peak of 1.7% in 2017, followed by a decline to -0.4% in 2019. This period reflects the low-growth trend typical of a

mature economy. In 2020, the economy contracted sharply by -4.2% due to the COVID-19 pandemic, which caused disruptions in global trade, domestic demand, and tourism. A strong recovery followed in 2021 with growth reaching 2.7%, driven by government stimulus, export rebound, and improving consumption. However, growth slowed again to 0.9% in 2022 and modestly rebounded to 1.5% in 2023, indicating a partial but uneven recovery.

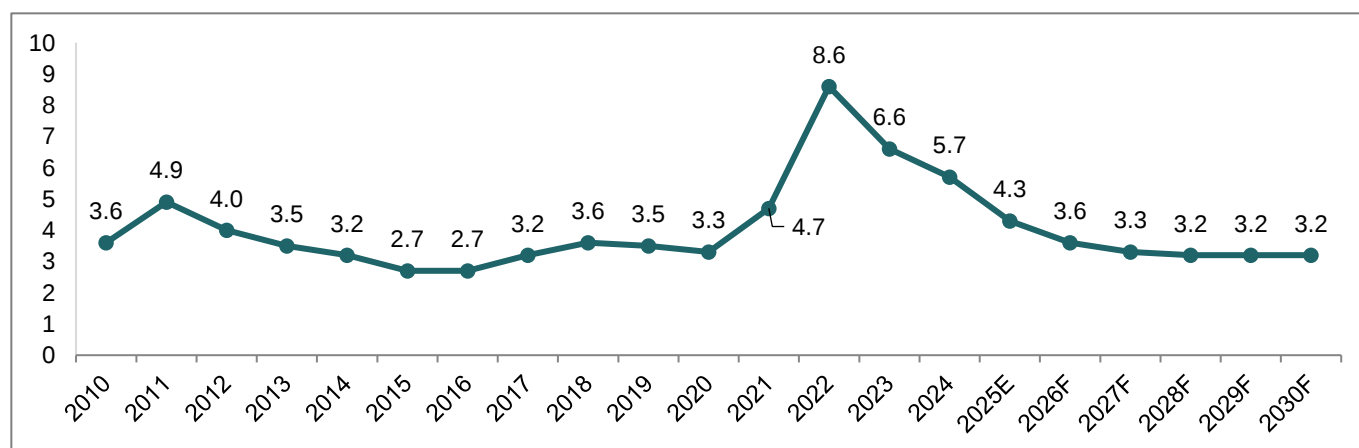
The growth rate is projected to stabilize at low levels from 2024 onward, with 0.1% growth in 2024 and consistent forecasts between 0.5% and 0.6% annually through 2030. This suggests that Japan faces long-term structural constraints on its economic potential. Demographics play a major role, as Japan's rapidly aging population and declining workforce suppress labour supply and domestic consumption. Persistent deflationary pressures and low inflation have further dampened consumer spending and investment. As an export-driven economy, Japan is also sensitive to global economic fluctuations, trade dynamics, and geopolitical tensions.

1.3 Global inflation overview

Global inflation declined steadily from 3.6% in 2010 to 2.7% in 2016 due to post-crisis recovery and accommodative policies. Between 2017 and 2020, it stabilized between 3.2% and 3.6%. However, it started increasing in 2021 and spiked sharply to 8.6% in 2022, driven by pandemic-related disruptions, supply chain issues, and geopolitical tensions, such as the Russia-Ukraine war, which significantly impacted energy and commodity prices. The inflation fall from 6.6% in 2023 to 5.7% in 2024 and is likely to reach 4.3% in 2025. The chemical industry has been heavily affected by inflation through rising raw material and transportation costs, disrupted supply chains, and weaker downstream demand, particularly in sectors like automotive and packaging.

The global economy continues to experience high rates of inflation and though inflation appears to be gradually declining in certain parts of the world, inflationary pressure and price uncertainty is expected to continue in 2024. In the 2025-2030 period, global headline inflation is forecast to average 3.5%.

Figure 2: Global Inflation Rate (Average Consumer Prices) (%) 2010-2030F



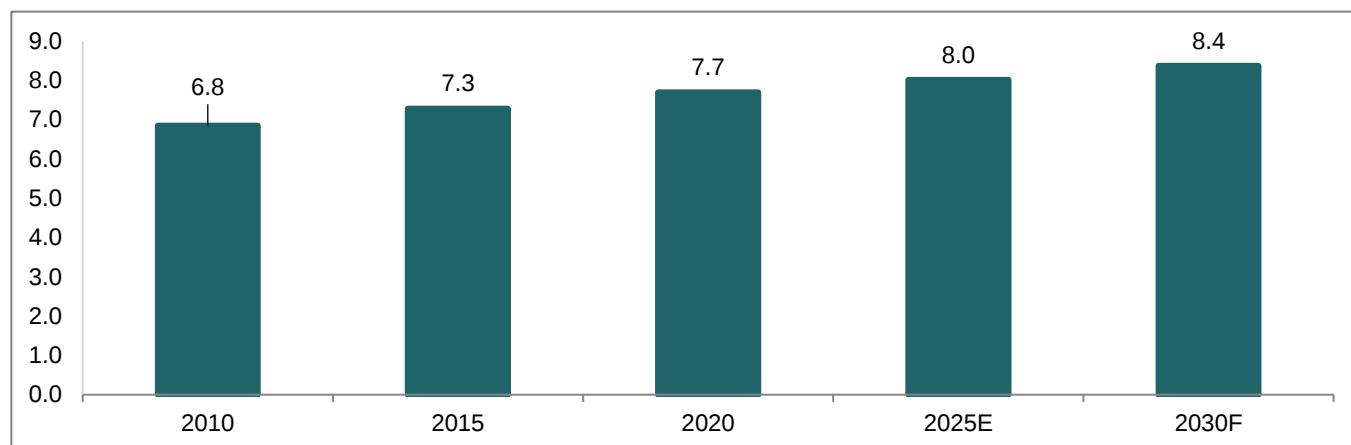
Note: E: Estimate, P: Projection

Source: International Monetary Fund (IMF) World Economic Outlook April 2025

1.4 India's GDP logged 5.7% CAGR during fiscal 2012-2023

The total population has more than doubled since the 1950s and is forecasted to surpass the 8.3 billion mark by 2030. Populous middle-income countries account for a considerable share of the growth in world population between 2010-25. Just five nations – China, India, Indonesia, Pakistan, and Nigeria – are expected to account for around 3.6 billion people in 2025. If the current trend continues, the majority of the next billion is destined to be born in low- and middle-income countries. However, the median age of the existing population in these nations – especially Nigeria, Pakistan, and India at an estimated 19.3 years, 22.9 years, and 29.8 years, respectively in 2024 underscore the massive demographic dividend potential. A young and cost-effective labour will drive the attractiveness of these nations as offshore manufacturing destinations.

Figure 3: World Population Estimates



Note: E-Estimated, F-Forecast

Source: International Monetary Fund (IMF) World Economic Outlook April 2025

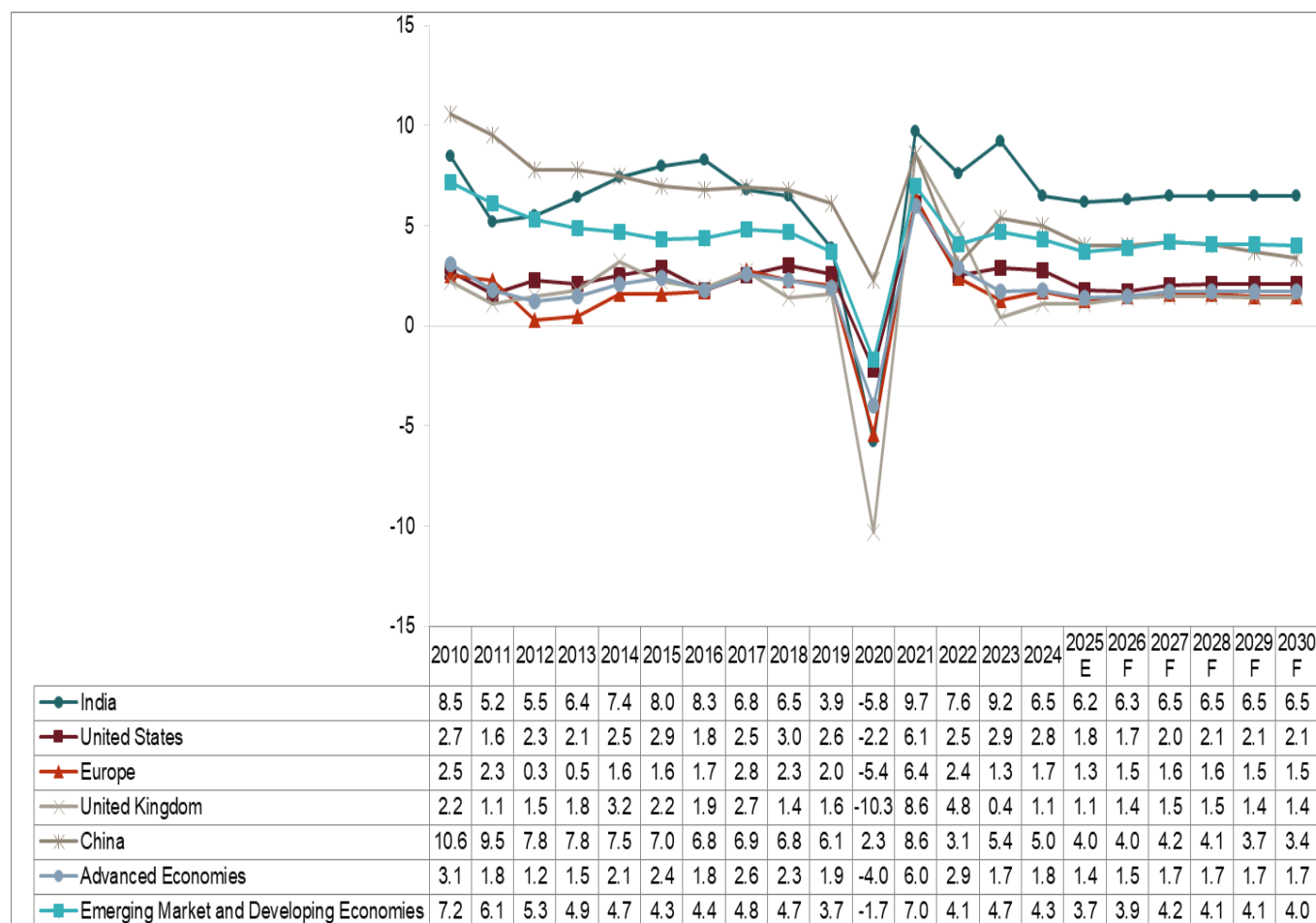
1.5 India Macroeconomic overview: GDP overview

The Indian economy posted a robust economic rebound of 9.7% in 2021, following the Covid-19 induced 5.8% GDP contraction in 2020. In response to the economic challenges posed by the COVID-19 pandemic, India implemented a series of comprehensive structural reforms aimed at revitalizing its manufacturing sector and enhancing its global competitiveness. The government's disinvestment strategy underwent a significant transformation, the new approach facilitated landmark privatizations such as Air India's acquisition by the Tata Group. The primary objectives behind this disinvestment push were to reduce the fiscal burden on government finances, improve operational efficiency through private sector management, and generate substantial resources for funding critical development programs. The Indian government as part of its proactive fiscal and monetary policies introduced several stimulus measures such as loan moratoriums, credit guarantees, and direct cash transfers to support businesses and households during the year. These measures helped sustain domestic consumption and mitigate the economic impact of the pandemic in 2021. Recovery within manufacturing as well as the services industry – particularly within segments such as information technology, healthcare, and e-commerce – provided further impetus.

GDP growth fell to 7.6% in 2022, mainly due to the Russia-Ukraine war and the resultant supply disruptions which led to a sharp increase in food and fuel prices. To curtail these high price pressures, the Reserve Bank of India (RBI) adopted a restrictive monetary policy – with the repo rate hiked to 6.25% by the end of 2022. This dampened consumer spending and business confidence during the year. As per IMF World Economic Outlook April 2025, GDP grew by 9.2% in 2023 considering strong domestic consumption and demand, public infrastructure investment and an upswing in household investments in real estate.

India's real GDP grew by 6.5% in 2024, a bright spot in an otherwise subdued global economic environment. The focus on infrastructural development, expanding manufacturing and services sectors, resilient credit growth and robust private consumption propelled economic momentum in 2024. However, in 2025 India's economic growth perform slightly weaker due to the uncertainty which could arise from shifts in US trade policy, which may further impact the global economic landscape. As per IMF, the real GDP is estimated to grow by 6.2% in 2025. Over the forecast period, the Indian economy is likely to grow by more than 6%. Consistent public expenditure on building and upgrading infrastructure and connectivity, boosting the scalability and uptake of the digital economy, strengthening domestic green energy generation capabilities, and undertaking economic policies that foster inclusive social development will be at the forefront of India's long-term economic vision.

Figure 4: Real GDP Growth Comparison (%) 2010-2029F



Note: E-Estimated, F: Forecast

Source: International Monetary Fund (IMF) World Economic Outlook April 2025

1.6 India Macroeconomic overview: India's inflation

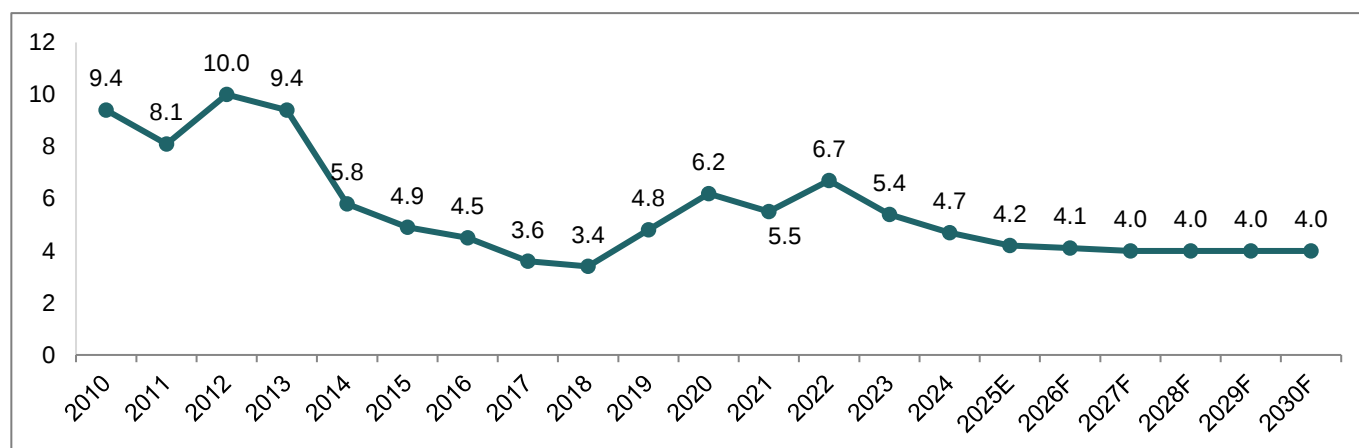
During the period from 2010 to 2013, inflation remained persistently high, ranging between 8.1% and 10.0%. This phase was driven primarily by supply-side constraints, high global crude oil prices, and elevated food inflation. From 2014 onward, inflation began to moderate, declining sharply to 5.8% in 2014 and eventually reaching a low of 3.4% in 2018. This period of moderation was the result of falling global oil prices, improved agricultural productivity, and tighter monetary policy measures implemented by the RBI.

However, the onset of the COVID-19 pandemic in 2020 disrupted this trend. Inflation rose to 6.2% due to supply chain bottlenecks and cost-push pressures, before dropping to 5.5% in 2021 as conditions began to stabilize. In 2022, inflation surged again to 6.7%, influenced by the Russia-Ukraine war, which led to a spike in global commodity and energy prices. The inflation rate began moderating again in 2023 and 2024, falling to 5.4% and 4.7% respectively, indicating a return to stability.

Food inflation has been taking a toll on the Indian economy since 2023, with several categories witnessing significant inflation. This includes oils and fats at +17.4% YOY, fruits at +13.8% YOY, personal care and effects at +12.9% YOY, cereals and products at +5.3% YOY, sugar and confectionary at 4.6% YOY, non-alcoholic beverages at 4.4% and housing at +3.0% YOY in April 2025.

Since May 2022, the RBI implemented a significant tightening cycle, raising the repo rate by a cumulative 250 basis points from 4.0% to 6.5% to counter post-pandemic inflationary pressures. This rate remained unchanged since February 2023, with the central bank maintaining a "withdrawal of accommodation" stance till January 2025. Currently, the central bank reduced the report rate by 25 bps to 6% for the second consecutive policy review, taking the cumulative cut by 50 bps in last two months. In the long run, India's annual inflation is forecast to average ~4.1%, well within the central bank's target range of $4.0 \pm 2\%$.

Figure 5: Inflation Rate in India, Average Consumer Prices



Note: E-Estimated, F-Forecast

Source: International Monetary Fund (IMF) World Economic Outlook April 2025

1.7 India's macroeconomic overview: India's population

India's population has grown by more than 1 billion since 1950. India's population stood at 1.24 billion in 2010 and has grown with a CAGR of 3.8% till 2024 to reach 1.44 billion. In 2022, India surpassed China to become the most populous country in the world. It is estimated that India's population will surpass 1.5 billion people by 2029 and will continue to slowly increase till early 2060s, when it will peak at 1.7 billion people.

As of 2022, people under the age of 25 accounted for more than 40% of India's population. Adults with age 65 and above comprise ~7% of India's population, compared with 14% in China and 18% in the US. As per United Nations projections, the share of Indians who are 65 and above is likely to remain under 20% until 2063 and will not approach 30% until 2100.

Table 2: Population (billions of people) 2010-2030F

Year	World	Advanced Economies	Emerging markets & developing economies	China	India
2010	6.85	1.03	5.81	1.34	1.24
2011	6.91	1.04	5.87	1.35	1.26
2012	7.01	1.04	5.97	1.36	1.27
2013	7.10	1.05	6.05	1.37	1.29
2014	7.19	1.05	6.14	1.38	1.31
2015	7.28	1.06	6.22	1.38	1.32
2016	7.37	1.07	6.30	1.39	1.34
2017	7.46	1.07	6.39	1.40	1.35
2018	7.54	1.07	6.46	1.41	1.37

Year	World	Advanced Economies	Emerging markets & developing economies	China	India
2019	7.62	1.08	6.54	1.41	1.38
2020	7.69	1.08	6.61	1.41	1.40
2021	7.76	1.08	6.68	1.41	1.41
2022	7.82	1.09	6.73	1.41	1.42
2023	7.90	1.10	6.80	1.41	1.43
2024	7.93	1.10	6.83	1.41	1.44
2025E	8.01	1.11	6.90	1.41	1.45
2026F	8.08	1.11	6.97	1.40	1.47
2027F	8.15	1.12	7.04	1.40	1.48
2028F	8.22	1.12	7.11	1.40	1.49
2029F	8.30	1.12	7.17	1.39	1.50
2030F	8.37	1.13	7.24	1.39	1.51

Note: E-Estimated, F-Forecast

Source: International Monetary Fund (IMF) World Economic Outlook April 2025

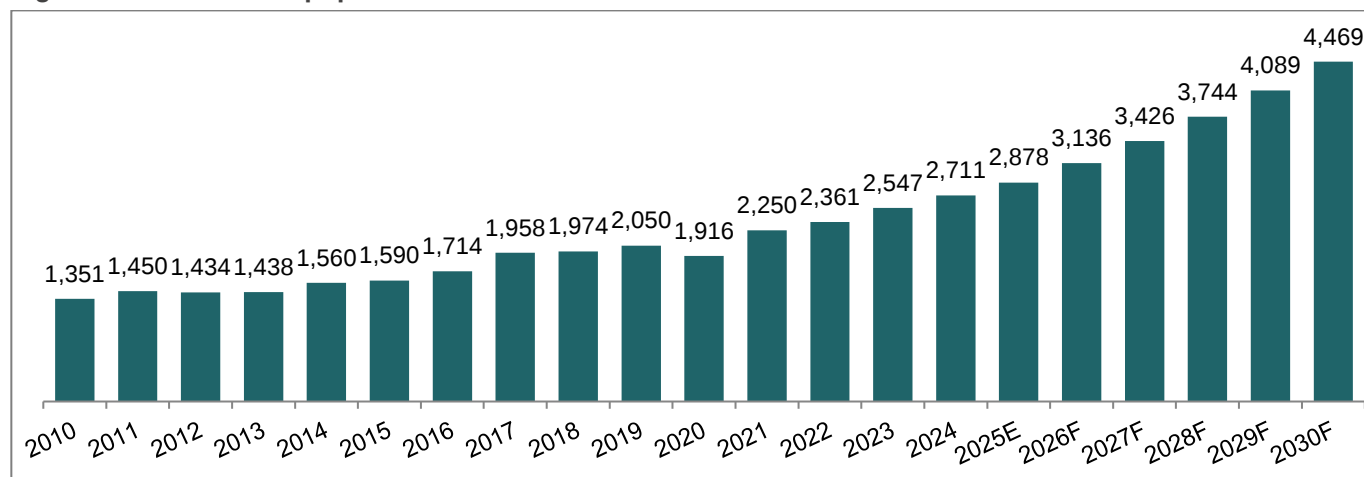
1.8 India's macroeconomic overview: GDP per capita at current prices and its growth

India's GDP Per Capita (at current prices) is likely to reach ~USD 4.47 thousand by 2030, growing at a CAGR of 9.2% between 2025 and 2030. This boost in per capita GDP levels will play a crucial role in propelling India's vision to become a USD 5 trillion economy by 2030. The IMF expects India's GDP to reach ~USD 6.77 trillion which represents a growth of 10.07% CAGR between 2025-2030. This upward trend in per capita GDP levels will be supported by domestic structural reforms, fiscal prudence, monetary policy stability, reduced input costs, falling price pressures, political stability, and rapid urbanization.

Expansion of capacity utilisation and productivity across critical sectors such as manufacturing, transport, infrastructure, construction, chemicals, telecom, and financial services will lead to a sustained growth in GDP per capita levels, with positive spillovers being witnessed in India's economic growth.

Increased infrastructural investment inflows, an accelerating green transition, strengthening energy and commodity supply chains, and building multi-industry economies of scale for the digital economy will boost competitiveness, enhance efficiency, and create new job opportunities, thus promoting India's transition to an upper-income country over the coming decade. However, geopolitical tensions, extreme climate events, and international financial sector volatility can present short-term to medium-term challenges to this growth outlook.

Figure 6: India's urban population versus rural



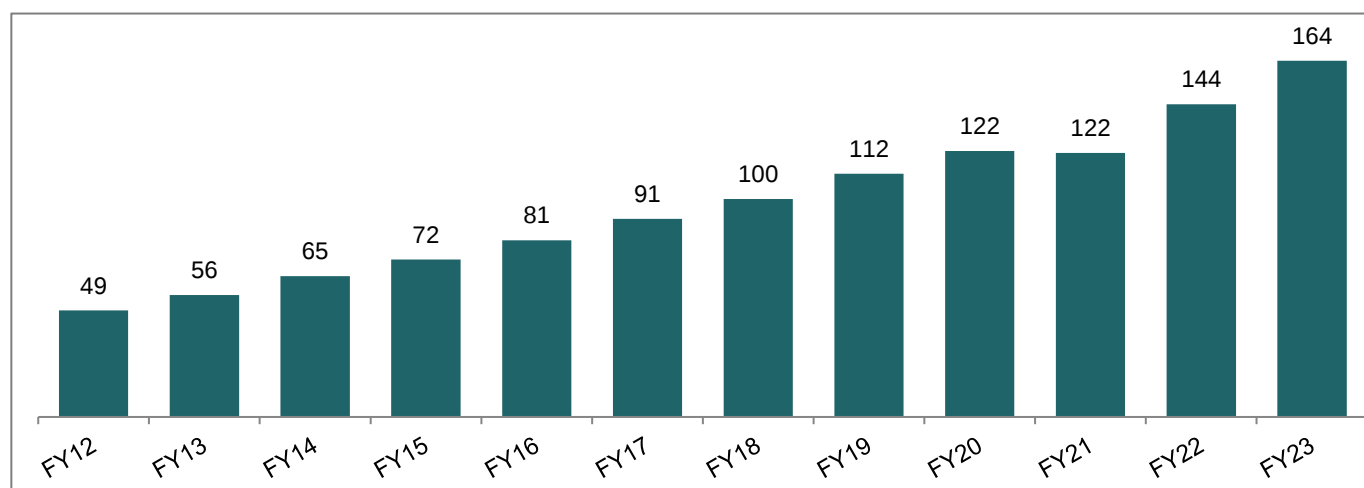
Note: F-Forecast

Source: International Monetary Fund (IMF) World Economic Outlook April 2025

1.9 India's macroeconomic overview: PFCE (% of GDP) and growth

Private Final Consumption Expenditure (PFCE) has remained an important factor in insulating the Indian economy, contributing to over 60.0% of the country's GDP. PFCE picked up steam after a brief plunge in 2020 due to the pandemic. In FY2022-23, PFCE witnessed growth of 13.9% compared to the previous year. A pattern has been emerging in India's demand recovery thus far, by which demand growth for mid-premium products has been stronger, while that for budget and entry-level products has been weaker. Looking at automotive sales, for example, sales for entry-level cars saw some challenges in 2023, while luxury car sales growth was strong.

Figure 7: Private Final Consumption (INR 000'Bn) and Growth, %, India, FY12 to FY23



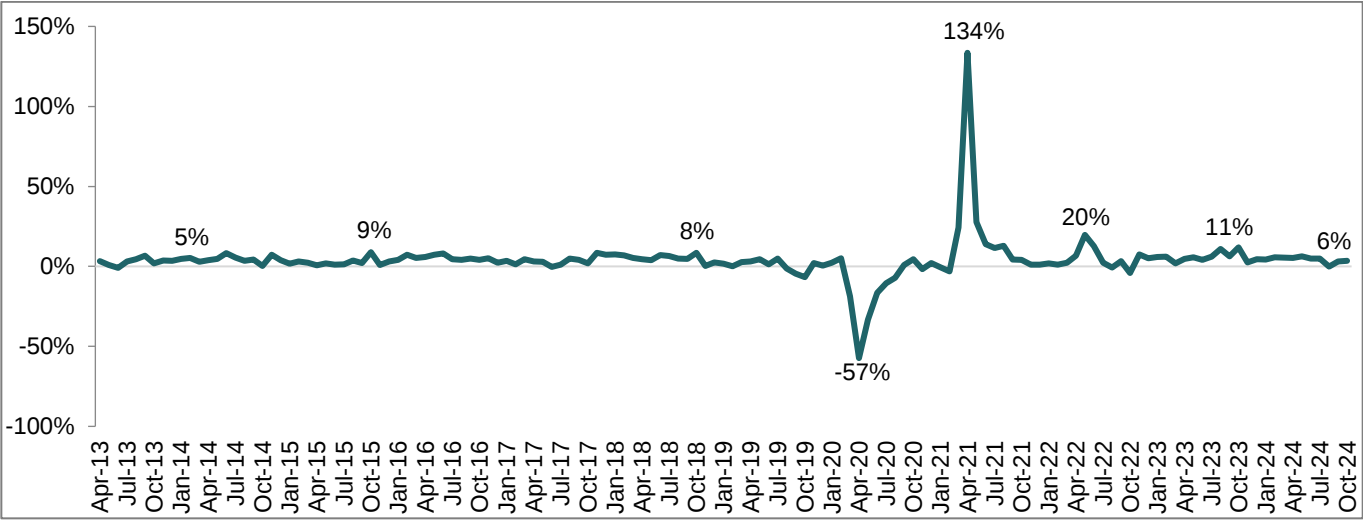
Source: MOSPI

1.10 India's macroeconomic overview: Index of Industrial Production IIP & its growth

Robust growth in the manufacturing, mining, as well as the electricity sectors helped overall industrial activity expand by 3.5% year-on-year (YoY) in October 2024. The IIP growth rates for electricity, mining, and manufacturing stood at 2.0%, 0.9%, and 4.1%, respectively, over the same period. Infrastructure/capital goods IIP, as per the use-based

classification¹, posted the largest growth at 9.7% in 2023-24 compared to the previous fiscal, followed by capital goods and the primary goods categories at 6.3% and 6.1%, respectively. In October 2024, the highest IIP year-on-year growth was posted by consumer durables and infrastructure/capital goods at 5.9% and 4.0%, respectively, whereas intermediate and consumer non-durable goods' IIP growth stood at 3.7% and 2.7%, respectively.²

Figure 8: IIP Growth (%)



Source: MOSPI

¹ 6 Use-based categories have been defined: Primary Goods, Capital Goods, Infrastructure/ Construction Goods, Intermediate Goods, Consumer Durables, Consumer Non-durables. Full definitions on page 4 of [IIP FAQ](#)

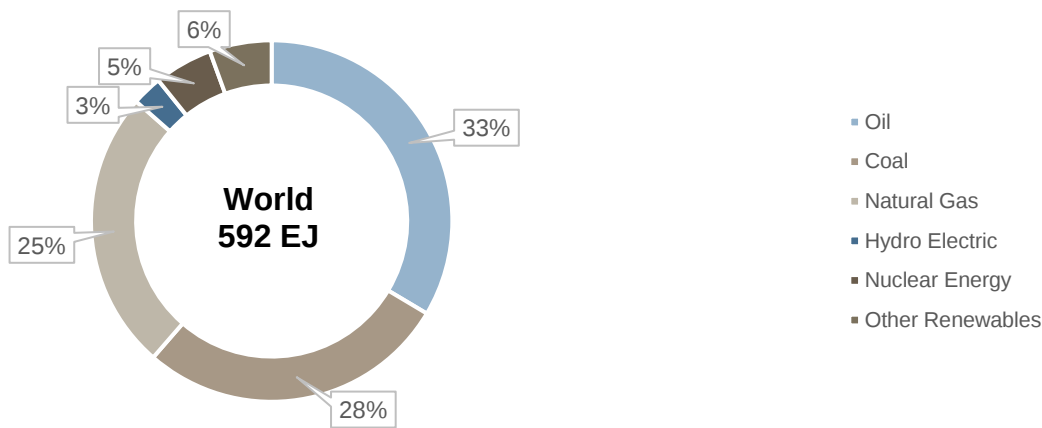
² MOSPI

2 Overview of the broader energy market in the world and in India

2.1 The evolving energy landscape of the world

As per the Statistical Review of World Energy 2025 Report, global energy demand increased 2% in 2024 with non-OECD countries dominating both the share of absolute demand and annual growth rates. Fossil fuels continue to underpin the energy system accounting for 86% of the energy mix.

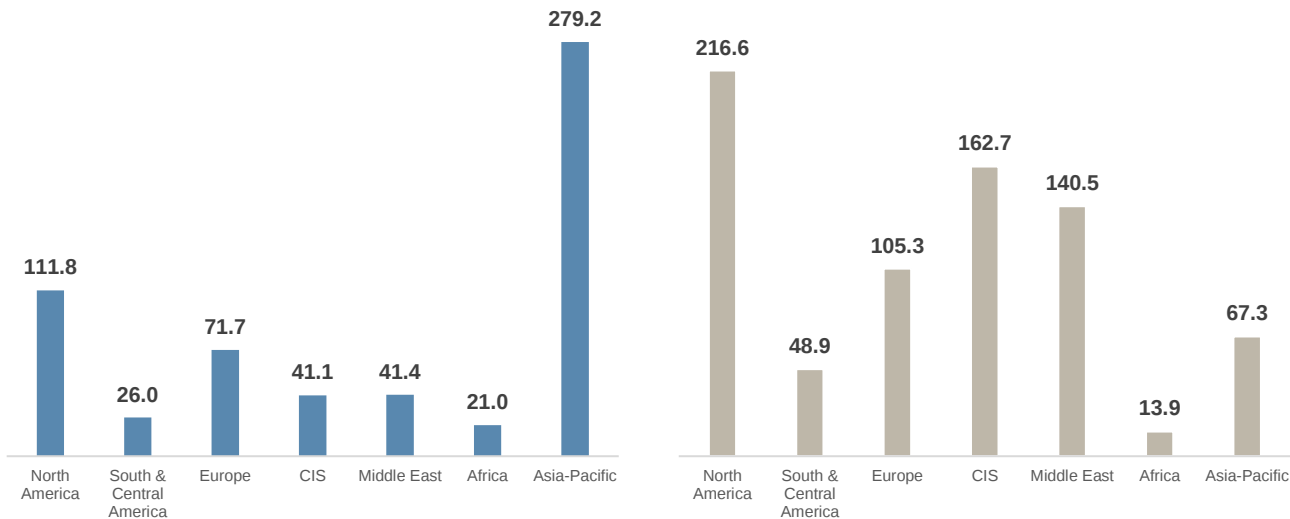
Figure 9: World overview of energy consumption, 2024



Source: Statistical Review of World Energy 2025

Total energy demand increased across all regions, but the growth was far from evenly distributed, reflecting stark regional variations shaped by economic development, climate conditions, and energy policy. North America and Europe exhibited the slowest growth rates at 0.4% and 0.7%, respectively. However, in absolute terms, Africa had the smallest increase in energy demand, at 0.2 EJ its increase in demand was less than half of Europe's increased energy demand (0.5 EJ). The Asia Pacific region drove 68% of the total global energy demand increase and was responsible for 47% of total global energy demand. Total renewable energy demand increased by 7%, of which China alone was responsible for more than the rest of the world combined (at 56%).

Figure 10: Region overview – Total energy supply (EJ) & total energy supply per capita (GJ/ capita), 2024



Source: Statistical Review of World Energy 2025

In terms of absolute primary energy consumption, the world consumed ~592 EJ in 2024. The Asia-Pacific region had the largest share of ~47% followed by North America with ~19%. This, however, does not reflect the true picture as the consumption levels seen in the Asia-Pacific region are primarily driven by higher population numbers and faster economic growth. When one looks at the primary energy consumption levels per capita, one can see developed regions having a much higher per capita number as compared to developing regions. The world average per capita energy consumption stood at ~73 GJ/ capita. As is expected, the growth in per capita is much higher in developing regions as compared to the developed ones. This is especially true for the Asia-Pacific region which with the presence of rapidly growing economies like China and India saw the most robust growth making them key developing markets on which the success of the sustainability efforts will be hinged.

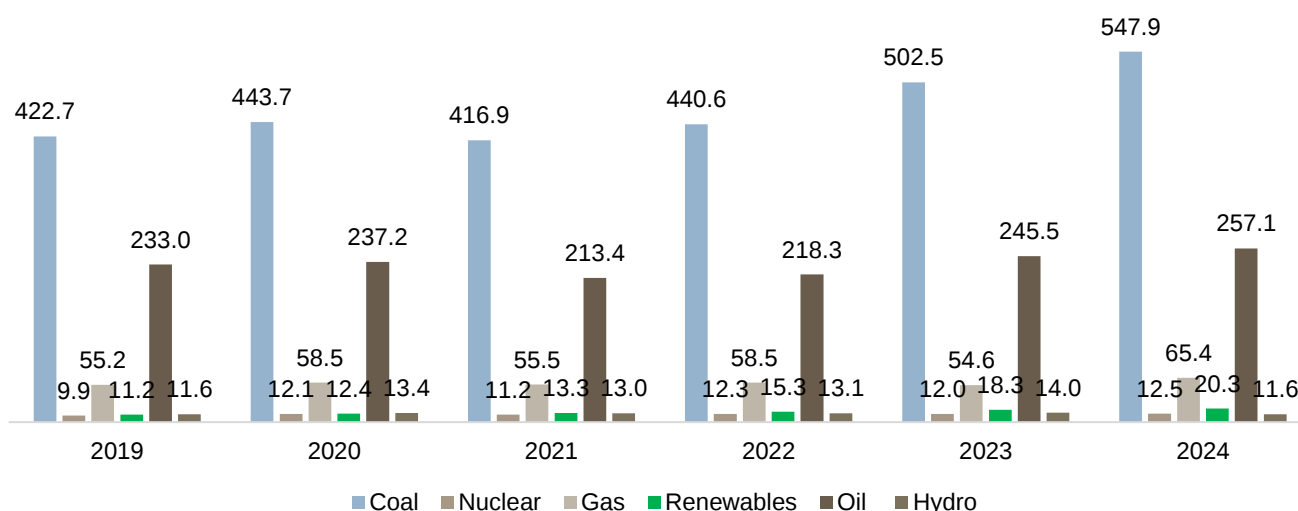
2.2 The evolving energy landscape of India

Energy demand in India is growing rapidly with major implications for the global energy market. The Government of India has made remarkable progress in providing access to electricity and clean cooking while implementing a range of energy market reforms and integrating a high share of renewable energy sources into the grid. India, with a population of ~1.4 billion and a fast-growing economy, has seen its energy demand increasing rapidly as the country continues to urbanize and the manufacturing sector develops. While developing clean sources of energy is a major challenge, the Government of India is continuing to focus on providing secure, affordable, and sustainable energy, while achieving its ambitious renewable energy targets and reducing local air pollution.

Energy is the mainstay of socio-economic growth and development for a nation like India which is currently the third largest primary energy consumer while its per capita energy consumption is only a third of the global average. As per various projections India's Energy demand is expected to grow 2.7% till 2050 as compared to the world's 0.6%. India constitutes 6% of the global primary energy wherein it constitutes 9.4% of global oil demand and 2.2% of the global gas demand. This provides a scope and opportunity for increasing energy consumption by India near future and it being the central driving force in the global energy narrative.

According to Energy Statistics India 2025, India's Energy mix has been seeing a shift from more conventional resources of energy to renewable sources. The financial year 2023-24 has witnessed a growth of 14.77% over last year in the installed capacity of Renewable Energy Sources. As per insights from Energy Outlook 2024 of BP, India's primary energy is expected to grow strongly, nearly doubling between 2022-2050. As a result of this strong growth, India is likely to account for around 13% of the global primary energy consumption in 2050 up from a little over 7% in 2022. Given the role India is expected to play in the global energy market, decarbonizing its energy basket must become a central focus on India's energy policy. Conventional and polluting fuels like coal and oil made up ~89% of the energy consumption in 2023-24 in India and while the situation has been improving there still is a significant distance to cover in order to reach the sustainability targets set by the government.

Figure 11: Source-wise Primary Energy Supply, India (in Mtoe)

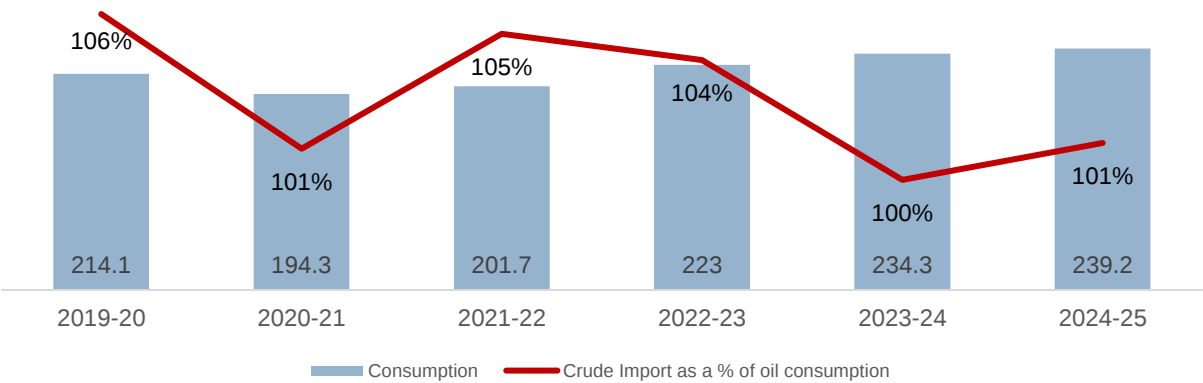


Source: India Climate & Energy Dashboard

The shifting and growing energy landscape represents an ideal opportunity for entities operating in the clean energy sector, especially, the ones operating in the bioenergies sector. The sector has the ability to tackle two birds with one stone, it can not only enhance India’s energy independence by reducing reliance on energy imports but can also help India achieve its sustainability targets. That is precisely why sectors like biofuels (ethanol, biodiesel, and sustainable aviation fuel) and compressed biogas (CBG) have garnered attention from the government, public sector, and private sector entities alike in the past decade or so.

This is especially true for India’s consumption of crude oil, in FY2025, India’s oil consumption surged to approximately 239 million metric tons (MMT). The Indian oil market is predominantly influenced by imports, which account for about 86-88% of the nation’s total oil demand for the past 10 years.

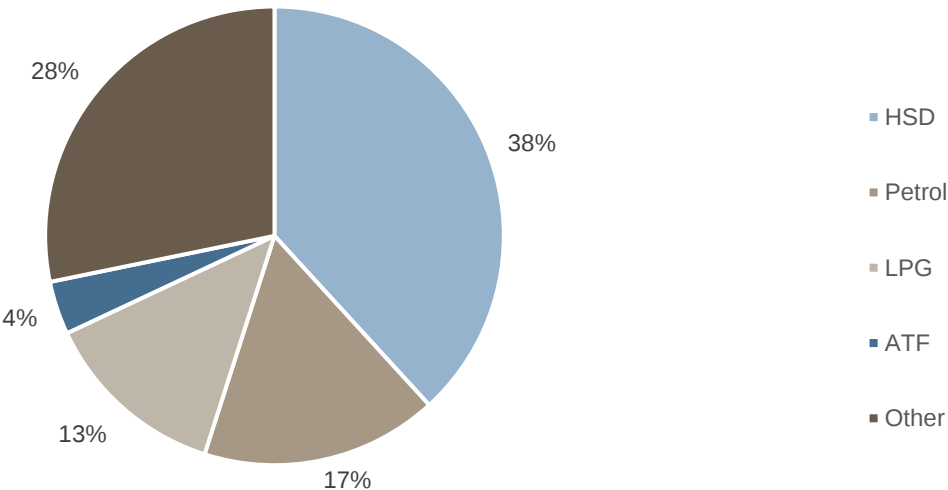
Figure 12: Oil consumption trend 2019-20 – 2024-25 (in MMT)



Source: PPAC

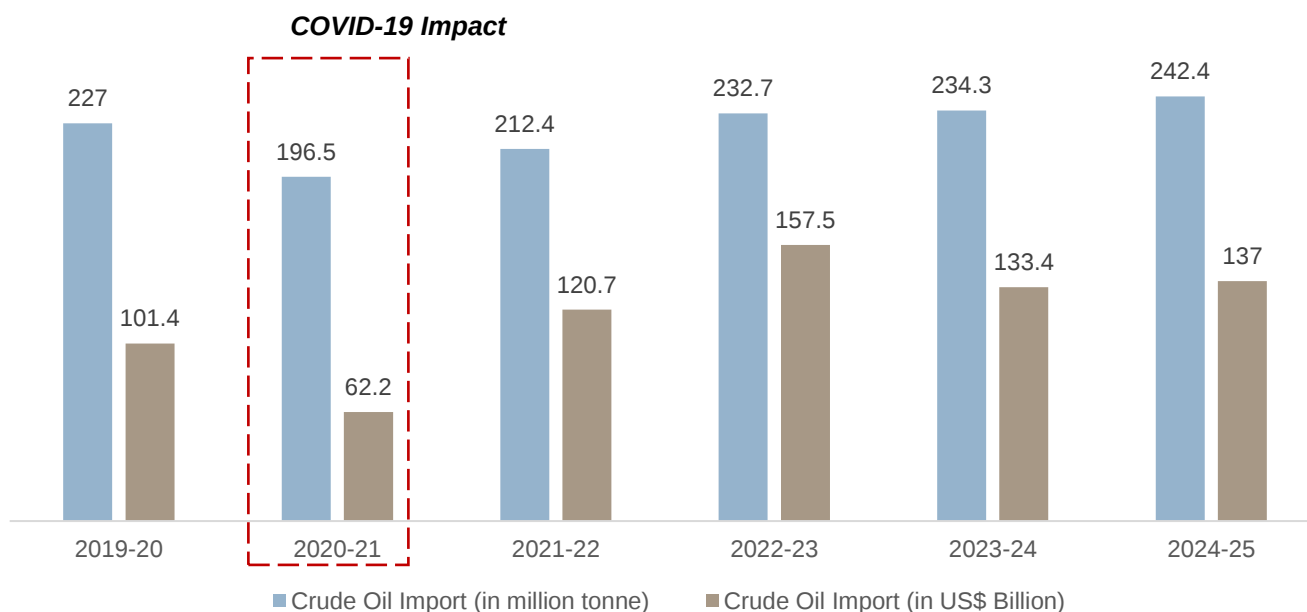
The majority of the oil consumption is encumbered in high-speed diesel oil (HSD), petrol and LPG. Petrol accounts for ~17% of the total petroleum product consumption. Furthermore, India’s petroleum product production grew by ~3% in FY2025 compared to previous year, reaching a total volume of 284.1 million tonne in FY2025 from to 276.1 million tonne in FY2024. This growth was led through an increase in petrol consumption and in the consumption of high-speed diesel. Robust economic growth, increased industrialization, urbanization, and infrastructure development, along with rising vehicle sales, contributed to the overall higher demand for transportation, energy, and fuel, thereby driving up the consumption of petroleum products.

Figure 13: Petroleum products consumption for FY2025



Source: PPAC

Figure 14: Crude oil imports, India (2019-20 to 2024-25)



Source: Petroleum Planning and Analysis Cell

Another major benefit that emanates from the push towards clean energies is the reduction in India's energy import bill, more specifically, the cash outflow dedicated towards crude oil which has risen at a rapid pace as India progresses, and its per capita energy requirements rise. The amount of crude oil India imports has risen consistently in the past 5 years barring 2020-21 on account of the COVID-19 pandemic.

The push that came for fuels like ethanol and biodiesel is rooted in this need to reduce dependence on oil imports. It not only enables India to become more resilient to geopolitical shocks but also ensures that funds that would have potentially left India's ecosystem, now stay within the country and are utilized to boost farmer incomes, create jobs, and take the fight for sustainable growth forward.

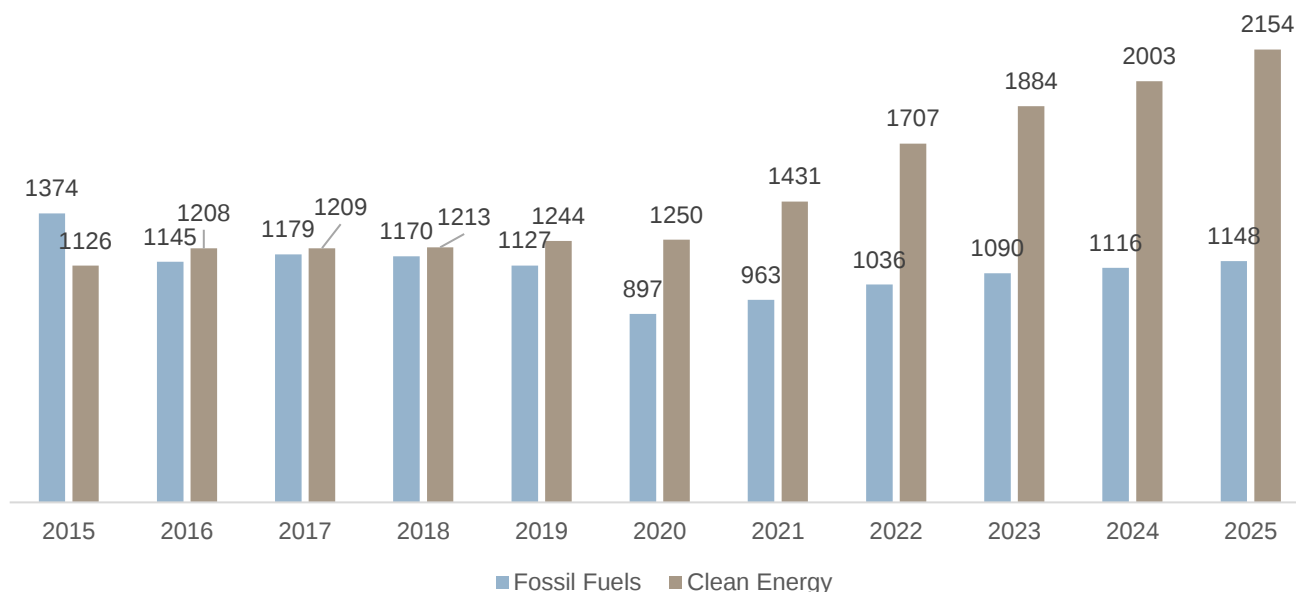
Bioenergies align seamlessly with the Government's vision for India's future energy sector, which is built upon four key pillars:

1. Energy access
2. Energy efficiency
3. Energy sustainability
4. Energy security

2.3 The evolving landscape of energy investing

As the world takes cognizance of the need to reduce its collective carbon footprint, the same gets reflected in the way it is investing into the future of energy. Despite geopolitical headwinds, global energy investments exceeded USD 3 trillion for the first time in 2024 and are set to rise by 2% to reach USD 3.3 trillion in 2025, with over USD 2.1 trillion going to clean energy technologies and infrastructure. Investment in clean energy has accelerated since 2020, and spending on renewable power, grids and storage is now higher than total spending on oil, gas, and coal.

Figure 15: Global investment in clean energy and fossil fuels, 2015-2025 (in US\$ Billion)



Source: World Energy Investment 2025

Note: Clean energy includes investments in renewable power, grids and storage, energy efficiency and end-use, nuclear and other clean power, and low emissions fuels

These trends can be seen the world over, the annual World Energy Investment report of IEA warned of energy investment flow imbalances, particularly insufficient clean energy investments in EMDE outside China who received USD 627 billion of clean energy investing. However, now there are tentative signs of a pick-up in these investments: clean energy investments in other EMDE are set to approach USD 300 billion in 2025, while India is set to receive USD 100 billion. Advanced economies like EU, USA, and other advanced economies are set to receive USD 386 billion, USD 400 billion, and USD 175 billion respectively in clean energy investing.

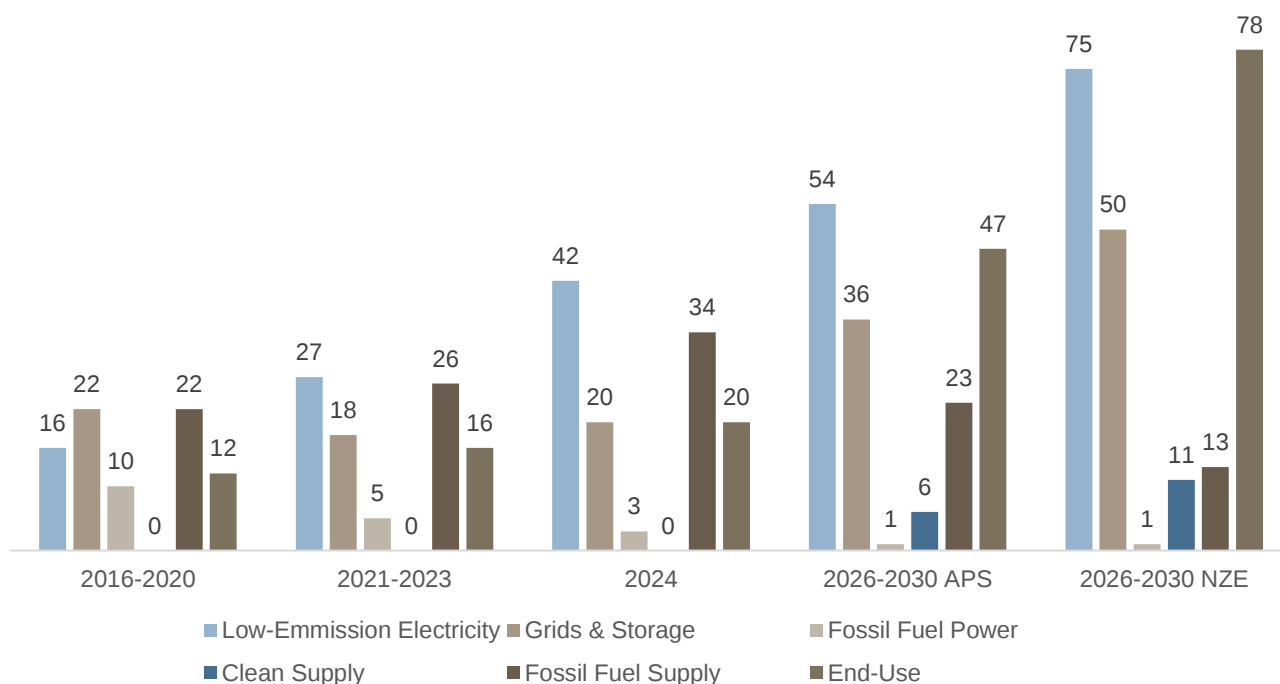
Reiterating India's situation with its GDP growth potential, urbanisation, growth in built spaces, and the increased demand for electricity as well as materials such as cement and steel, energy demand growth in India is on track to outpace all other regions of the world by 2050. This could put strains on its energy system, which for the moment relies heavily on imported fossil fuels, especially crude oil, and natural gas. In tandem with this sharp rise in energy demand, carbon emissions in India could increase significantly over this period due to a growth in fossil fuel use for transport, power generation and industry.

The Government of India has addressed these concerns and has articulated the same and put across the concerns of developing countries at the 26th session of the Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change (UNFCCC) held in Glasgow, United Kingdom. Further, India presented the following five nectar elements (Panchamrit) of India's climate action:

1. Reach 500GW non-fossil energy capacity by 2030.
2. 50 per cent of its energy requirements from renewable energy by 2030.
3. Reduction of total projected carbon emissions by one billion tonnes from now to 2030.
4. Reduction of the carbon intensity of the economy by 45 per cent by 2030, over 2005 levels.
5. Achieving the target of net zero emissions by 2070.

These goals are ambitious but have set the tone for how India invests into its future. The trend that has been seen at a global level is also being observed in the way investments are flowing into India and within the Indian markets itself.

Figure 16: Past and future energy investment in India in the Announced Pledges Scenario (APS) and the Net Zero Emissions (NZE) by 2050 Scenario, 2016-2030



Source: World Energy Investment 2024

India made its debut in the sovereign green bond market in January 2023. Two tranches of bonds valued at USD 1 billion (INR 80 billion) were marketed primarily to local investors. The issue of bonds – whose proceeds were destined to support renewables, metro rail lines, and low-carbon hydrogen production – was more than four times oversubscribed. Such initiatives have led to a surge in India's clean energy investment in recent years. Spending reached USD 68 billion in 2023, up by nearly 40% from the 2016-2020 average. Clean energy investment is on track to double by 2030 under today's policy settings but would need to rise by a further 20% to get fully on track for the country's energy and climate goals. Addressing risks that push up the cost of capital will be critical in this endeavour.

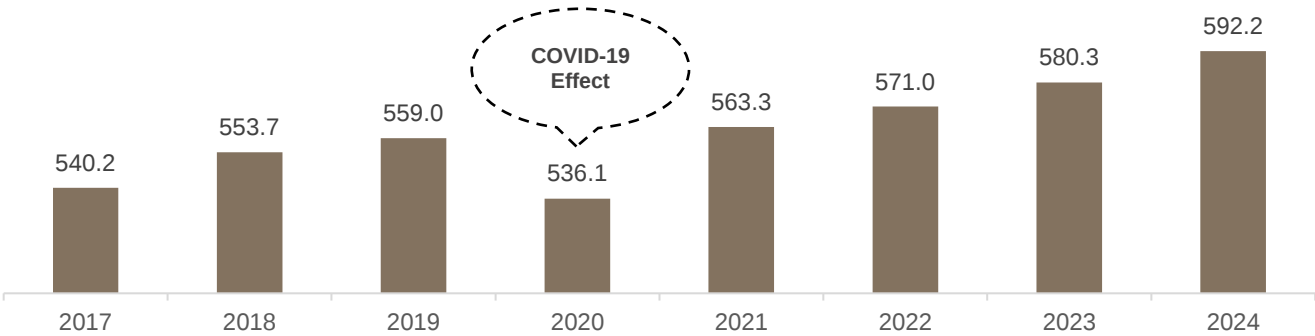
These numbers point clearly towards a growing market for clean energy investment around the globe, the same is true of the Indian investment landscape as far as energy sector is concerned. This augurs well for clean energy sectors in India which have the support of the Government to bolster investor confidence in the market. Sector like biofuels (ethanol, biodiesel, CBG, sustainable aviation fuel, etc.) are likely to benefit from this shift in addition to other sectors like solar power, wind power, etc. The market conditions are developing in line with sustainability initiatives which favour such sectors over conventional fossil fuel-based energies.

3 Global biofuel market overview

3.1 Global fuel industry overview

The global fuel industry is a critical component of the world economy, dominated by fossil fuels such as oil, coal, and natural gas. These resources continue to supply most of the world's energy needs, powering transportation, industries, and households. However, there has been a growing push for renewable and sustainable alternatives given climate change and environmental degradation.

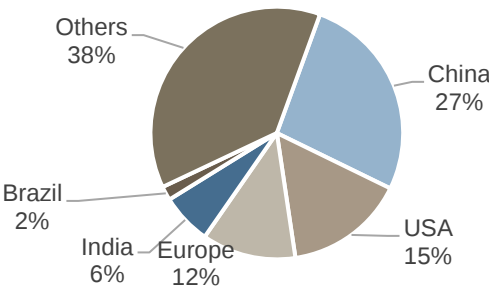
Figure 17: Global primary energy supply trends (Exajoules)



Source: Statistical Review of World Energy 2025

EIA expects global energy demand to increase 47% in the next 30 years (2050), driven by population and economic growth, particularly in developing Asian countries. However, the structure of energy demand is expected to change, with the importance of fossil fuels declining, replaced by a growing share of renewable energy and by increasing electrification. The transition to a low-carbon world requires a range of other energy sources and technologies, including low-carbon hydrogen, modern bioenergy, and carbon capture, use and storage.

Figure 18: Global energy supply (2024)



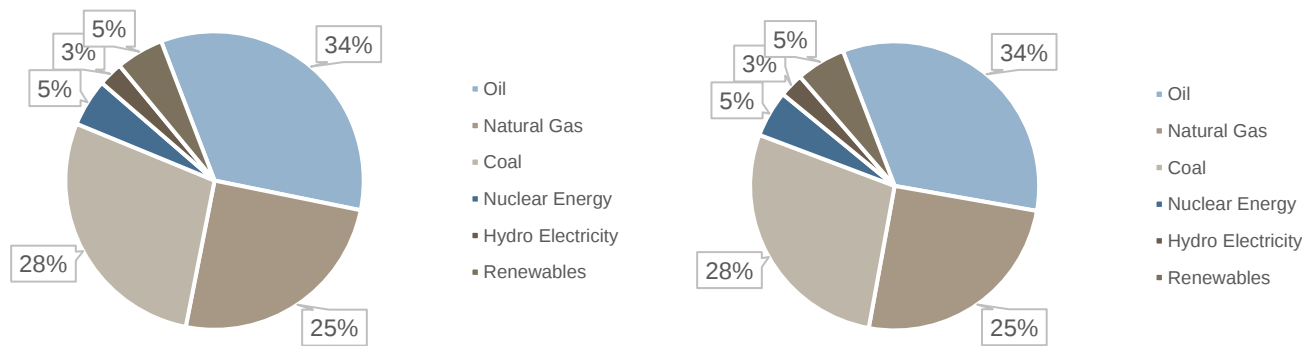
Source: Statistical Review of World Energy 2025

As per Statistical Review of World Energy 2025, total energy supply increased by 2.7% in China while it increased by just 0.7% in the USA. Strong economic growth pulled up energy supply in India by 4.6%, Singapore by 6.5%, Vietnam by 7.5%, and in United Arab Emirates by 6.4% during 2024. It also increased by around 2% in the Middle East and increased by about 1.4% in Africa. Primary energy supply increased in Europe as the region gets used to its new reality after Russia's invasion of Ukraine and surging energy prices.

India currently accounts for approximately 6.5% of primary energy supply, and this share is projected to report a CAGR 9.8% by 2050 according to current policy scenarios. To address this increasing demand for hydrocarbon fuels, India has implemented several key strategies. These strategies encompass attracting investments in Exploration & Production to boost domestic oil and gas production, transitioning towards a gas-based economy, adopting technological advancements to enhance refinery processes, improving energy efficiency and productivity, promoting

the biofuel sector, expanding its international oil and gas portfolio, and diversifying sources of oil and gas supply. Additionally, the government is actively involved in the development of a National Gas Grid and City Gas Distribution Networks to cover major demand centers across the nation, ensuring the provision of cleaner and more environmentally friendly fuels to the public.

Figure 19: Global energy supply by fuel, 2023 & 2024 respectively



Source: Statistical Review of World Energy 2025

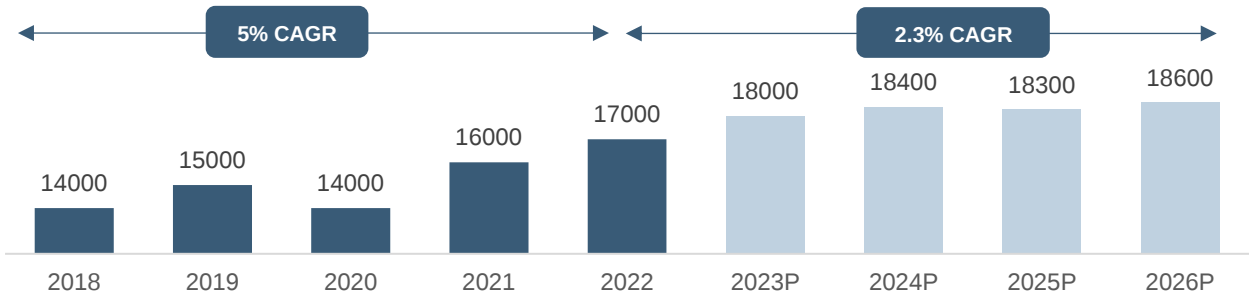
The primary source satisfying a significant portion of global energy demand is crude oil or petroleum, followed closely by coal as the second major energy contributor. Renewables, in contrast, constitutes a relatively modest 5% share within the overall energy consumption mix at present although their contribution in the energy mix is on the rise.

3.2 The global biofuel industry overview

The term biofuels refer to liquid fuels and blending components produced from biomass materials called feedstocks. These fuels are primarily used as transportation fuels but may also be used for heating and electricity generation. Furthermore, terminology for what constitutes as a “biofuel” differs from government to government and country to country, however, some of the major fuels accepted as biofuels around the world include – ethanol, renewable diesel/biodiesel, and other biofuels (including SAF and CBG, etc.). According to IEA, Brazil, India and the United States have deployed policies which sustained annual growth rates above 20% over at least a 5-year period. This section will provide a brief overview the global market of biofuels.

3.2.1 The global biofuel demand overview and outlook

Figure 20: Biofuel demand historical trend and projections 2018-2026 (in crore litre)



Source: OECD-FAO agricultural outlook 2023-2032

P: Projected

As per an IEA study, the annual global demand for biofuels is expected to grow by 2.3% during 2022-2026, reaching a total of 18,600 crore litre. USA leads the volume increase, however, much of the growth is a rebound

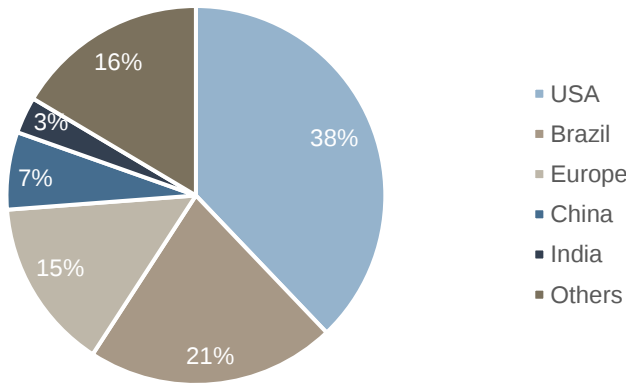
after the pandemic drop. Asia accounts for almost 30% of new production over the forecast period, overtaking European biofuel production by 2026, due to the strong domestic policies, growing liquid fuel demand and export-driven production in the South Asian countries.

India is expected to contribute much to the growing biofuel production in Asia due to its recent ethanol policies and blending targets, potentially making it the third largest market for ethanol by 2026. Apart from India, production in Indonesia and Malaysia is also expected to boom and aid in the total demand.

3.2.2 The global biofuel market by country

According to the latest report (2024) on Statistical Review of World Energy by energy institute, Global biofuels production grew by over 8% in 2023 with the biggest increases seen in the US and Brazil. Indonesia was responsible for around 46% of Asia Pacific region's production. The production split in 2023 was 54% bio gasoline and 46% biodiesel. The US, Brazil and Europe was responsible for around three quarters of all biofuels consumed globally.

Figure 21: Global biofuel consumption by country in 2022

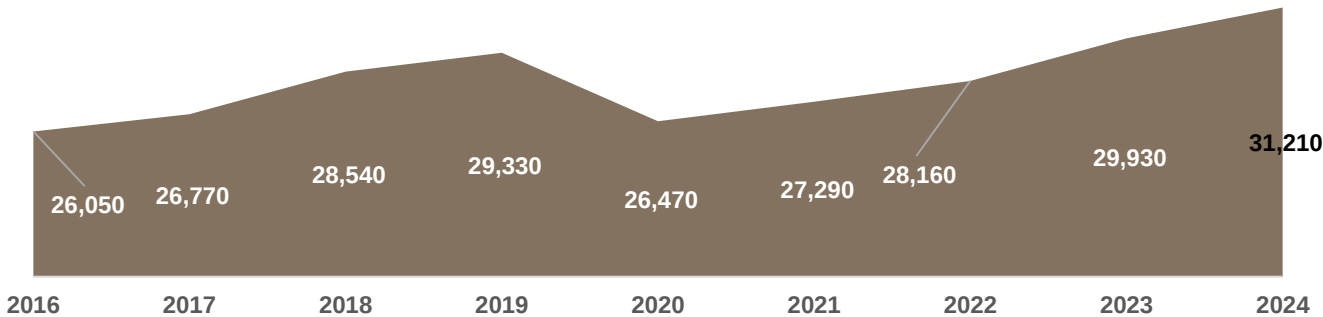


Source: OECD-FAO agricultural outlook 2023-2032

3.2.3 Global ethanol market

Ethanol is a renewable fuel that can be made from various plant materials, collectively known as biomass. It is an alcohol, used as a blending agent with gasoline to increase octane and cut down carbon monoxide and other smog-causing emissions. Various governments around the world are implementing programs to increase ethanol blending and decrease their reliance on fossil fuels.

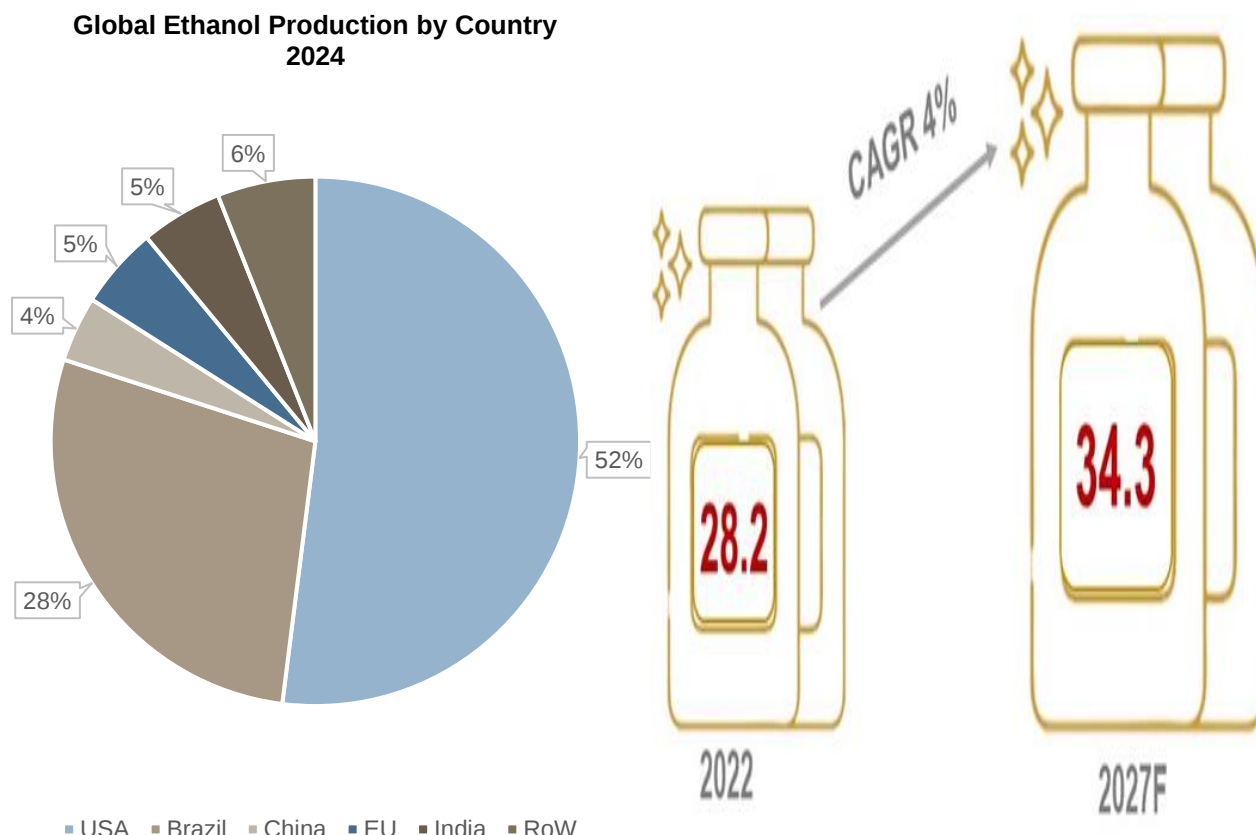
Figure 22: Global ethanol production trend 2016-2024 (in million gallon)



Source: Renewable fuels association

Global Ethanol market saw a decline during the COVID-19 pandemic due to decreased production of feedstock and decline in the consumption. However, since then, the annual production has been rising constantly, expected to beat the pre-pandemic levels soon.

Figure 23: Global ethanol production overview (%) and outlook (in billion gallons)



Source: Renewable fuels association
EU: European Union; RoW: Rest of world

Over the years, USA has established a control over the global Ethanol Production Market due to its easier access to feedstock. However, Indian ethanol market is growing at a tremendous pace and is expected to contribute significantly to new demand in the coming years.

Table 3: Ethanol production share ranking and major feedstock among top ethanol producing countries

Country	Ethanol production ranking	Major feedstock
USA	1	Maize
Brazil	2	Sugarcane / Maize / Sugar beet / Molasses
China	3	Maize / Cassava
EU	4	Sugar beet / Wheat / Maize
India	5	Molasses, Sugarcane and Grain

Source: OECD-FAO agricultural outlook

3.2.3.1 Ethanol blending success story

Figure 24: Mandates for ethanol blending in different countries/region-2022



Source: CRISIL MI&A Consulting

Countries	Mandatory blending rate %	Actual blending rate %
Brazil	27.00%	27.50%
India	10.00%	19.93%*

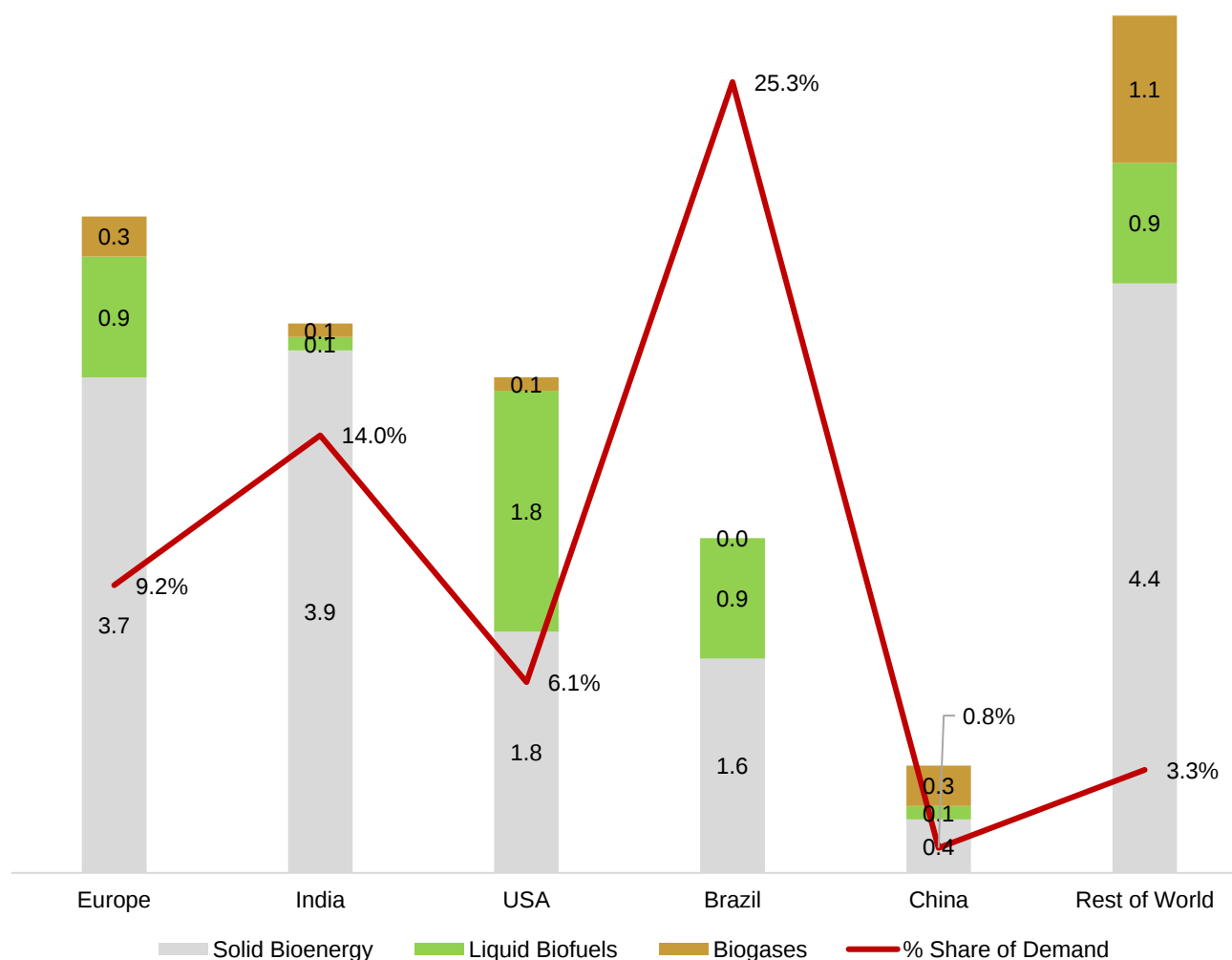
Source: Press Information Bureau (Government of India); S&P Global

*Blending rate achievement in July 2025. Till July 2025 a blending rate of 19.05% was achieved which required 740+ crore litres of ethanol

Globally, the highest mandatory ethanol blending rate is observed in Brazil, whereas the United States stands as the largest global producer of ethanol. Brazil notably leads in terms of achieving its targeted ethanol blending rate. As of 2022, Brazil's ethanol blending rate is expected to reach an impressive 27.5% against the mandate in Brazil which aims for 27% blending, this is by far the largest globally. However, the government of Brazil wants to take this a step further. On June 25 it was announced that Brazil will increase the mandatory blend of ethanol in gasoline from 27% to 30% and the mandatory blend of biodiesel in diesel from 14% to 15% (effective August 01, 2025). The announcement was made by Brazil's National Energy Policy Council (CNPE), a division of the Ministry of Mines and Energy. The increased mandates aim to eliminate gasoline imports while reducing emissions and fuel prices. Expanded use of biofuels will also boost domestic biofuel producers. The new biofuels policy is expected to generate an exportable surplus of approximately 700 million litres (184.92 million gallons) of gasoline annually. The move to E30 is also expected to spur more than USD 1.8 billion in investments and create more than 50,000 jobs.

India blending ratio till 2022 was 10% whereas India, in the month of July 2025, it stands at an average ethanol blending of 19.93%, however, till July 2025 in ESY 2024-25, a blending rate of 19.05% was achieved which required the purchase of 740+ crore litres of ethanol. In the past ten years or so, this initiative has delivered significant benefits, including savings of INR 1,13,007 crore in foreign exchange, a reduction of CO2 emissions by 544 lakh metric tons, and a substitution of 193 lakh metric tons of crude oil. Furthermore, the program has had a considerable economic impact, with OMCs disbursing ₹1,45,930 crore to distillers and ₹92,409 crore to farmers.

Figure 25: Renewable fuel demand by country (in EJ), 2023



Source: International Energy Agency (IEA)

Brazil

Brazil has been at the forefront of the paradigm shift in the field of bio energy, especially for biofuels with special focus on bioethanol. In fact, Brazil has been at it well before such a shift was necessitated through climate change action with biofuels being a part of its national energy policies for nearly 50 years. Brazil delved into biofuels as a response to the first oil shock it faced in 1975. At the time, the 'Proalcool' (Pro-alcohol) program was launched in order to nurture and develop the indigenous ethanol-based transport industry to mitigate Brazil's dependence on fossil fuels as it imported more than 70% of its fuel requirements.

Brazil, a country with challenges and a cultural profile similar to India, has shown impressive growth as a leading player in the global ethanol market being second only to the US, which makes it an impressive achievement. Brazil's journey of building an ethanol-based economy has the potential to help any other country that wishes to follow in its footsteps.

Since its beginnings in 1975, Brazil has managed to increase ethanol production by ~45 times owing to the impetus given to the sector by strong research conducted by the Brazilian Agricultural Research Corporation (EMBRAPA) to improve productivity of the sugarcane crop, which brought down its price by ~70% in the same period. Regulatory

push towards incremental increase ethanol blending in petrol, which currently stands at 27%, has paved the way for sizeable rise in consumer uptake and demand for the fuel, it also has a blend rate of 12% for biodiesel which is set to expand to 15% by 2026. Brazil is also home to RenovaBio, the world's largest transport matrix decarbonisation programme, which came into force in 2019 and is expected to boost ethanol supply by another 45% by 2030, reaching an output of 50 billion litres.

Figure 26: Brazil's ethanol program

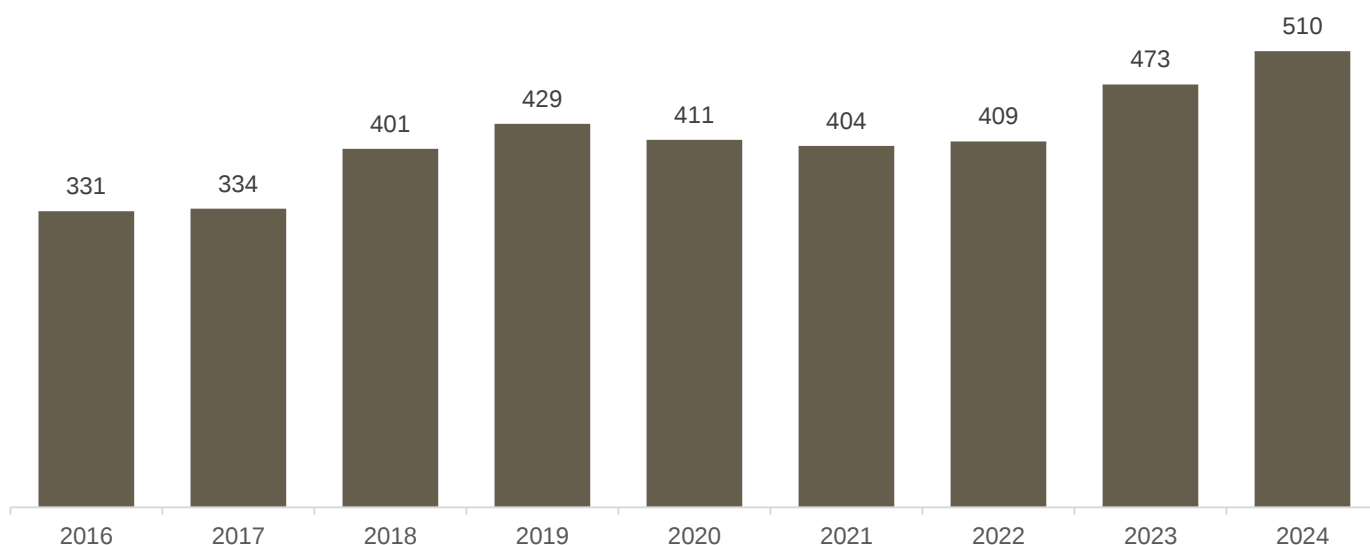
Phase 1: 1975-1978	• <i>Proálcool programme initiated</i> • <i>Ethanol and gasoline mixing begins with the so-called</i> • <i>E20 blend (1 part ethanol to 4 parts gasoline)</i> • <i>Expansion of distilleries</i> • <i>Production of E20-powered cars by the automobile industry</i>
Phase 2: 1979-1985	• <i>Hydrous ethanol production initiated under Proálcool</i> • <i>Cars powered exclusively by hydrated ethanol launched on the Brazilian market</i>
Phase 3: 1985-1990	• <i>Hydrated ethanol consumption increases due to a significant increase in ethanol-driven vehicles.</i> • <i>Rises in international sugar prices and the end of ethanol subsidies</i>
Phase 4: 1988-2001	• <i>Deregulation of the sugar and ethanol sector marks the end of the government's direct intervention</i>
Phase 5: 2002-2009	• <i>Increasing oil prices</i> • <i>Global concern for GHG emissions</i> • <i>Development of flex fuel engines</i> • <i>Renewed expansion of ethanol production</i>
Phase 6: 2008-Present	• <i>Navigating geopolitical crises and reduction in investments</i> • <i>Focus on continually increasing ethanol and diesel blending mandates to reduce dependence on international fuel sources and increase energy security</i> • <i>Increase of mandatory blend rates to 27% and then to 30% from August 2025</i>

Source: Evidence and Lessons from Latin America and CRISIL MI&A Consulting

In terms of monetary savings and environmental impact, Brazil has achieved forex savings of ~\$260 billion, while having kept more than 135 crore tonne of CO₂ equivalent emissions out of the environment, which has contributed to ~50% reduction in air pollution and improved public health in major cities. Ethanol received a major boost in Brazil in the early 2000s with the proliferation of the 'flex engine' in cars which enabled a vehicle to be run on 100% ethanol or petrol or any mix of these two. With nearly two decades of experience in the space, Brazil is a leader in 'flex engine' automobiles with more than 93% of Brazilian cars today being run on such engines. After years of research efforts, these engines have become more environment-friendly than even battery electric vehicles (BEV) and are seen to

release 10-11% less CO₂ per kilometre into the environment on a comparative basis (assuming ~85% renewable electricity is being used for charging).

Figure 27: Biofuels production in Brazil (Thousand barrels of oil equivalent per day)



Source: Statistical Review of World Energy 2025

United States of America (USA)

United States of America is one of the largest Ethanol consuming countries with approximately 55% of the global annual ethanol demand. Furthermore, in FY23, the USA produced 15,365 million gallons of Ethanol, which is more than 50% of the total production of ethanol around the world.

In the 1970s, as U.S. domestic crude oil production began to decline, prices rose and imports sharply increased. Corn processors and farmers saw an opportunity to market ethanol as a fuel additive to expand the domestic fuel supply. The OPEC oil embargo of 1973–1974 galvanized this objective and provide a push for increased use of ethanol to reduce dependence on foreign oil.

Congress boosted the ethanol market in 1978 by exempting E10 fuel from the federal excise tax on motor fuels Energy Tax Act 1978). Twenty-five states followed the ruling and exempted E10 from their state gasoline-excise taxes. In 1979 the U.S. Environmental Protection Agency ruled that E10 was “substantially similar” to gasoline under the Clean Air Act (CAA) thereby legalizing it as a fuel. The ethanol market enhanced when Octane was removed from TEL, which lead to synergies between the traditional and E10 fuel in the country.

In the Energy Policy Act of 2005, Congress removed the oxygenate requirement for reformulated gasoline and replaced it with the Renewable Fuel Standard. The RFS requires motor fuels to contain an increasing portion of renewable fuels, which lowers dependence on foreign oil and reduces greenhouse gas (GHG) emissions. This led to an increase adoption of ethanol in the country.

2G Biofuel Adoption in Brazil/ USA/ Romania

Ethanol production in Brazil is majorly dominated by first generation technologies based on the use of sucrose content of the sugarcane. However, the demand for the alternative 2nd generation of ethanol has also been increasing over the years as the end result of both the processes is exactly the same.

Brazil also currently has two cellulosic ethanol plants with a combined 7.5 crore litres of capacity, compared to three facilities with 7.5 crore litres of capacity in 2021 and three facilities with 12.7 crore litres of capacity in 2020. Capacity

use is at 73% for 2022, up from 53% in 2021 and 25% in 2020. This space is seeing robust development with several R&D efforts and new projects underway. Raizen, which is one of the largest private business groups in Brazil inaugurated its second cellulosic ethanol plant in May 2024. This is part of a larger plan to open four more production units by the 2025-26 harvest season. Raizen's new units are likely to bring its total fuel production capacity to 440 million litres per year, and the company is considering selling new contracts to expand its plan from 2025. Generally speaking, the demand for cellulosic plants has seen a significant uptick as countries aim to expedite their energy transition journeys

Several ambitious ventures in the United States, including those led by Poet & DSM, and DuPont, encountered difficulties in handling feedstock and achieving profitability. The closure of these plants underscores the complexities of scaling up cellulosic ethanol production. Additionally, Clariant's sunliquid® bioethanol production facility in Podari, Romania, ceased operations in December 2023 due to continued losses. However, amidst these setbacks, there remains optimism as companies persist in researching and developing technologies for cellulosic ethanol production, heralding potential advancements in the future.

3.2.4 Global SAF market

Rising global awareness about the imperative for decarbonization is increasingly

Aviation may not be the largest polluter when it comes to its share in global emissions but is one of the most challenging sectors to decarbonise. Despite reductions in flying during the Covid-19 lockdowns, demand is expected to grow rapidly through 2030 with the International Civil Aviation Organization has predicted a 100 percent increase in global air travel by the year 2030, creating a need for extensive efforts to bring the entire aviation ecosystem up to pace. New aircraft can be up to 20% more efficient than the models they replace, but growth in activity has outpaced efficiency improvement. Technology innovation is needed across the sector, including in production of low-emission fuels, improvements in aircraft and engines, and operational optimisation. Demand restraint solutions will also be needed to get on track with the Net Zero Emissions by 2050 Scenario – to curb growth in emissions and ultimately reduce them this decade, of these, sustainable aviation fuel (SAF) is a relatively straightforward method to curb a major chunk of the emissions contributed by the aviation sector.

SAF is a biofuel used to power aircraft that has similar properties to conventional jet fuel but with a much smaller carbon footprint. Depending on the feedstock and technologies used to produce it, SAF can reduce life cycle GHG emissions by up to 80% compared to conventional jet fuel. SAF is blended with the traditional aviation fuel to ensure similar characteristics and performance. This is because, there exist no type of engine that could run entirely on SAF, however, efforts to develop aircrafts that support 100% SAF are also underway. SAF can be made from different technological pathways and feedstock combinations, which means that there are several kinds of SAF. Each SAF variety works with different technologies, cost profiles, carbon abatement profiles, environmental impact, and of course, feedstock.

The potential of SAF has been recognized on an international scale, as per the International Air Transport Association (IATA), the net-zero by 2050 goal has been a major focus of the aviation industry in general in 2023. As per IATA estimates, 65% of the carbon mitigation needed for net zero by 2050 is likely to come from SAF. To put things in perspective, the aviation industry purchased and consumed as the SAF produced in 2023, but it still could only account for 0.2% of the total fuel used. This shows the massive appetite for SAF within the industry and the business opportunity that SAF production can represent.

In 2024, SAF production volumes reached 1 million tonnes (1.3 billion liters) which was double the 0.5 million tonnes (600 million liters) produced in 2023. SAF accounted for 0.3% of global jet fuel production and 11% of global renewable fuel. In 2025, SAF production is expected to reach 2.1 million tonnes (2.7 billion liters) or 0.7% of total jet fuel production and 13% of global renewable fuel capacity.

IATA aims to establish the IATA SAF Registry which can help provide an impetus to the uptake of SAF and can also aid in the reliable and efficient reporting and mapping of emissions reduction via the SAF route. The Registry, which

is being developed in consultation with airlines, manufacturers, fuel suppliers, etc. will have the following capabilities in mind:

- Wide geographic scope
- Broad application and neutrality
- Independent in terms of governance
- Cost efficient (Participation will be on a cost-recovery basis to avoid additional cost barriers to the SAF adoption)

Table 4: Pathways/ Technology certified by American Society for Testing and Materials (ASTM)

S. No.	Technology / Pathway & Chemical Process	Common Name	D7566 Annex	Feedstock	Max % in the final product
1	Fischer -Tropsch hydro-processed synthesized paraffinic kerosene Woody biomass is converted to syngas using gasification, then a Fischer-Tropsch synthesis reaction converts the syngas to jet fuel. Feedstocks include various sources of renewable biomass, primarily woody biomass such as municipal solid waste, agricultural wastes, forest wastes, wood, and energy crops.	FT-SPK	A1	Waste CO2 and renewable power, Municipal Solid Waste & Agricultural Waste/ Waste Wood	50
2	Synthesized paraffinic kerosene from hydro-processed esters and fatty acids Triglyceride feedstocks such as plant oil; animal oil; yellow or brown greases; or waste fat, oil, and greases are hydro processed to break apart the long chain of fatty acids, followed by hydro isomerization and hydrocracking. This pathway produces a drop-in fuel.	HEFA SPK	A2	Vegetable oils and waste oils (e.g. Used cooking oil)	50
3	Synthesized iso-paraffins from hydro-processed fermented sugars Microbial conversion of sugars to hydrocarbons. Feedstocks include cellulosic biomass feedstocks (e.g., herbaceous biomass and corn stover). Pre-treated waste fat, oil, and greases also can be eligible feedstocks.	SIP	A3	Fermented sugars	10
4	Synthesized kerosene with aromatics derived by alkylation of light aromatics from non-petroleum sources Biomass is converted to syngas, which is	FT-SPK/A	A4	Waste CO2 and renewable power, Municipal Solid Waste & Agricultural Waste/ Waste Wood	50

S. No.	Technology / Pathway & Chemical Process	Common Name	D7566 Annex	Feedstock	Max % in the final product
	then converted to synthetic paraffinic kerosene and aromatics by FT synthesis. This process is similar to FT-SPK ASTM D7566 Annex A1, but with the addition of aromatic components.				
5	Alcohol to jet synthetic paraffin kerosene Conversion of cellulosic or starchy alcohol (isobutanol and ethanol) into a drop-in fuel through a series of chemical reactions—dehydration, hydrogenation, oligomerization, and hydrotreatment. The alcohols are derived from cellulosic feedstock or starchy feedstock via fermentation or gasification reactions. Ethanol and isobutanol produced from lignocellulosic biomass (e.g., corn stover) are considered favorable feedstocks, but other potential feedstocks (not yet ASTM approved) include methanol, iso-propanol, and long-chain fatty alcohols.	ATJ-SPK	A5	Ethanol and Iso-butanol	30
6	Synthesized kerosene from hydrothermal conversion of fatty acid esters and fatty acids Also called hydrothermal liquefaction), clean free fatty acid oil from processing waste oils or energy oils is combined with preheated feed water and then passed to a catalytic hydrothermolysis reactor. Feedstocks for the CH-SPK process can be a variety of triglyceridebased feedstocks such as soybean oil, jatropha oil, camelina oil, carinata oil, and tung oil.	CHJ	A6	Vegetable oils and waste oils (e.g. Used cooking oil)	50
7	Synthesized paraffinic kerosene from hydrocarbons, esters and fatty acids Conversion of the triglyceride oil, derived from Botryococcus braunii, into jet fuel and other fractionations. Botryococcus braunii is a high-growth alga that produces triglyceride oil.	HC-HEFA-SPK	A7	Botryococcus braunii species of algae	10

Source: British petroleum and CRISIL MI&A consulting

Two of the technology pathways and associated feedstocks are approved to produce SAF through coprocessing. With co-processing, vegetable oils, waste oils and fats, or FT-wax is, processed along with conventional crude oil

feedstocks in existing refining complexes. It is not per se a SAF-focused production pathway, but more a result of the approval of co-feeding a small percentage of vegetable oils, or FT-wax into a refining complex.

Table 5: More on certified technologies

S. No.	Technology / Pathway & Chemical Process	Common Name	D1655 Annex	Feedstock	Max % in the final product
1	Co hydro-processing from Fischer-Tropsch	FOG Co-Processing Fats, oils, and Greases co-processing with petroleum intermediates as a potential SAF pathway. Used cooking oil and waste animal fats are two other popular sources for co-processing.	A1	Fat, oils and greases	5
2	Co hydro-processing from hydro processed esters and fatty acids	FT Co-Processing Syncrude co-processing with petroleum crude oil to produce SAF.	A1	FT biocrude	5

In an uncertain world, airlines are strengthening their profitability. The projected \$30.5 billion net profit in 2024 is a significant achievement post-pandemic. In 2023, connectivity of international and domestic routes grew by 28% and 10%, respectively. A major factor behind this evolution is the resurgence of the Asia-Pacific markets whose international connectivity rose by 62% in 2023 as travel restrictions were removed. Along with the continuing strong and steady YoY growth in North American and European international connectivity of 18% and 17%, respectively, global air connectivity is set to reach record highs in 2024.

Over the next 20 years, the International Air Transport Association (IATA) expects world passengers to increase by 3.8% per year on average, resulting in over 4 billion additional passenger journeys in 2043 compared to 2023. European and North American markets will see a slower rise in demand, 2.3% and 2.7% per year respectively. Asia Pacific is anticipated to record the fastest rise in passenger numbers and to contribute to more than half of the net increase in global passenger numbers by 2043.

Strengthening profitability and financial resilience is crucial for continued investments in customer needs and sustainability solutions, essential for achieving net zero carbon emissions by 2050.

Advanced biofuels

Advanced biofuels (also referred to as second- and third-generation biofuels): biofuels that do not compete directly with food and feed crops. Second-generation biofuels may be derived from waste and agricultural residues (such as wheat straw and municipal waste) or non-food crops (such as miscanthus and short-rotation coppice). Third-generation biofuels generally refer to biofuel production routes which are further away from commercialisation (for instance biofuels from algae or hydrogen from biomass). Advanced biofuels have low CO2 emission or high GHG reduction and reaches zero or low ILUC impact.

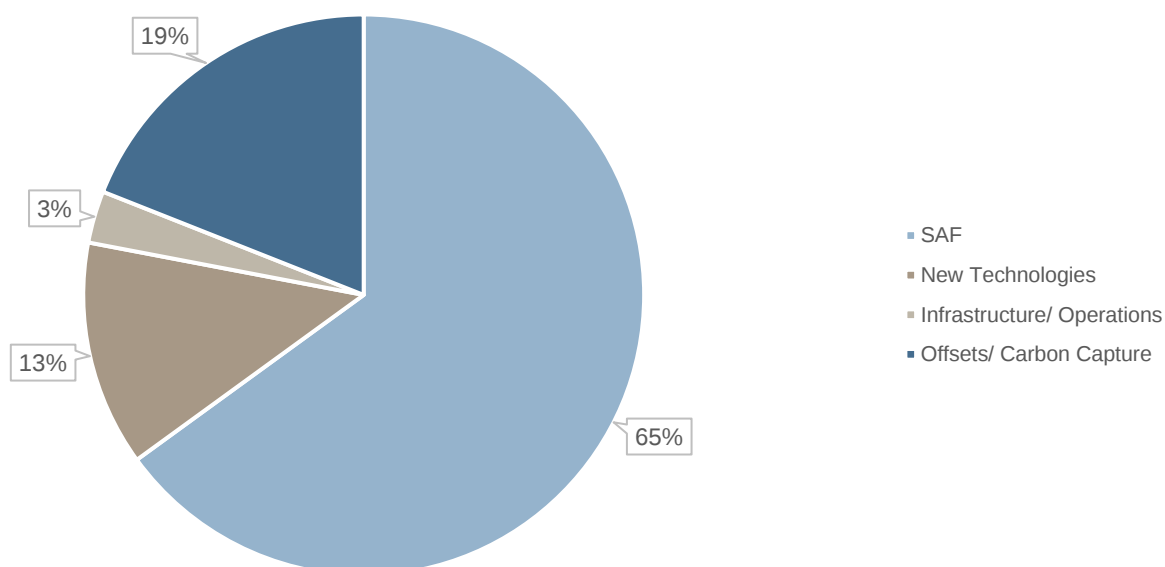
As the fight for sustainable growth rages on, advanced biofuels will become indispensable to make the aviation sector more sustainable. A dedicated, long-term target for advanced biofuels within the SAF proposal is indispensable to get investment decisions on new capacity made.

Several international standards and specifications are there for SAF to ensure quality, sustainability, and compatibility with existing aviation infrastructure. Some of the key standards are:

- **ASTM D7566:** This standard was developed by ASTM International; it outlines specifications for aviation turbine fuels containing synthesized hydrocarbons.
- **ISO 23274:** Published by the International Organization for Standardization (ISO), this standard also provides specifications for aviation turbine fuels containing synthesized hydrocarbons.
- **ASTM D1655:** This is the standard specification for aviation turbine fuels, which includes requirements for conventional jet fuel as well as certain alternative fuels.
- **SAE International ARP 5915:** This provides guidance on the use of aviation turbine fuels derived from renewable sources.

Other than that, agencies such as International Civil Aviation Organization (ICAO), Roundtable on Sustainable Biomaterials (RSB), International Sustainability and Carbon Certification (ISCC), Sustainable Aviation Fuel Users Group (SAFUG), European Union Renewable Energy Directive (EU RED), etc. play an important role in ensuring the quality and sustainability characteristics of SAF.

Figure 28: Different levers of Net Zero for the Aviation Industry



Source: IATA Sustainability and Economics

The global aviation industry, which presently contributes to approximately 3% of the total global greenhouse gas emissions with the potential to contribute 22% by 2050 if left unchecked, has set an ambitious net-zero carbon emission target by 2050, which is focused on delivering maximum reduction in emissions at source through the use of SAF, innovative new propulsion technologies and other efficiency improvements. While the use of multiple levers is expected to be employed in order to achieve the net-zero targets, SAF is expected to be the major lever by far. IATA estimates that a 1,000x increase in production is needed by 2050 (500Mt) to be able to produce the required quantities of SAF to achieve the net-zero targets. According to IATA, at least 50 airlines have committed to use SAF with goals ranging from 5% to 30% of their total fuel usage, with most of them committing to 10%. IATA estimates that 20 million tonnes of SAF uptake by 2030 could be possible under industry proposed and committed policies.

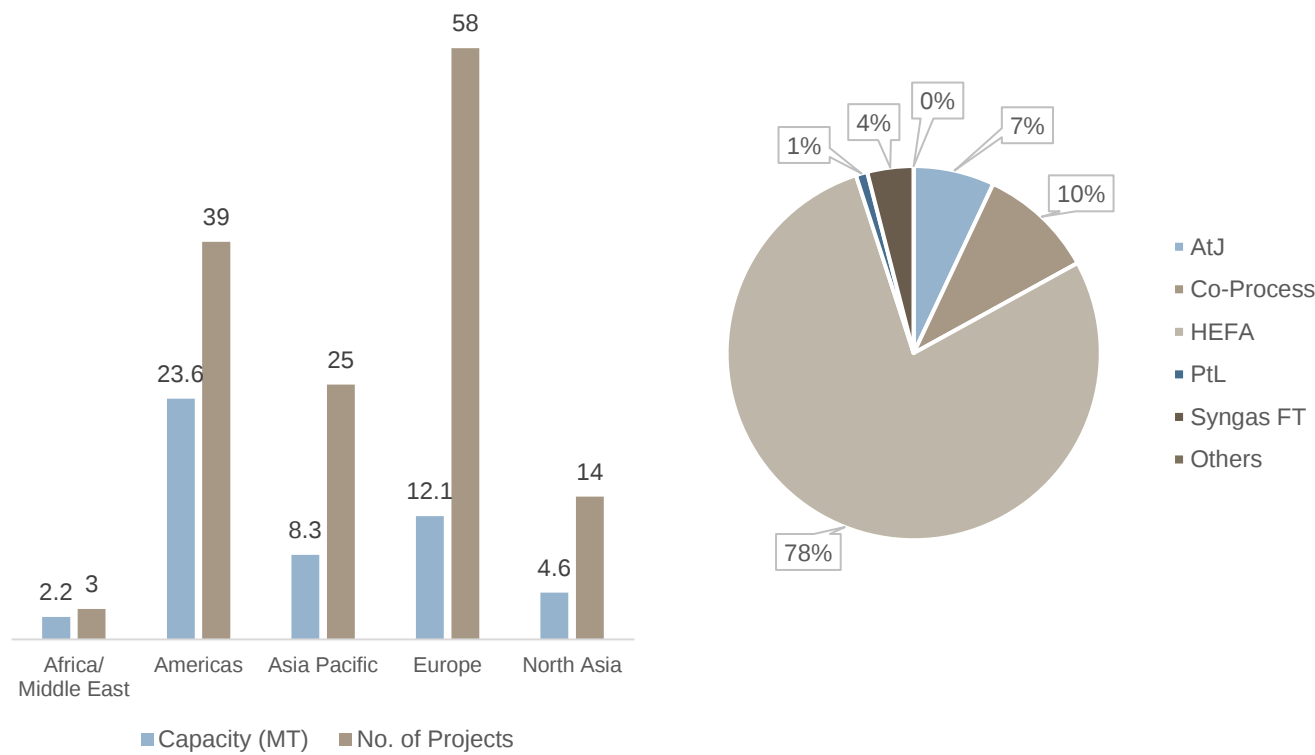
The International Air Transport Association (IATA) has projected that SAF could contribute to a reduction of around 65% of the emissions required to achieve global Net-Zero by 2050. Notably, several major economies are incentivizing SAF adoption. The USA has introduced legislation proposing up to \$2 per gallon of tax credit for SAF producers, while the EU has outlined a mandate to gradually increase SAF blending from 2% by 2025 to 63% by

2050. SAF production in the U.S. has increased in recent years. While U.S. production reached 15.8 million gallons in 2022, SAF accounted for less than 0.1% of the total jet fuel used.

Multiple airlines, such as American, Delta, Southwest, and United, have taken on self-imposed mandates for SAF blending as a part of their commitment to achieving net-zero greenhouse emissions by 2050. To meet these targets, they are implementing a range of strategies such as investing in more fuel-efficient aircraft, transitioning to electric ground vehicles, and optimizing operational efficiency.

Rolls-Royce has achieved a milestone by confirming that all its current aircraft engines, including models like Trent 700, 800, 900, 1000, XWB-84, and others, are fully compatible with 100% SAF. The successful tests conducted in Canada mark a significant move towards reducing the environmental impact of air travel. Rolls-Royce's commitment to achieving net-zero emissions by 2050 aligns with the aviation industry's efforts to adopt more sustainable practices. While SAF presents a promising solution, the future balance with emerging technologies, such as electric aircraft engines, remains uncertain.

Figure 29: Projects and SAF pathways to 2030



Source: Source: IATA Sustainability and Economics

About 140 identified SAF projects are progressing in various parts of the world by 100+ producers in 31 countries. The focus of projects in certain geographies is aligned to policies to promote SAF. It is expected that HEFA will continue to dominate SAF production unless the deployment of alternate pathways is accelerated.

Market Potential for SAF

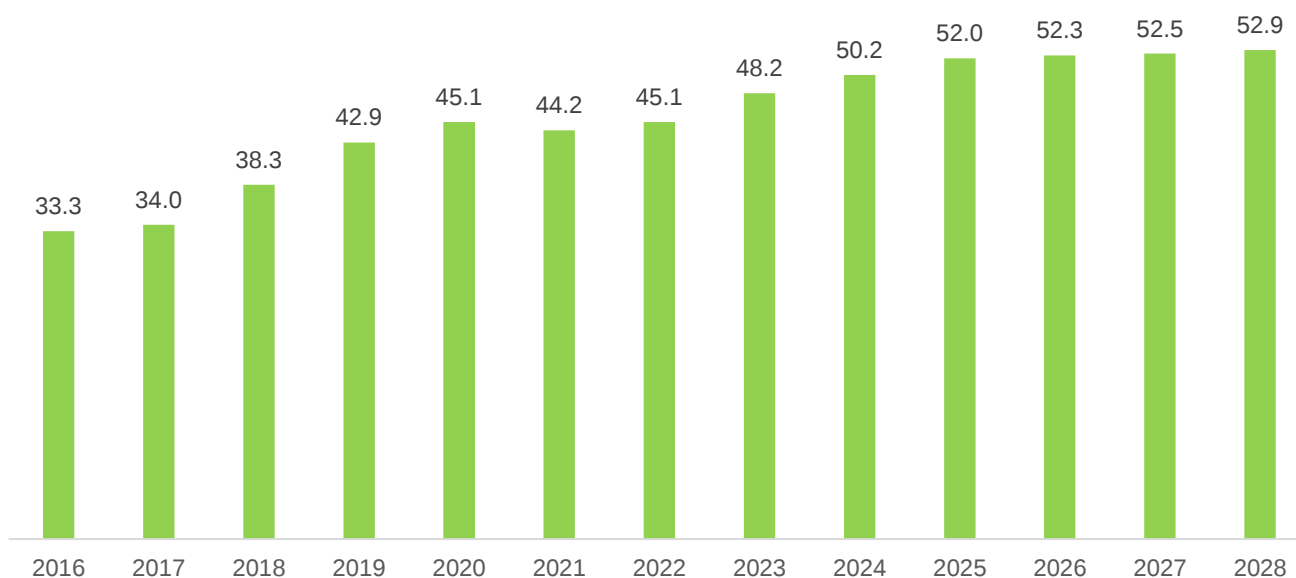
- USA aims to produce 3 billion gallons (approximately 9 million tons per year) of SAF by 2030, primarily utilizing Low Carbon Intensity (CI) 1st Generation Ethanol. However, the achievement of these ambitions will depend on the backing SAF receives from the Trump administration.

- The EU is mandating the increased use of SAF at airports (2% by 2025, 20% by 2035 and 70% by 2050). 2025 will also mark the beginning of the minimum SAF blending obligations under ReFuelEU Aviation Regulation (RFEUA)
- The EU envisions a demand of around 1.3 million tons per year of SAF, adhering to the proposed 2% blending mandate by 2025, sourced from waste and residues.
- The UK SAF mandate will also come into effect from 2025. As the scheme awards certificates based on emissions savings, the use of lower-CI SAF may result in lower quantities of SAF being required to meet targets.
- India has feedstock for potential production of 19 to 24 million tons of SAF per year, whereas the estimated maximum requirement of SAF in India, considering 5.0% blend, is around 8 to 10 million tons per year by 2030.
- Beyond India, opportunities for SAF projects also exist in regions such as Latin America, Asia Pacific, and Africa, where sugary feedstock or ethanol can be converted into SAF.

3.2.5 Global biodiesel market

Biodiesel is produced from vegetable oils, yellow grease, used cooking oils, or animal fats after conversion into a range of fatty acid methyl or ethyl esters (esterification), it is a sustainable replacement for petroleum/ fossil diesel that significantly reduces carbon emissions and makes environmental sustainability a commercial proposition. Biodiesel is, thus, a renewable fuel that can be used in diesel vehicles and has physical properties that are like those of petroleum/ fossil diesel, but it is a cleaner-burning alternative.

Figure 30: Global biofuel demand, 2016-2028 (in billion litres)



Source: International Energy Agency (Renewables 2023)

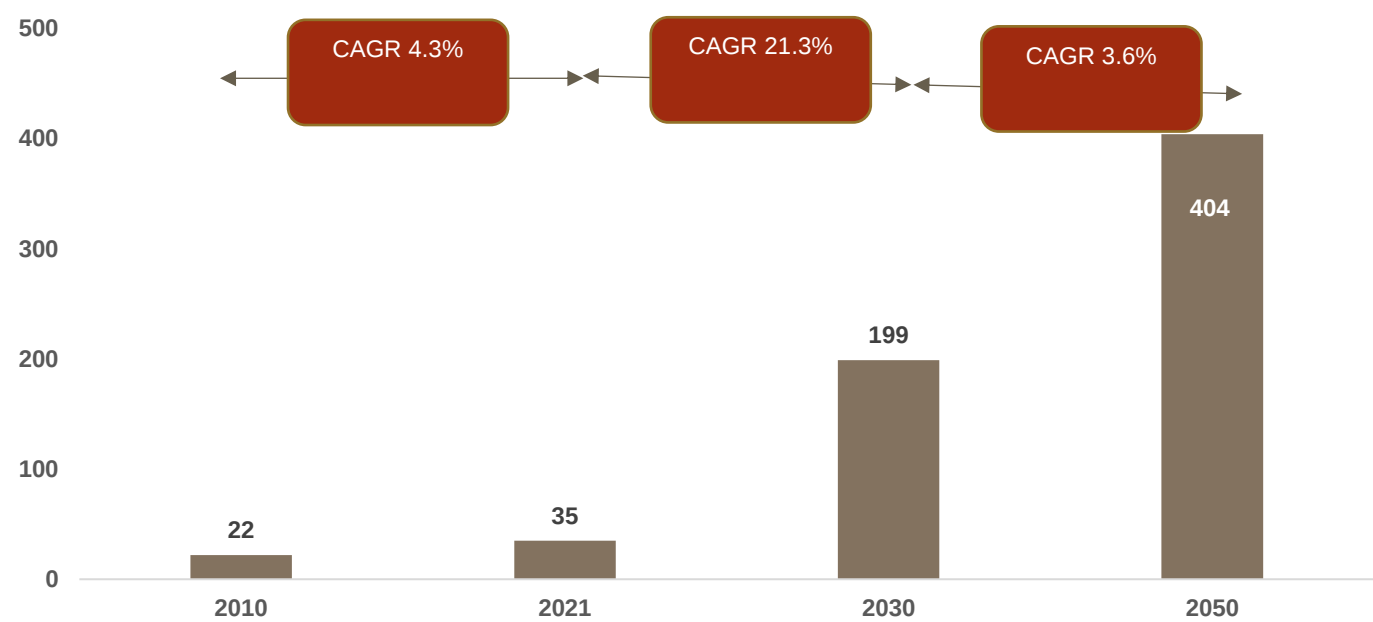
The global biodiesel market has experienced significant growth in the recent past and is expected to continue to on an upward trajectory driven by rising environmental concerns, government policies, and increasing demand for sustainable energy sources. As per IEA estimates, the global biodiesel market is expected to grow at approximately 2% CAGR between 2023-2028.

Various economies are employing different tactics to propel the biodiesel market forward, in Indonesia, palm oil export levies subsidise biodiesel costs, while the United States offers a biodiesel blending tax credit of USD 0.26/ litre. It plans to extend the tax credit through the IRA, with added incentives for lower GHG emissions.

Overall, the biodiesel market will be a critical component of the transition towards cleaner energy and will play a significant role in reducing the global carbon footprint and in fostering a culture of sustainable growth and development.

3.2.6 Global CBG market

Figure 31: Global biogas demand (In bcme)



Source: IEA world energy outlook

BCME: billion cubic meter equivalents

The upgraded form of biogas, known as compressed biogas (CBG) or bio- CNG (biomethane in Europe and renewable natural gas in the United States), contains over 98 per cent methane and is generated through anaerobic digestion from organic waste streams. These waste materials arise from diverse industrial, economic, agricultural and household activities. The CBG cycle serves as an ideal representation of circularity, as it is derived from various wastes generated by human activities and is subsequently utilized as a resource in the form of clean energy and biofertilizer.

The global CBG market is experiencing significant growth due to increasing demand for sustainable and renewable energy sources. CBG, derived from organic waste materials through anaerobic digestion, is a clean alternative to conventional fossil fuels, reducing greenhouse gas emissions and promoting waste management. Europe, in particular, Germany has been a pioneer in the CBG sector driven by stringent environmental regulations and substantial investments. The Asia-Pacific region, particularly India and China, is also seeing rapid growth due to an increasing need for clean energy given the rapid urbanization and industrialization that these countries are experiencing.

Achieving net-zero energy target by the fiscal year 2050, the total biogas demand globally is expected to surge to 404 bcme, indicating a CAGR of 9% during 2021 to 2050. This is because of the increase renewable energy requirement globally and increased feasibility of biomethane as an energy source.

The major demand drivers for compressed Biogas (CBG) from 2021 to 2030 include increasing environmental regulations, a focus on sustainability and renewable energy sources, government initiatives and incentives, expanding use in transportation and industry, and the need to reduce greenhouse gas emissions. These drivers are pushing the growth of CBG production and consumption, aiming to reach 199 billion cubic meters equivalent (BCME) by 2050.

3.2.7 Growth drivers and market trends

The biofuel market, globally, has seen a rise in the past years owing to the endeavours of various governments to reduce fuel import bill and shift towards the use of renewable energy sources. USA and Brazil have always been at the forefront of biofuel adoption with their early practices in adopting waste-to-fuel technology. With increased global concerns towards climate change and increased promises for Net Zero Emission Targets globally, more countries have realised the importance of Biofuels in the total fuel mix for consumption and have increased biofuel share in their total consumption. Following are some key growth drivers and market trends observed all around the world:

Global ethanol initiatives: Driving biofuel policies to meet energy demand and environmental goals

Countries, worldwide, have started to understand the importance of biofuels in the increasing energy demand mix, and have started initiating Biofuel supporting policies and mandates that require certain biofuel blends or targets, and initiatives, such as the Low Carbon Fuel Standard (LCFS), which requires a reduction in the carbon intensity (CI) of transportation fuels over time. Policies that create incentives for biofuels are expected to continue to spread and become more stringent in the coming time, like India's National Policy on Ethanol Blending, which aims to achieve a 20% blending target by 2025.

India in collaboration with Singapore, Bangladesh, Italy, USA, Brazil, Argentina, Mauritius, and UAE, unveiled the Global Biofuel Alliance (GBA).

- ✓ This initiative was spearheaded by India, serving as the G20 Chair, and was designed to accelerate the worldwide adoption of biofuels.
- ✓ The GBA's primary objectives include promoting technological advancements, increasing the use of sustainable biofuels, establishing robust standards and certification processes with the involvement of various stakeholders, and functioning as a centralized repository of knowledge and expertise.
- ✓ The GBA strives to be a catalytic platform that encourages global cooperation to advance and widely implement biofuels.

Growing sustainable aviation fuel (SAF) demand

Increased awareness of reducing CO₂ emissions in the aviation industry has been gaining momentum over the past years. Several airlines have announced their GHG reduction targets and offtake agreements for sustainable aviation fuel. There is an emerging trend of airlines investing in non-bio-oil technologies and feedstocks, such as biomass and ethanol-to-jet fuel. Airlines are also increasingly taking the lead in establishing policies and incentives favourable for adoption of SAF. IATA estimates that nearly 100 million tonnes of biomass would still be available in the Indian market for SAF after its use in other bio-energy sectors. They foresee a massive opportunity in India with a SAF production of ~40 million tonnes by 2050 which can position India as a global hub for SAF production.

Others biofuel

Biomethane: Utilizing organic waste through anaerobic digestion or gasification to produce biomethane reduces methane emissions and offers a cleaner energy source for vehicles. Certification systems ensure sustainable biomethane production, and biogas upgrading technologies enable injection into natural gas pipelines.

Other Renewable Fuels: Research into diverse feedstocks and advanced conversion methods is expanding the biofuel landscape, driven by energy security goals and the need to reduce fossil fuel reliance. Algal biofuels show promise, waste-to-fuel conversion technologies are gaining traction, and integration with existing infrastructure facilitates biofuel adoption.

The Need to secure steady supply of sustainable feedstock

Biodiesel, renewable diesel and SAF demand is expected to report a strong growth between 2023 and 2030. A feedstock gap is expected to emerge and become more pronounced over the next couple of years if the planned

capacities come online. Several feedstock supply bottlenecks need to be handled to ensure feedstocks availability. These include:

- Increase in feedstock production, primarily vegetable oils.
- Redirect fat and grease supplies to biofuels from existing lower value uses, such as animal feed.
- Redirect oilseed, vegetable oil, fat, and grease exports to domestic markets.

Redirection of oilseed trade will have knock-on effects, such as incentivizing production of vegetable oil, including palm oil, and increasing production of oilseeds as well as spurring greater investment in oilseed productivity in main supply regions. Additionally, the production of biofuel dedicated oilseeds or biomass to liquid fuels are also expected to grow and support the supply of lower carbon intensity feedstocks; the impact can be significant in the future, but not in the near term.

4 India biofuel market and growth outlook

As India has grown, the usage of fuels such as motor spirit (MS) or petrol, diesel, ATF, and natural gas has grown with it. MS consumption stood at 17,128 thousand Metric Tonne (TMT) in 2013-14 which has grown to ~40,000 TMT in fiscal 2025, representing a growth of ~8% CAGR. The consumption of diesel (HSD) grew at ~3% CAGR in the same period and reached ~91,400 TMT in 2024-25 while that for ATF grew at ~4% CAGR and stood at ~9,000 TMT in 2024-25. Natural gas, being a part of India's energy transition agenda has been receiving attention from the Indian government as it is being seen as a bridging fuel between more polluting conventional fuels and greener renewable fuels. Compressed biogas (CBG) finds its niche there as the government aims to use it to reduce LNG imports and increase the sustainability factor.

This is the universe that is available to biofuels like ethanol, biodiesel, sustainable aviation fuel (SAF), and CBG for conversion, it represents a massive opportunity which appears to be ripe for investment as the green investment and sustainability agenda become mainstream. With the Indian Government's increased support for alternative energy sources, India's biofuel industry is growing at a tremendous pace and is exploring forms of renewable bio-energy sources such as sustainable aviation fuel, CBG, 2G ethanol, and green hydrogen along with promoting the manufacturing and consumption of fermented organic manure (FOM). The current biofuel market in India is mainly divided into ethanol, compressed biogas (CBG), and biodiesel currently, of which ethanol forms a major chunk. Sizeable investments, especially by the government, aimed at converting excess sugar availability into ethanol to strengthen its pursuit of creating an ethanol economy are noteworthy. India may even surpass China as the third-largest ethanol consumer as early as 2026. Indian SAF market is in a very nascent stage and is expected to catch up by 2025-26.

Indian Biofuel market is dominated by Ethanol, followed CBG and biodiesel. SAF and other renewables do not form a major chunk of the total biofuel demand in India currently, but the scenario is expected to change with governments current Net Emissions Targets. This section will provide a brief overview of each of these biofuels and their place in the Indian energy spectrum; it will also shed some light on TruAlt Bioenergy Limited's positioning in the biofuel sector within India. Sections subsequent to this one will dive deeper into each biofuel.

The Ministry of New & Renewable Energy has issued Revised Scheme Guidelines (Aug 2025) under the National Green Hydrogen Mission with a budget of ₹200 crore till FY26 to run pilot projects on innovative and decentralized hydrogen production (floating/rooftop solar, micro-hydel, biomass, wastewater) and end-use applications (cooking, heating, off-grid power, off-road vehicles, city gas blending, residential and community uses). These pilots aim to test feasibility, safety, and performance, cut reliance on LPG/diesel, and cover new sectors beyond earlier schemes. Outcomes will guide scaling, policy, and infrastructure planning, strengthening India's goal to be a global hub for green hydrogen.

4.1 National Biofuels Policy 2018 & its 2022 amendment

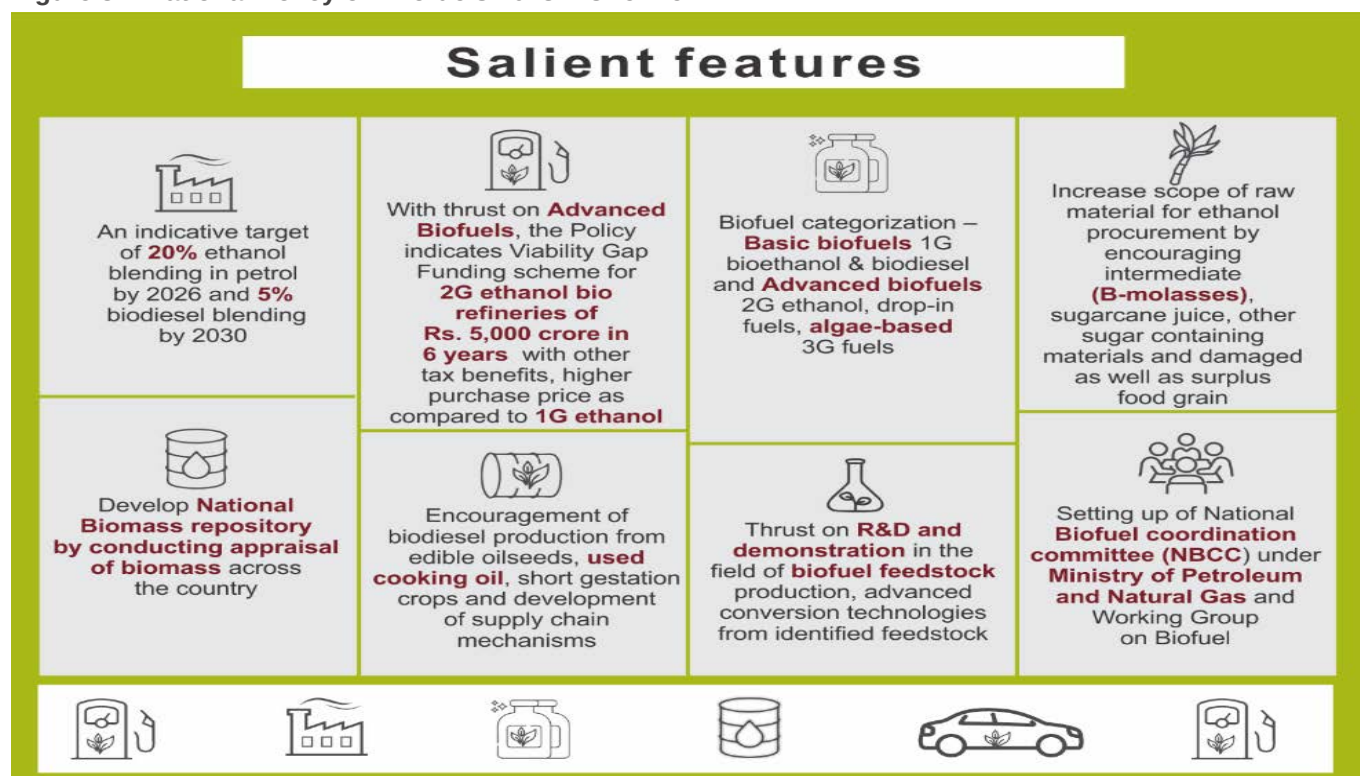
National Biofuel Policy was implemented in 2018 by the Government of India. The Policy aims to increase biofuel usage in different sectors of the economy and make a transition towards a cleaner fuel during the coming decade. Further, the Government of India aims to utilize, develop and promote domestic feedstock for the production of biofuels to increasingly substitute fossil fuels while contributing to national energy security, climate change mitigation, strengthening of foreign exchange reserves, and creating new employment opportunities in a sustainable way, particularly through building a circular economy in the most rural parts of India.

The Goal of the Policy is to increase availability of biofuels in the market and increasing their blending percentage. An indicative target of 20% blending of ethanol in petrol and 5% blending of biodiesel in diesel is proposed by 2030, which was amended and preponed to 2025 under the 2022 amendments.

The National Policy on Biofuels 2018 was notified by the Ministry of Petroleum and Natural Gas on June 4, 2018, superseding the National Policy on Biofuels, promulgated via the Ministry of New & Renewable Energy in 2009.

The amended policy allows for more feedstock to be considered for biofuel production and promotes the production of biofuels in the country under the Make in India initiative by units located in special economic zones and export-oriented units and also reduced Goods & Service Tax (GST) on ethanol meant for EBP Programme from 18% to 5%.

Figure 32: National Policy on Biofuels 2018 – Overview



Source: CRISIL, Ministry of Petroleum and Natural Gas (MoPNG)

The policy categorized biofuels as:

1. Basic biofuels, i.e., first generation bioethanol and biodiesel
2. Advanced biofuels, i.e., second generation (2G) ethanol, municipal solid waste, drop-in fuels, third generation biofuels, bio-CNG, etc., to enable extension of appropriate financial and fiscal incentives under each category.

The following are the main amendments approved to the National Policy on Biofuels:

1. to allow more feedstocks for production of biofuels,
2. to advance the ethanol blending target of 20% blending of ethanol in petrol to ESY 2025-26 from 2030,
3. to promote the production of biofuels in the country, under the Make in India program, by units located in Special Economic Zones (SEZ)/ Export Oriented Units (EoUs),
4. to add new members to the NBCC.
5. to grant permission for export of biofuels in specific cases, and

6. to delete/amend certain phrases in the Policy in line with decisions taken during the meetings of National Biofuel Coordination Committee.

This government hopes that with this amendment the industry will pave the way for Make in India drive thereby leading to reduction in import of petroleum products by generation of more and more biofuels. Since many more feedstocks are being allowed for production of biofuels, this will promote the Atmanirbhar Bharat and give an impetus to the government's vision of India becoming 'energy independent' by 2047.

The amended policy expands the scope of raw material for ethanol production by allowing use of sugarcane juice, sugar containing materials like sugar beet, sweet sorghum, starch containing materials like corn, cassava, damaged food grains like wheat, broken rice, rotten potatoes, unfit for human consumption for ethanol production.

The Policy allows use of surplus food grains for production of ethanol for blending with petrol with the approval of National Biofuel Coordination Committee. With a thrust on Advanced Biofuels, the Policy indicates a viability gap funding scheme for 2G ethanol Bio refineries of Rs. 5000 crores in 6 years in addition to additional tax incentives, higher purchase price as compared to 1G biofuels. The pricing mechanism for ethanol from different feedstocks has also been reworked. IREDA is also joining in the effort and will provide support through financing initiatives. The main objective of their Scheme is to provide financial assistance for setting up of new Distillery or expansion of existing Distillery for manufacturing of Ethanol, which in turn promote blending of biofuel in petroleum for reduction in pollution levels and addressing the issues of sugar demand. All the commercially viable First-generation Ethanol manufacturing plants either newly set up Distilleries (or) expansion (enhancement of capacity) of existing Distilleries using 'Molasses / Sugar Syrup / Cane Juice / Damaged Food Grains / Surplus Rice with FCI' and other feedstock such as Sugar Beet / Sorghum, etc. as Raw Material are viable for IREDA assistance while Interest rate may vary time to time as per IREDA policy. However, an additional rate of interest of 0.10% to be charged on the entire loan amount in case the loan amount exceeds 75% of the project cost. In addition to this, several states like Karnataka, Maharashtra, Uttar Pradesh, etc. have their own policies for helping out the biofuels sector projects.

4.2 Indian ethanol market

Ethanol, commonly known as ethyl alcohol, is a versatile and flammable chemical that is both renewable and colourless. Its primary production method involves the fermentation of various sugar-based materials, starches, and cellulose-based feedstocks such as corn, barley, wood, and wheat. One of the key characteristics of ethyl alcohol is its high solubility, making it an effective organic solvent. This property is particularly valuable in the production of alcoholic beverages, where ethanol is the main active ingredient. Additionally, its preservative qualities make it indispensable in the pharmaceutical industry, where it helps maintain the stability and effectiveness of various medications.

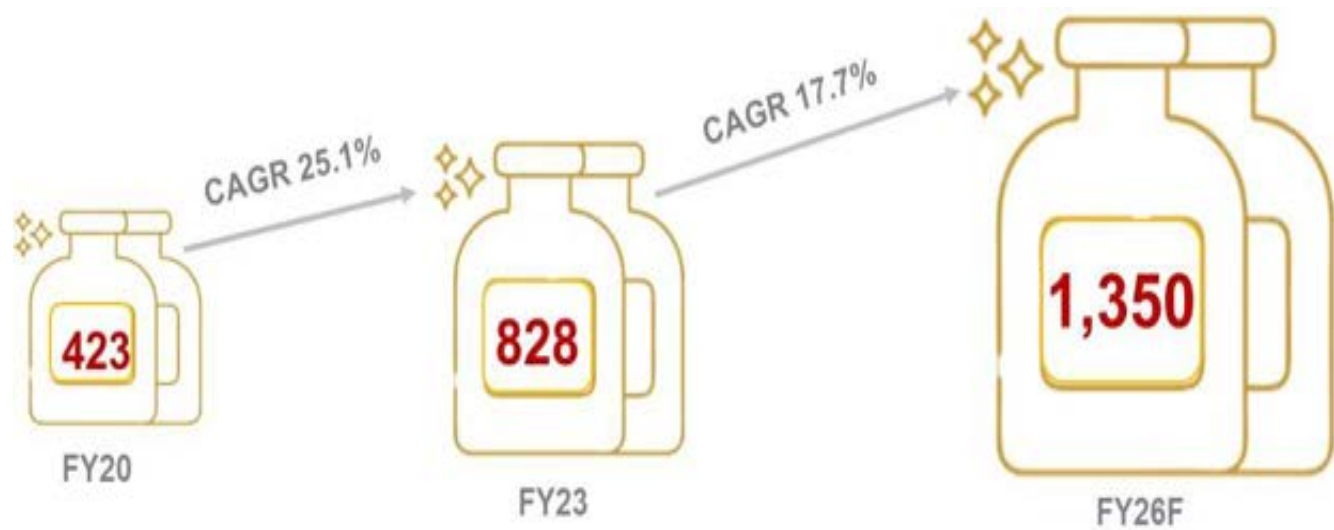
Beyond its use in beverages and pharmaceuticals, ethanol plays a significant role in a wide range of applications. In the energy sector, it is used as a fuel and fuel additive, contributing to cleaner-burning fuels and helping to reduce greenhouse gas emissions. Its disinfectant properties make it a critical component in hand sanitizers and other cleaning products, especially important in maintaining hygiene and preventing the spread of infections.

In the realm of personal care, ethanol is found in numerous products such as perfumes, lotions, and hair sprays, where it serves as a solvent and helps to preserve the formulations. Industrially, it is used as a solvent in the production of various chemicals and materials, showcasing its versatility. Overall, ethanol's applications are diverse and impactful, spanning across multiple industries and contributing to both everyday products and essential industrial processes.

Ethanol has been the primary biofuel used in India for over a decade. The demand began after the introduction of Ethanol Blending Program in January 2003; however, it has become a main focus in only the past decade. Ethanol market is expected to expand even more due to the ambitious Ethanol Blending Program (EBP) that has targets of achieving 20% blending in petrol by ESY 2025-26, as well as other growing sectors such as the alcohol, cosmetics,

pharmaceuticals, Sustainable Aviation Fuel (SAF), bioplastics and biochemicals industries where ethanol is applied/ingredient, which will drive demand in the blending sector. Given the importance of this sector, the Government of India and certain State Governments have also included Ethanol projects under their priority sector lending criteria, which has encouraged banks to sanctions loans for Ethanol projects to achieve priority sector lending thresholds. Furthermore, the Government has begun to establish a roadmap for sustainable energy solutions beyond the 20% blending target, indicating a forward-thinking strategy that anticipates future energy needs.

Figure 33: India Ethanol demand overview and outlook (in crore litre)



F: Forecasted
Source: NITI Aayog and Ministry of Petroleum and Natural Gas

4.2.1 Different generations of ethanol

Figure 34: Difference between Different Generations of Biofuels

Feature	1G Ethanol	2G Ethanol	3G Ethanol
Feedstock	Sugarcane, corn, wheat, barley, etc.	Lignocellulosic biomass (e.g., wood, agricultural waste)	Algae
Process	Fermentation of sugars.	Pretreatment of biomass, enzymatic hydrolysis, fermentation	Photosynthesis, fermentation
Yield	Low; 1-2 gallons of ethanol per bushel of feedstock	High; 1-2 gallons of ethanol per ton of feedstock	High; 100-200 gallons of ethanol per ton of biomass
Cost	Low	High	Very high
Environmental impact	Relatively low	Relatively high	Very high
India Positioning	Demand is fulfilled though 1G Ethanol	2G ethanol at nascent stage, the industry is expanding	3G ethanol process is not yet adopted in the country

Source: CRISIL MI&A Consulting

4.2.1.1 1st Generation Biofuels/Bioethanol

First-generation (1G) Bioethanol is produced from biomass such as sugar-containing materials (like sugar cane juice, molasses, sugar beet etc.) and starch-containing materials (such as corn, cassava, rotten vegetables such as potatoes, damaged food grain etc.). The process of converting biomass into bioethanol severely harms the food as well as water industry, which is often considered to be the biggest drawback of 1G ethanol, creating a food insecurity in the country because of its competing nature with food land.

The process of manufacturing 1G Ethanol is a simple and cost-efficient process with no intensive pre-treatments and a well-established infrastructure in the country, however, it leads to a conflict of food vs fuel and require high land and water usage.

4.2.1.2 2nd Generation Biofuels/Bioethanol

Second-generation biofuels are defined as fuels produced from several feedstocks, especially but not limited to non-edible lignocellulosic biomass. Cultivating these second-generation biofuels requires vast land, water, and fertilizer to grow the biofuels producing plants. The feedstock for Ethanol does not compete with the food security of India, but is however, requires significant costs as compared to 1G Ethanol. Majority of the India's need for the ethanol feedstock is fulfilled through the 1G feedstock, however, the government is also encouraging the production of 2G ethanol from non-food feedstock and a number of Oil PSUs have started establishing 2G Ethanol bio-refineries in various parts of the country. 2G ethanol presents distinct value for both existing ethanol producers and new entrants. Existing ethanol producers can improve margins and meet growing demand by integrating 2G ethanol plants through 'bolt-on technology,' which offers a strategic advantage by leveraging the synergies of existing ethanol capacities.

Existing producers also benefit from first-mover advantage. Meanwhile, new entrants have a strategic advantage as well, given that there is currently one operational 2G plant in India, located in Panipat, operating at 30% capacity as of December 31, 2023.

Second-generation (2G) ethanol offers advantages over traditional ethanol:

- Utilizes non-food sources like agricultural and forestry residues, reducing competition with food crops.
- Addresses waste management by using agricultural and forestry residues, contributing to a circular economy.
- Reduces concerns about land use and food security compared to first-generation ethanol.
- Can achieve greater greenhouse gas emission reductions due to the use of advanced feedstocks and conversion technologies.
- Incorporates advanced technologies for more energy-efficient production processes.
- Ongoing research is leading to cost-effective and scalable production methods.
- Helps minimize the indirect land-use change impact associated with biofuel production.
- 2G ethanol has a much lower carbon footprint as it repurposes waste materials, reducing greenhouse gas (GHG) emissions significantly. Global regulatory frameworks and sustainability mandates favour low-carbon fuels, allowing 2G ethanol producers to command higher prices in premium markets
- Global regulatory frameworks and sustainability mandates favour low-carbon fuels, allowing 2G ethanol producers to command higher prices in premium markets

The production of 2nd generation Ethanol leads to the circular economy and bypasses the food vs fuel conflict; however, it requires extensive pre-treatment.

TruAlt aims to expand and leverage its existing platforms to expand its product portfolio to include 2G ethanol, by 2025 by upgrading and enhancing its existing facilities. It has further developed a long-term growth strategy to lower its dependency on a single variety of feedstock and diversify its raw material base, increase efficiency, become a carbon neutral bio-fuel company.

4.2.1.3 3rd Generation Biofuels/Bioethanol

This uses algae as a feedstock to produce ethanol. This generation is highly sustainable in the long run due to no competition with food or water in the value chain, however, it induces high cost of production as it requires extensive technology not yet developed for the masses and induces high downstream costs for production. Production of 3rd generation ethanol allows to directly capture the CO₂ emissions, leading to carbon negativity, and bypasses the food vs fuel conflict with no additional land and water requirements. It is largely still in the research phase of development.

Table 6: Applications of 1G and 2G ethanol (Present and Prospective)

S. No.	Present Applications	Prospective Applications
First Generation (1G) Ethanol		
1	Ethanol blended petrol for fuel grade Ethanol.	To produce SAF
2	Ethanol serves as an essential industrial solvent, used in the manufacturing of paints, coatings, varnishes and inks, providing efficient dissolution of various compounds, and for	Ethanol is used as cooking fuel in households and commercial kitchens as an alternative to traditional fossil fuels like LPG and kerosene.

	degreasing applications.	
3	Ethanol is a critical ingredient in medical and pharmaceutical industries, used in the production of antiseptics, disinfectants, and tinctures.	Biofuels, including Ethanol and biogas, can be used in power plants for electricity generation.
4	Ethanol is the primary ingredient in the production of alcoholic beverages to create beverages such as beer, wine, and spirits.	Ethanol and other bio-derived chemicals are used in the production of bioplastics and biochemicals for alternatives to petroleum-based plastics and chemicals.
5	Ethanol is also used as a chemical feedstock in personal care and cosmetics, as well as in agriculture and animal husbandry as a carrier for active ingredients. It serves as a solvent for dyes and textile finishing chemicals and is utilized in the processing of both natural and synthetic rubber.	MVL can be used to produce various valuable products, for the synthesis of elastomers, specialty fuels, and SAF molecules.
Second Generation (2G) Ethanol		
1	-	As a fuel additive, 2G ethanol improves combustion efficiency, boosts octane ratings, and lowers emissions, making it a valuable component in cleaner gasoline formulations.
2	-	For electricity generation, 2G ethanol offers a renewable power source that can be utilized in power plants and cogeneration systems, providing both electricity and heat efficiently.
3	-	In the realm of bioplastics and biochemicals, 2G ethanol acts as a sustainable feedstock, reducing reliance on petroleum-based products. It facilitates the production of biodegradable polymers for packaging, agriculture, and medical applications, and supports green chemistry initiatives by contributing to the synthesis of environmentally friendly products.
4	-	2G ethanol can be converted into high-value by-products such as furfural, xylitol, L-arabinose, and high fructose syrup, each finding significant applications in bio-based chemicals, food, and pharmaceutical industries.

		Further can be applied to produce Elastomers, Specialty Fuels and SAF Molecules. The production of mevalonolactone (MVL) from 2G ethanol opens avenues in biotechnology and pharmaceuticals, serving as a precursor for isoprenoids and cholesterol synthesis. This versatility extends to advanced materials and specialty chemicals. Beyond these applications, 2G ethanol can be transformed into bio-based elastomers for tires and industrial uses, specialty fuels meeting specific performance criteria, and sustainable aviation fuel (SAF), contributing to the aviation industry's efforts to reduce its carbon footprint. Overall, the diverse applications of 2G ethanol underscore its importance in fostering a more sustainable and eco-friendly future.
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Source: CRISIL MI&A Consulting

NOTE: 3G ethanol/ biofuels are being researched upon at present, hence, their scope of applications is yet to be defined

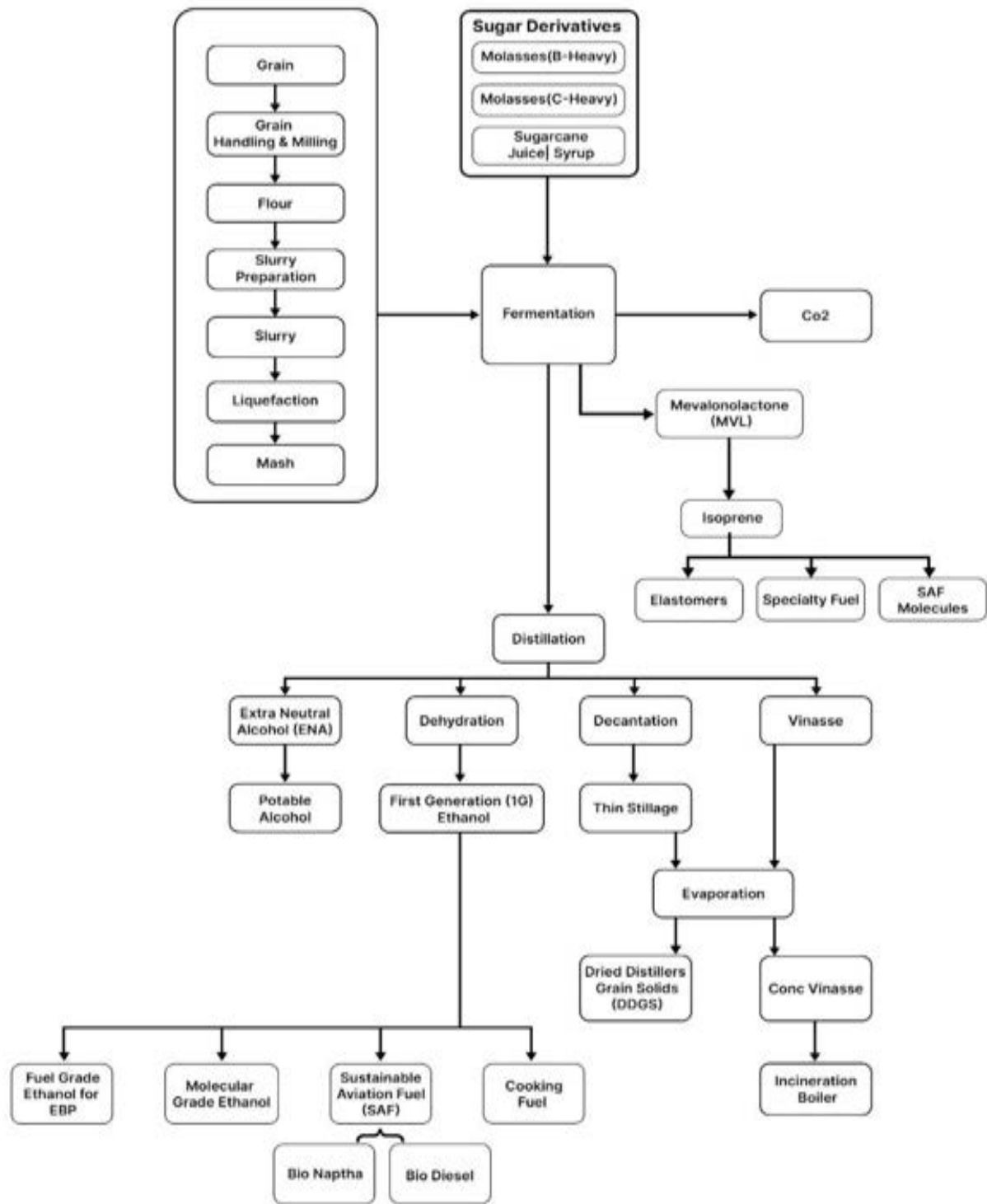
4.2.2 Process flow: Ethanol

In India, distilleries generally produce ethanol from molasses which is a byproduct of the sugar-making process, and it is derived after sugarcane is crushed. However, government has realized that this route is not sufficient for the 20% blending target, therefore, ethanol from foodgrains such as maize, damaged food grains (DFG) and surplus rice available with FCI has also been promoted to further achieve the targets set by the government. Around the world, maize is a primary feedstock for production of ethanol as it consumes less water and is economical, however, in India, the use of maize as a feedstock for ethanol production is gaining momentum with various government initiatives to promote maize as a feedstock for ethanol. Use of multiple feedstocks for ethanol production will ensure feedstock security thereby not putting any stress on the availability of any single feedstock.

Ethanol Production supply chain from various feedstocks

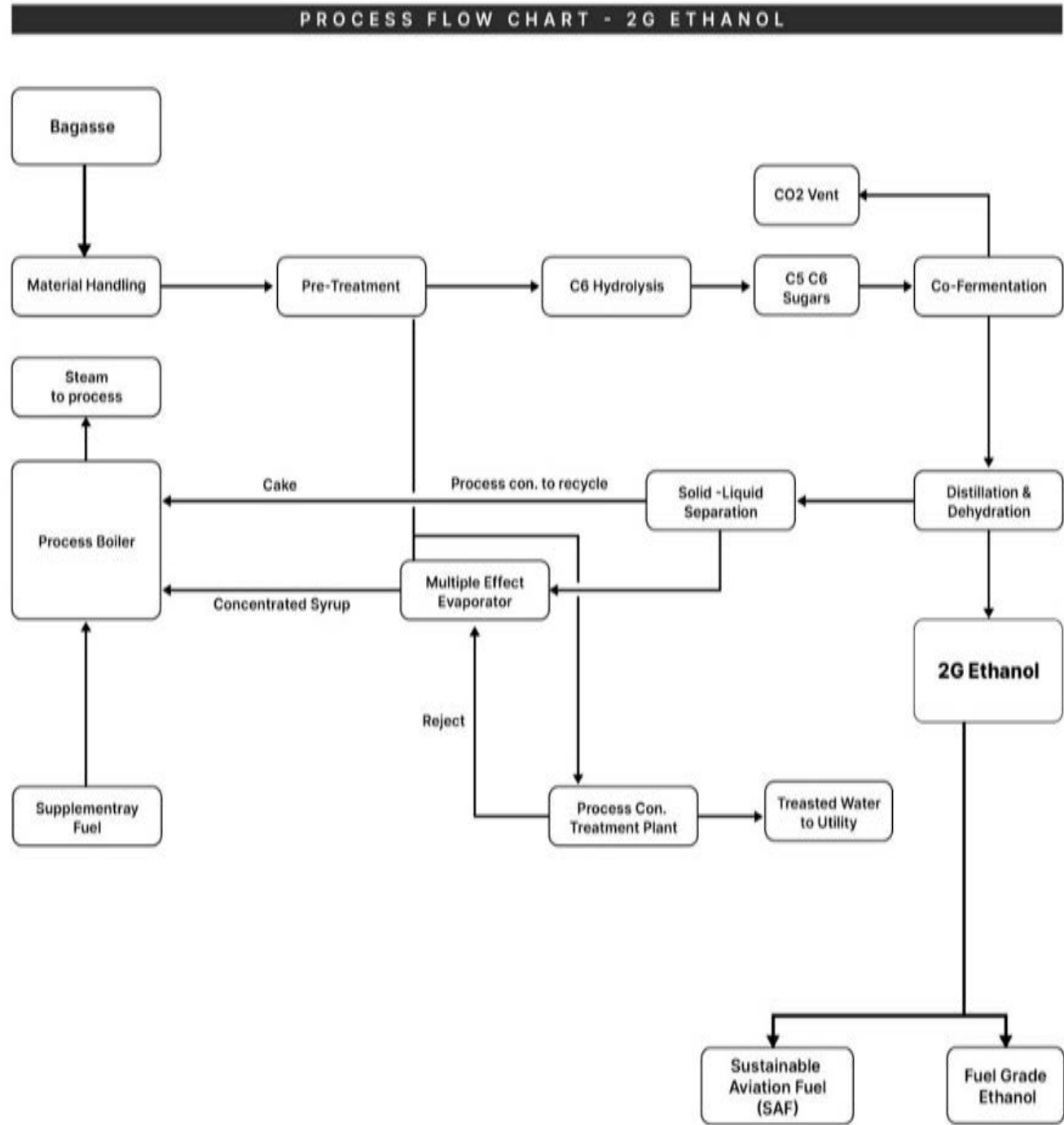
Figure 35: 1G ethanol process flow.

PROCESS FLOW CHART - 1G ETHANOL



Source: CRISIL MI&A Consulting

Figure 36: 2G ethanol flow chart



Source: CRISIL MI&A Consulting

4.3 Indian SAF market

India's civil aviation MRO industry is one of the fastest-growing sectors in the country and is expected to reach USD 4 billion by 2031. This represents a growth of 8.9% CAGR which significantly outpaces the global average of 5.6%. It is expected to drive substantial advancements in MRO capabilities throughout the Asia-Pacific region. While this is impressive, it also poses a legitimate challenge to India's net-zero emission efforts. Efforts towards efficiency

improvements will help, however, one needs to tackle a more fundamental problem, i.e., the fuel itself, this is where sustainable aviation fuel (SAF) steps in. SAF is a liquid fuel that can be used in commercial aviation and has the potential to reduce CO₂ emissions by up to 80% compared to traditional jet fuel. The global aviation industry has set an ambitious net-zero carbon emission target by 2050, which is focused on delivering maximum reduction in emissions at source using SAF, innovative new propulsion technologies and other efficiency improvements. SAF demand is expected to begin from 2025 and would play an important role in ensuring the Net Zero emission targets globally.

SAF market in India is in nascent stages. In May 2023, Air Asia tested its flight between Pune and Delhi completely on SAF, produced using indigenous feedstock. Indian government has set a target of 1% blending of SAF by 2027 and 2% blending by 2028 both for international flight initially. IATA believes that SAF can transform the economy of rural India. India is one of the global feedstock hotspots with ~10% of global bio-feedstock being available for SAF. India has the potential to produce around 40 million tonnes of SAF by 2050. This is a massive economic opportunity for rural Indian transformation and to fuel sustainable aviation growth provided it is supported by policy initiatives and industry participation. With feedstock prioritization, India could position itself as a leading regional SAF hub in future.

Table 7: Applications of SAF (Present and Prospective)

S. No.	Present Applications	Prospective Applications
1	Sustainable aviation fuel (SAF) is a lower-carbon alternative to normal jet fuel that can be used to fuel existing aircraft without making significant modifications to the aircraft and its engines.	Bio-naphtha is currently used for two major downstream applications - fuel blending and bioplastics production - in major markets such as Europe
2	Several airlines around the globe have started using SAF blends in their commercial flights as part of their sustainability initiatives.	Biodiesel is used in conjunction with the petroleum-based diesel, i.e., biodiesel is blended with the petro-diesel in different proportions depending on the availability of biodiesel as well as its costing, the engines or equipment in which the blend is to be used as fuel, and the desired performance.

Source: CRISIL MI&A Consulting

4.3.1 Process flow: SAF

Sustainable aviation fuel can be produced from non-petroleum-based feedstocks including municipal solid waste, wood biomass, fats/grease/oils etc. The demand for SAF is expected to begin by 2025 globally, owing to extensive research and Net Zero targets. While several ways to produce SAF in India are being explored, given the ease of availability of feedstock, the alcohol-to-jet technology (AtJ) to manufacture SAF looks the most promising for India. AtJ converts alcohols into SAF by removing the oxygen and linking the molecules together to get the desired carbon chain length (i.e. oligomerization). Currently, there are two feedstocks approved for use in the AtJ technology: ethanol and iso-butanol.

SAF represents a crucial innovation in the aviation industry's pursuit of environmental sustainability. Unlike conventional jet fuels derived from fossil sources, SAF is produced from renewable feedstocks such as agricultural residues, waste oils, or non-food crops. The primary advantage of SAF lies in its potential to significantly reduce the aviation sector's carbon footprint, as it emits fewer greenhouse gases during combustion compared to traditional jet fuels.

Figure 37: SAF process flow



Source: CRISIL MI&A Consulting

The figure above focuses on the AtJ technology as it is the most well-suited solution for SAF production in India, owing to the country's abundant ethanol capacity. This innovative technology converts ethanol into a low-carbon jet fuel, offering a cleaner and more environmentally friendly alternative to traditional fossil fuels. The AtJ technology can be leveraged to produce SAF, reducing the country's dependence on imported fossil fuels and minimizing greenhouse gas emissions. This technology has the potential to not only support India's climate goals but also provide a cost-effective and sustainable solution for the aviation sector, making it an attractive option for the country's fast-growing aviation industry.

4.4 Indian biodiesel market

High speed diesel (HSD) is one of the more polluting petroleum products and it is still an integral part of the Indian economy, especially its transport sector. It is the major petroleum product consumed in India and has typically accounted for ~40% of India's petroleum product consumption in the recent past. This alone necessitates the urgent need to help reduce the emissions profile of this fuel. Through various efforts of the government and the market, biodiesel has emerged as one key solution to this conundrum.

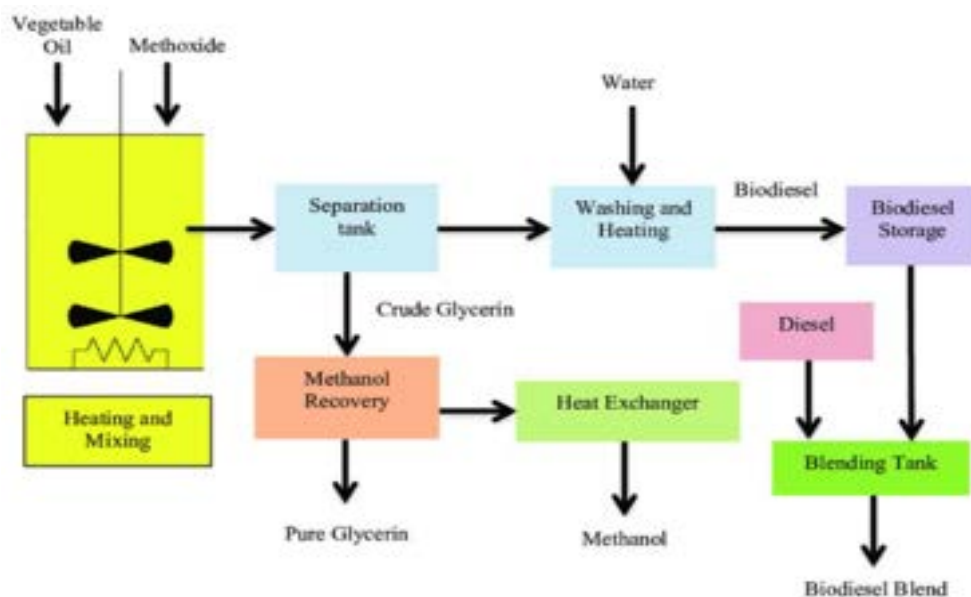
India's biodiesel market has been gaining traction as a sustainable alternative to petroleum/ fossil diesel. The sector is driven by the need to reduce dependence on imported fossil fuels, mitigate environmental impact, and promote rural development through agriculture.

Key factors shaping the market include government policies and incentives encouraging biodiesel production such as the National Biodiesel Mission of 2002-03 which kicked off the biodiesel sector in India, it is presently governed by the National Biofuels Policy, 2018 which sets a blending target of 5% for biodiesel by 2030 which would require almost 4.5 billion litres of biodiesel per year.

About 90% of biodiesel produced presently in India is from imported palm stearin, while the rest is from animal tallow, acid oil and Used Cooking Oil. Challenges remain including feedstock availability, technological advancements, and infrastructure development. However, the biodiesel market in India shows promise with increasing interest from the government, research institutions, and the broader market.

4.4.1 Process flow: Biodiesel

Figure 38: Biodiesel process flow



Source: Environmental and Climate Technologies 2022

The process starts with the preparation of vegetable oil (palm oil, soybean oil, or canola oil are typically used) to remove any impurities and water. Then the transesterification process happens wherein the vegetable oil reacts with an alcohol (methanol or ethanol) in the presence of a catalyst (such as sodium hydroxide or potassium hydroxide). This converts the oil to fatty acid methyl esters which are biodiesel and glycerol. The biodiesel now has to be separated from glycerol and other by-products through centrifugation (it may even be allowed to settle on its own). The crude biodiesel is then washed, purified, and dried before it goes for storage and distribution. It can now also be blended with petroleum/ fossil diesel in various proportions for use in the markets.

While biodiesel remains one of the best options for reducing the emissions profile of conventional diesel, other research is still ongoing to find other avenues, one such avenue is e-diesel. Blends of up to 15% of ethanol in diesel fuel, known as e-diesel, can be used in compression ignition engines. E-Diesel can produce certain reductions in regulated diesel emissions, especially those of diesel particulate matter, however, more research is still needed to make e-diesel commercially viable and to bring about surety in terms of safety as well.

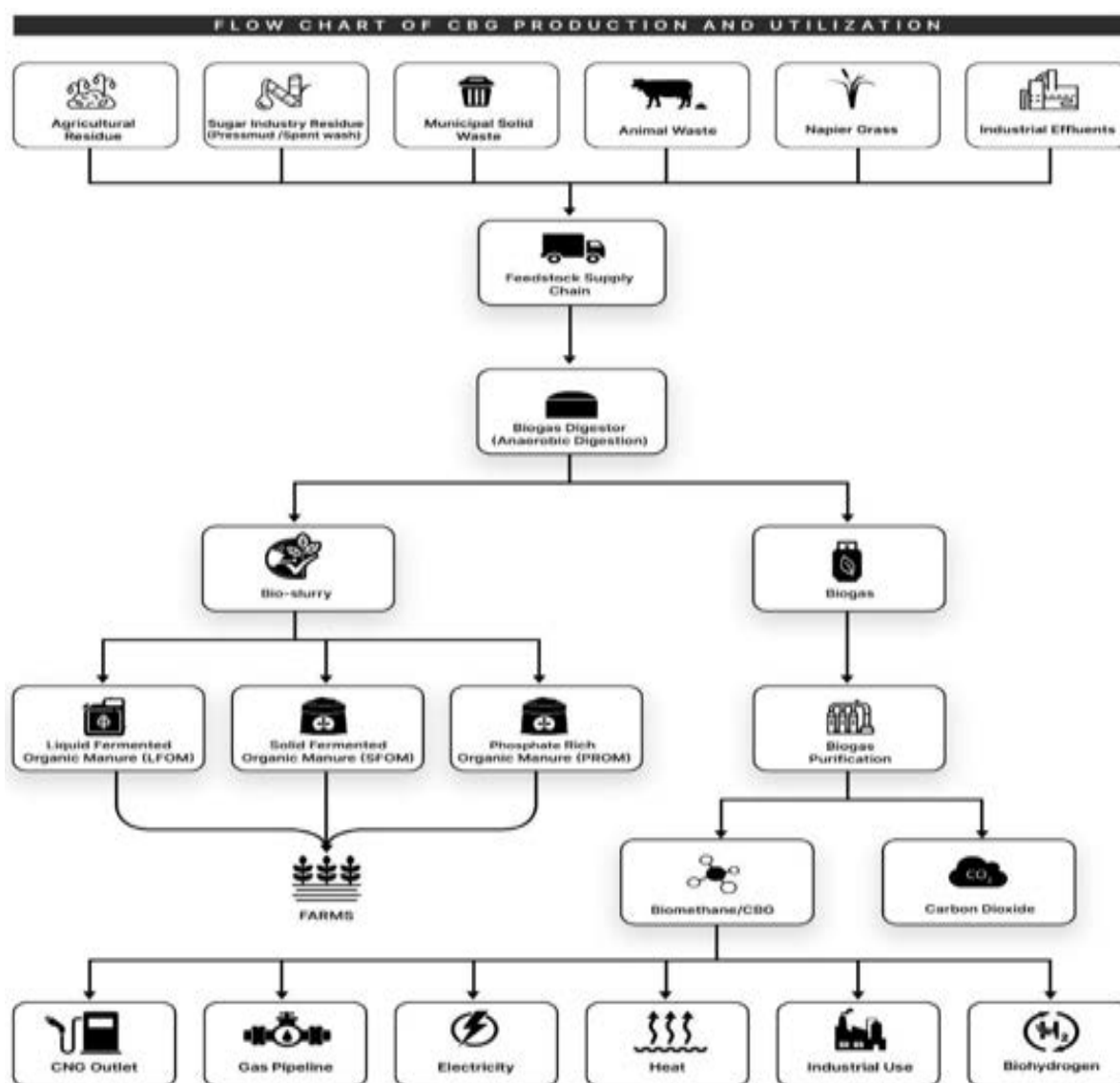
4.5 India compressed biogas (CBG) market

India aims to become a gas-based economy by taking the share of natural gas in India's present 6.6% to 15% by 2030. While India is less reliant on imports of natural gas as compared to crude oil, the dependence still hovers in the range 45%-50% and is expected to rise significantly as the demand for natural gas grows, this is something that can be mitigated through CBG, a biofuel capable of replacing natural gas. The government is, thus, looking forward to exploring compressed biogas (CBG) as an addition to the biofuel mix of the country. India biogas market is expected to grow up to \$2.25 billion in 2029, logging a CAGR of 6.3% between 2022 and 2029. Despite Covid-19 denting the sector's growth, it has shown a good recovery and is expected to continue the upward trajectory with large investments coming in from big conglomerates, both Indian and international, Public-Sector Units and entrepreneurs. Additionally, CBG projects are categorised as agricultural infrastructure as per RBI guidelines. Loans pertaining to agricultural infrastructure are being classified as priority sector lending, which has encouraged banks to sanction loans for CBG projects.

4.5.1 Process flow: CBG

CBG value chain initiates from processing the feedstock in the anaerobic digester, where the gas is captured and sent through the purification process, where it passes through several stages and then sent to the compressor to formulate the end product of compressed biogas. This is then sent to retail outlets to customers. The waste produced after the anaerobic stage is further processed and formed into a bio-manure or bio-slurry. In this way, production of biogas leaves no residue and aids the environment, however the process takes a lot of time for completion.

Figure 39: Compressed Biogas Value Chain



Source: CRISIL MI&A Consulting

CBG can be produced by utilizing diversified feedstock, as outlined in the table below. Additionally, bagasse can be utilized to produce it. To produce biogas from the organic waste, the required feedstock is preliminary collected, crushed and mixed with other waste materials and is allowed to ferment anaerobically in a digester for 30-40 days at a temperature of 34-38 degree Celsius. The biogas produced is further processed and hydrogen sulphide and carbon dioxide are removed so that the end product will have more than 90% - 95% methane which will be used as fuel.

Table 8: Different Feedstocks for CBG

Feedstock	Avg. biogas yield (nm ³ /mt)
OFMSW (organic fraction of municipal solid waste)	80-100
Napier Grass	110-130
Poultry Litter	80-100
Press Mud	90-110
Spent Wash	40-50
Bagasse	150-170
Segregated Food Waste	110-130
Paddy Straw	300-350
Cow Dung	40-50

Source: CRISIL MI&A Consulting

As per CRISIL MI&A consulting, the average yield per feedstock varies between 40-400 (nm³/mt) depending upon the type of feedstock subject to anaerobic conditions and temperature maintained. Compressed Biogas mainly consists of Methane (more than 90%) and other gasses like Carbon Dioxide (4%). The composition of methane depends upon the feedstock and the anaerobic digestion; thus, the yield varies from situation to situation.

Utilizing spent wash and press mud as feedstock for compressed biogas (CBG) production is a sustainable and environmentally friendly solution. Spent wash, a by-product of distilleries, contains a wealth of organic material, while press mud, generated during sugarcane juice extraction, is rich in organic matter. Both waste materials can be processed through anaerobic digestion, a biological process that converts their organic content into biogas. This biogas, primarily composed of methane (CH₄) and carbon dioxide (CO₂), can then be purified and upgraded to produce high-quality CBG. CBG, once compressed, becomes a versatile and clean fuel suitable for a range of applications, including transportation, power generation, and industrial processes.

The use of spent wash and press mud as CBG feedstock offers dual benefits: It addresses the challenge of waste disposal in distilleries and sugar mills, reducing environmental pollution, and simultaneously provides a renewable energy source that contributes to a greener and more sustainable future. Moreover, governments often incentivize CBG production from organic waste materials, making it economically viable and environmentally responsible. This approach aligns with global efforts to reduce greenhouse gas emissions and transition toward cleaner and more efficient energy alternatives.

Table 9: Applications of CBG (Present and Prospective)

S. No.	Present Applications	Prospective Applications
1	CBG is compressed and used as a fuel for vehicles, particularly in city transport fleets.	Bio-CNG, which is primarily CBG compressed for use in CNG vehicles, is likely to see significant expansion.
2	CBG is blended with natural gas or used directly for cooking and heating purposes in	CBG can play a crucial role in this shift by fuelling buses, taxis, and other public transport vehicles.

S. No.	Present Applications	Prospective Applications
	households and industries connected to city gas networks.	
3	CBG is used in gas turbines or engines to generate electricity, either for direct use or for feeding into the grid.	CBG can be used in microgrid systems to provide reliable electricity, supporting rural electrification efforts and enhancing energy security.
4	Cities and municipalities are setting up Bio-CNG stations where vehicles equipped to use compressed natural gas.	CBG can contribute to grid stability by providing a dispatchable and reliable source of power. Its use can help balance fluctuations in renewable energy generation.
5	Organic Manure - Liquid Fermented Organic Manure - Fermented Organic Manure - Phosphorate Rich Organic Manure	CBG can be utilized in combined heat and power systems, where it not only generates electricity but also provides heat for industrial processes or district heating. This enhances overall energy efficiency and reduces emissions.

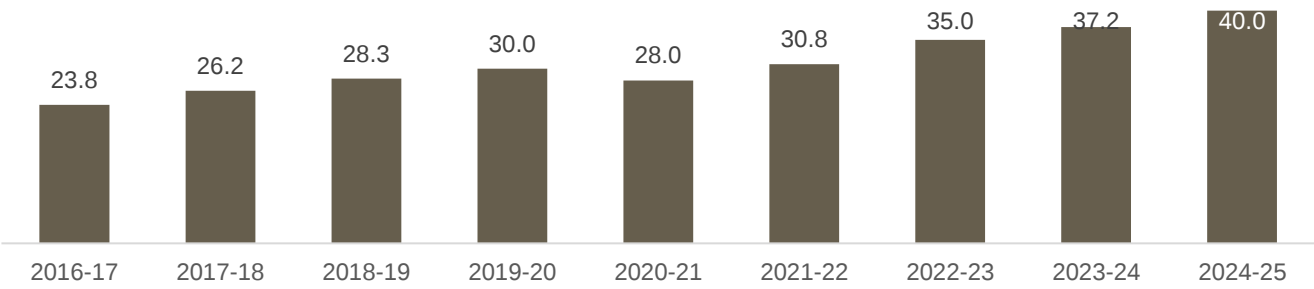
Source: CRISIL MI&A Consulting

5 Ethanol market

5.1 India MS/Petrol consumption trend and potential blending market

In FY2025, India's petrol consumption surged to approximately 40.0 million metric tons (MMT). The Indian oil market is predominantly influenced by imports, which account for about 86-88% of the nation's total oil demand for the past 10 years.

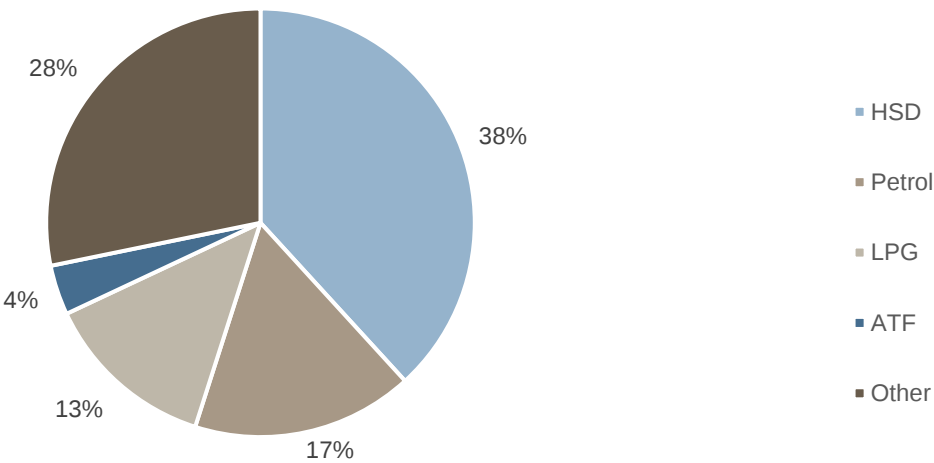
Figure 40: MS/ Petrol consumption trend 2017-2025 (in MMT)



Source: Ministry of petroleum and natural gas

Beyond petrol consumption, the majority of the oil consumption is encumbered in high-speed diesel oil (HSD) and LPG. Petrol accounts for 17% of the total petroleum product consumption while HSD and LPG account for 38% and 13% respectively. Furthermore, India's petroleum product consumption grew by ~3% in FY25 compared to previous year, reaching a total volume of 239.2 million tonne. This growth was led through a 7.5% increase in petrol consumption and 2% increase in high-speed diesel usage. Robust economic growth, increased industrialization, urbanization, and infrastructure development, along with rising vehicle sales, contributed to the overall higher demand for transportation, energy, and fuel, thereby driving up the consumption of petroleum products.

Figure 41: Petroleum products consumption for FY25



Source: PPAC

From the above data, it becomes clear that there is significant potential for ethanol use in blending in petrol. The same can be inferred from NITI Aayog's Report on Roadmap for Ethanol Blending in India 2020-25. The government and the industry are working towards this goal consistently and rapidly. The efforts expended in this direction have already begun to bear fruits in real and measurable terms in the last 10 years, India's ethanol blending program achieved remarkable milestones both in terms of economic savings and environmental impact. It has led to forex savings of INR 1,13,007 crore (As of 31.12.2024), significantly reducing India's reliance of energy imports.

Additionally, the program effectively substituted 193 lakh metric tons of crude oil and curtailed CO2 emissions by 544 lakh metric tons thereby demonstrating its substantial environmental impact. It has also helped the agriculture and allied sectors; distilleries have earned revenue of INR 1,45,930 crores from sale of ethanol which has added to their bottom line. As of 30.09.2024 this has benefitted farmers as well who have collectively received INR 92,409 crore from OMCs.

Table 10: Projected ethanol requirement, NITI Aayog

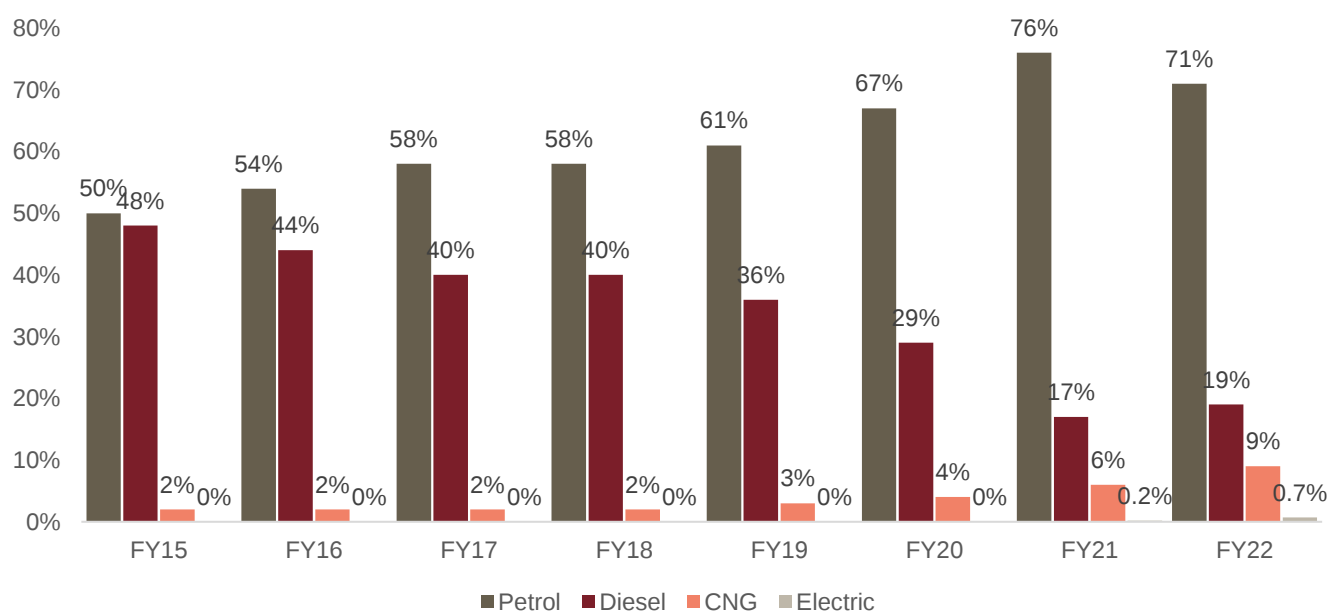
ESY	Projected Petrol Sale (MMT)	Projected Petrol Sale (Cr. Litre)	Blending (in %)	Ethanol Required for Blending in Petrol (Cr. Litre)
A	B	B1 = B x 141.1	C	D = B1 x C%
2019-20	24.1	3413	8	173
2020-21	27.7	3908	8.5	332
2021-22	31	4374	10	437
2022-23	32	4515	12	548
2023-24	33	4656	15	698
2024-25	35	4939	20	988
2025-26	36	5080	20	1016

Source: Roadmap for Ethanol Blending in India 2020-25 (NITI Aayog)

5.2 Petrol is the preferred fuel option among automotive segments in India

Petrol vehicles have gained preference over the diesel vehicles due to narrowing price gap between petrol and diesel.

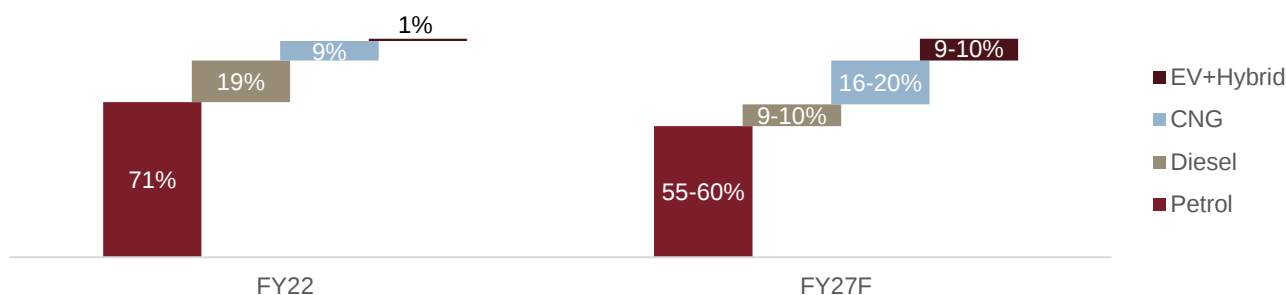
Figure 42: Trend in fuel mix for domestic passenger vehicles segment



Source: SIAM and CRISIL MI&A consulting

Petrol-based vehicles are likely to remain a significant portion of new Passenger vehicle sales over the medium term.

Figure 43: India fuel mix outlook in passenger vehicle



Source: SIAM and CRISIL MI&A consulting

The proportion of CNG, EVs and hybrid is likely to increase to 20-30% as proportion of new vehicles sales in the next 5 years.

- However, petrol-based vehicles are likely to remain a significant portion of new PV sales over the medium term.
- This makes it critical to reduce emissions from petrol-based vehicles to meet corporate average fuel economy (CAFE) norms and start the trajectory towards achieving carbon neutrality over the medium-to-long-term besides promotion through adoption of alternate powertrains including EVs and hybrids.

From the popularity of petrol vehicles, one can infer that there is a substantial market for ethanol even as competition from CNG and EV vehicles mounts up.

5.3 Government initiative in promoting ethanol Industry in addition to National Biofuels Policy

5.3.1 PLI incentive

To increase the production of ethanol in the country and achieve the much-stated target of 20% blending by 2025, the government has announced several schemes for the aligning industry, ultimately benefiting the ethanol production in the country. One of the incentives under the scheme is providing soft loans to sugar mills and a single-window mechanism for expedited regulatory clearance for building grain-based distilleries across the country. This is introduced with the aim of encouraging and enhancing diversion of sugarcane for ethanol production, as majority of the ethanol in the country is currently produced from sugarcane. Since ethanol production is currently concentrated in Uttar Pradesh, Maharashtra and Karnataka, incentives to expand distilleries across India will result in geographically widespread production of ethanol and save huge transport costs from moving ethanol to other states. Additionally, government has also introduced PLI scheme for millet-based products, promoting production of these special grains. Ethanol production from grains is more convenient and economical, however, this route has not been exploited by the country. In order to begin production of ethanol from grains, government has incentivized grains production to secure surplus which could be routed to ethanol refineries.

Under the New Industrial Policy 2025, Government of Karnataka has introduced a scheme where certain industries receive an incentive of 1.75% of their gross revenue for actively participating in and supporting the state's economy and job creation initiatives. Under the Government of Karnataka's scheme, if a company has topline of ₹ 1,000 crore in a financial year, it will receive incentives benefitting it to the tune of ₹ 17.5 crore. TruAlt Bioenergy has been

benefiting from the same, which is paid at the conclusion of each fiscal year, for a period of 10 years starting from Fiscal 2023.

The nationwide implementation of the Ethanol Blended with Petrol (EBP) Programme by the Government aims to boost ethanol production. Several Ethanol Interest Subvention Schemes have been introduced between 2018 and 2022, incentivizing entrepreneurs to establish new distilleries or expand existing ones. These schemes provide an interest subvention, which is borne by the Government of India of 6% or 50% of the interest charged by banks/financial institutions for five years, whichever is lower, accompanied by a one-year moratorium. In a significant development in 2021, the schemes were expanded to encompass ethanol production from grain, further promoting the growth of ethanol production in the country.

Under the New Industrial Policy 2020 – 2025, the government has also introduced the Production Linked Incentive (PLI) scheme for automotive & auto component industry, specifically for flex fuel engine (capable of running ethanol 85 (E85) fuel) manufacturers, providing them with tax incentives. This move is expected to accelerate introduction of Flex Fuel vehicles in India, thus, growing the demand for ethanol in the country.

To further enhance the biofuel roadmap of India, Madhya Pradesh and Rajasthan government have come up with specific ethanol policies, providing incentive packages & subsidies of around Rs 1.5 per litre of ethanol produced for a period of 7-10 years.

The Government of Karnataka has been working hard towards increasing their ethanol adoption. While the central government has set up a target of 20% ethanol blending by 2025, Karnataka government is already undertaking trials for 85% ethanol blend for public busses in collaboration with private companies. The government is in talks with companies to use 100% ethanol and gradually phase out dependence on fossil fuels and has set a target of next 10 years, marking a significant stride toward cleaner and more sustainable energy sources.

As for the incentive amount, the Government of Karnataka has introduced a scheme where certain industries, including distilleries, receive an incentive of 1.75% of their gross revenue for actively participating in and supporting the state's economy and job creation initiatives. Under the Government of Karnataka's scheme, if a company has topline of ₹ 1,000 crore in a financial year, it would receive incentives benefitting it to the tune of ₹ 17.5 crore. TruAlt Bioenergy has been benefiting from subsidy, which is paid at the conclusion of each fiscal year, for a period of 10 years starting from Fiscal Year 2023.

In addition to the incentive for ethanol production, Karnataka holds a significant position as part of India's sugar belt. The state is a major player in sugar production, which provides a readily available feedstock for ethanol manufacturing. This advantageous position in the sugar industry further strengthens Karnataka's capacity to meet its ethanol production goals. The availability of ample sugarcane resources, combined with the incentive scheme, places Karnataka in a favourable position to not only support the state's ethanol initiatives but also boost its economy and contribute to the national ethanol production targets.

5.3.2 Stamp duty exemption

Central Board of Indirect Taxes and Customs (CBIC), in July 2022, has exempted the excise duty on 12% ethanol blended petrol and 15% ethanol blended petrol in order to support the ethanol production in the country.

Special incentives package approval for TruAlt Bioenergy's Ethanol Production

The Government of Karnataka has granted a special incentives package for TruAlt Bioenergy effective from May 2023, concerning their ethanol production plants, which have collectively been recognized as a Super Mega Enterprise under the Industrial Policy 2020-2025. The incentives include a five-year exemption or reimbursement of all kinds of applicable stamp duty and registration charges, in addition to other incentives in line with the New Industrial Policy 2020-2025.

5.3.3 Price setting and subsidy for Potash Derived from Molasses (PDM)

PDM, a potassium rich fertilizer derived from ash in molasses-based distilleries is a by-product of sugar-based ethanol industry. Distilleries produce a waste chemical called spent wash during the production of ethanol which is burnt in an Incineration Boiler (IB) generating Ash to achieve Zero Liquid Discharge (ZLD). The potash-rich ash can be processed to produce PDM having 14.5% potash content and can be used by farmers in field as an alternative to MOP (Muriate of Potash with 60% potash content). Currently, potash as a fertilizer is totally imported in the form of MOP and the production of PDM domestically will reduce import dependency and will help in the government's efforts to make India self-reliant.

The Central Government has facilitated mutually agreed price of PDM at INR 4263/ MT for sale by sugar mills to fertilizer companies for the current year. In addition, PDM Manufacturers can also claim subsidy at INR 345/ Ton at present rates under Nutrients Based Subsidy Scheme (NBS) of Department of Fertilizers. The idea behind these efforts of the government is to facilitate long-term sale/ purchase agreement on PDM between sugar mills and fertilizer companies.

5.3.4 Interest cost subsidy for setting up ethanol plants

Interest Cost Subsidy for Setting-up Ethanol Plants. Under the 'scheme for extending financial assistance to sugar mills for augmentation of Ethanol production capacity', the Government of India extends soft loan to mills for setting up new distilleries/ expansion and installation of incineration boilers or installation of any method as approved by the Central Pollution Control Board for zero liquid discharge and interest cost subsidy on the loans to be extended by banks for five years including a one-year moratorium.

Table 11: State wise ethanol project overview (As of June 2025)

State/UT	Molasses-Based		Dual Capacity		Grain-Based Capacity		Total Capacity	
	No. of Distilleries	Annual Capacity (In Cr. Ltrs)	No. of Distilleries	Annual Capacity (In Cr. Ltrs)	No. of Distilleries	Annual Capacity (In Cr. Ltrs)	No. of Distilleries	Annual Capacity (In Cr. Ltrs)
Andhra Pradesh	7	7	1	3	9	38	17	48
Assam	0	0	0	0	5	26	5	26
Bihar	8	18	0	0	14	70	22	88
Chhattisgarh	1	2	0	0	8	32	9	34
Gujarat	13	16	0	0	3	23	16	40
Haryana	3	6	1	2	18	73	22	82
Himachal Pradesh	0	0	0	0	3	16	3	16
Jharkhand	0	0	0	0	5	32	5	32
Karnataka	36	212	5	29	5	29	46	270
Madhya Pradesh	3	6	1	3	19	94	23	102
Maharashtra	134	310	2	15	32	71	168	396

State/UT	Molasses-Based		Dual Capacity		Grain-Based Capacity		Total Capacity	
Odisha	0	0	0	0	6	23	6	23
Punjab	3	5	1	10	23	115	27	130
Rajasthan	0	0	0	0	10	25	10	25
Sikkim	0	0	0	0	1	2	1	2
Tamil Nadu	13	20	0	0	1	7	14	27
Telangana	2	2	2	6	8	42	12	50
Uttar Pradesh	55	207	8	60	15	64	78	331
Uttarakhand	2	5	1	7	3	30	6	42
West Bengal	0	0	0	0	7	50	7	50
Total	280	816	22	135	195	862	497	1,814

Source: National Government Sources

5.3.5 Use of multiple feedstocks for ethanol production

Earlier, the government only allowed sugarcane as a feedstock for ethanol production. Subsequently, in its Ethanol Blended Petrol Program (EBP) in 2020, it has allowed the use of surplus rice available with the Food Corporation of India (FCI) and maize respectively for blending with petrol. This was further extended to ethanol production from grains in 2021. Typically, dual-feed integration facilities operate for approximately 330 to 340 days per cycle compared to mono-feed facilities, which operate for around 250 to 300 days. In a further attempt to boost the sector, the government has fixed the price of surplus rice from the Food Corporation of India at INR 2,250 per quintal (INR 22.50 per kilogram) and has simplified the associated terms and conditions. This price has come down from INR 2,800 per quintal which was prevalent in the year past. The government is only extending this facility for sale of rice to ethanol distilleries for the purpose of producing ethanol with the FCI allocating the rice as per the quantity of ethanol allocated to distilleries in their contract with OMCs.

In case of shortage in supply of ethanol produced from maize/ other category of feedstock, as allotted during ESY 2024-25, the shortfall may be allotted to ethanol produced using FCI rice. Therefore, under the aforementioned, there are no restrictions on the quantity of FCI rice allocated for ethanol production. This flexibility allows grain-based distilleries to optimize their feedstock management throughout the year, which will significantly reduce inventory costs.

5.3.6 Pradhan Mantri JI-VAN Yojana

The government also approved the Pradhan Mantri JI-VAN Yojana in March 2019, which will support via viability gap funding 2G integrated bioethanol projects using lignocellulosic biomass and other renewable feedstock.

The objective of the scheme is to create an ecosystem for setting up commercial projects and boosting research and development of the 2G ethanol sector.

India is at the cusp of transforming to the 2nd Generation of Biofuel, due to recent government mandates and introduction of the policy “Pradhan Mantri JI-VAN (Jaiv Indhan- Vatavaran Anukool fasal awashesh Nivaran) Yojana” for funds providing an initial push to the 2G ethanol capacity in India and attract further investments in the sector.

Under the scheme, financial support to twelve Integrated 2G Bio-ethanol Projects with a total financial outlay of Rs 1,969.5 crore for the period 2018-19 to 2023-24 has been provided.

Under the PM JI-VAN Yojana initiative, the program establishes a maximum financial aid of Rs. 150 crores for commercial projects and Rs. 15 crores for demonstration projects. This financial support aims to enhance the economic viability of projects and foster research and development in the realm of 2G ethanol production technologies. Presently, the Indian government allows the export of ethanol for non-fuel purposes only for which one needs to have the appropriate licenses while produced 2G Ethanol cannot be exported, it will be necessarily supplied to OMCs and for that, proper connectivity is to be ensured before commissioning the project.

Within the framework of this scheme, a total of Rs. 880 crores have been sanctioned to both Public and Private Sector Oil Marketing Companies (OMCs) for six commercial Second Generation (2G) bio-ethanol projects in states like Punjab, Haryana, Odisha, Assam, and Karnataka. Additionally, two demonstration 2G ethanol projects, one in Haryana and another in Andhra Pradesh, have received approval. The Panipat (Haryana) commercial project has already been inaugurated, while projects in Bhatinda (Punjab), Bargarh (Odisha), and Numaligarh (Assam) are progressing well in their construction phases.

Apart from the financial assistance granted through the PM JI-VAN Yojana, various measures have been implemented to encourage the growth of 2G Ethanol Plants. These include introducing extra excise duty on non-blended fuels, ensuring a guaranteed offtake for 15 years to private stakeholders through Ethanol Purchase Agreements (EPA) signed by OMCs, diversifying the feedstock for 2G ethanol production, establishing a distinct price for 2G ethanol, reducing the GST rate to 5% on ethanol for the EBP Programme, and more.

In August 2024, to keep pace with the latest developments in the field of biofuels and to attract more investment, Government of India modified Pradhan Mantri JI-VAN Yojana. The modified scheme extends timeline for implementation of scheme by Five (05) year i.e. till 2028-29 and includes advanced biofuels produced from lignocellulosic feedstocks i.e. agricultural and forestry residues, industrial waste, synthesis (syn) gas, algae etc. in its scope. "Bolt on" plants & "Brownfield projects" would also now be eligible to leverage their experience and improve their viability.

To promote multiple technologies and multiple feedstocks, preference would now be given to project proposals with new technologies and innovations in the sector. The current scheme envisages setting up of about 12 commercial scale Advanced Biofuel Projects and about 10 demonstration scale Advanced Biofuel Projects based on non-food biomass feedstocks and other renewable feedstocks, this target will be achieved with a financial contribution of INR 1,969.50 crore from the Government. The broader idea is to promote new technologies and innovations in the sector.

The scheme aims to provide remunerative income to farmers for their agriculture residue, address environmental pollution, create local employment opportunities, and contribute to India's energy security and self-reliance. It also supports the development of advanced biofuel technologies and promotes the Make in India Mission. It also helps in achieving India's ambitious target for net-zero GHG emissions by 2070.

The Government of India's commitment to promoting advanced biofuels through the Pradhan Mantri JI-VAN Yojana reflects its dedication to a sustainable and self-reliant energy sector.

Table 12: Classification of biofuels (generation-wise)

Generation	Biofuel characteristics
First	Produced from food crops such as maize, corn, sugar cane, and soybean into ethanol and biodiesel, using a similar process to that used in beer and winemaking
Second	Produced from non-food crops and organic agricultural waste, which contain cellulose
Third	Derived from algae; also known as green hydrocarbons

Generation	Biofuel characteristics
Fourth	Produce sustainable energy as well as capture and store CO ₂ by converting biomass materials, which have absorbed CO ₂ while growing, into fuel

5.3.7 Long-term ethanol procurement policy

Ethanol Blended Petrol (EBP) Programme is aimed at achieving multiple outcomes such as addressing environmental concerns, reducing import dependency and providing boost to agriculture sector. To increase indigenous production of ethanol, Government since 2014 took multiple interventions including, administered price mechanism, opening alternate route for ethanol production, amendment to Industries (Development & Regulation) Act, 1951 which legislates exclusive control of denatured ethanol by the Central Government, reduction in Goods & Service Tax (GST) from 18% to 5%, Notification of National Policy on Biofuels – 2018, increasing scope of raw material for ethanol procurement, interest subvention scheme for enhancement and augmentation of the ethanol production capacity and extension of EBP Programme to whole of India except islands of Andaman Nicobar & Lakshadweep w.e.f. 01st April, 2019.

It has been decided that the price of ethanol derived from damaged and surplus food grains has to be fixed by OMCs. Based on the estimated petrol demand for an OMC location and ethanol prices as fixed for an ESY, OMCs estimate the ethanol demand and float tender/Expression of Interest (EOI). The salient features of this annual tender / EOI are as under:

- The tender is floated every year in the month of August-September for the upcoming ESY. This is followed by three cycles of three rounds each leading to quarter-wise allocation of ethanol quantities.
- Bidders quote the quantity of ethanol they wish to supply feedstock-wise, quarter-wise and location-wise.
- Allocation to successful bidders for a particular location of the OMC is done on the basis of economic linkages calculated as per the distance of the distillery / sugar mill to the OMC location.
- After mapping the ethanol quantity offers, from suppliers, with procurement demand of the OMC location, ethanol quantity gets allocated to the eligible suppliers.
- Legally binding contract is signed between the ethanol supplier and OMCs after collecting five percent of the purchase order amount as the Bank Guarantee (BG) amount.
- For ethanol manufactured from any new category of the product, DFPD issues the guidelines which form the basis for the competent authority in a State to certify the ethanol manufactured from that particular category.
- The main tender is followed by two to three EOI floated every two /three months to garner additional ethanol volumes and give chance to new entrants or capacity additions.
- There is a provision for raising the penalty under the Price Reduction Clause (PRC) of the tender document, if the supplies are less than 80% in a month or 95% in a quarter whichever is higher.

To summarize, annual ethanol procurement quantity (i.e. offtake assurance) is worked out by the OMCs along with ethanol procurement price derived from damaged and surplus food grains (if applicable), whereas, ethanol procurement price derived from sugarcane based raw materials is fixed by the Government taking into account sugar sector scenario. Government directs OMCs to accord prioritization of raw material for ethanol procurement, guidance on transportation rate (which is fixed by OMCs), payment of GST and other administrative requirements to take forward the EBP Programme.

Additionally, in order to simplify the procedure and facilitate the Ethanol production for blending into Petrol, the supply of surplus rice from the stocks of FCI for the production of ethanol was adopted. Permission to allow production of ethanol from surplus rice of FCI and maize was also given.

5.3.8 Ethanol blended petrol (EBP) programme

The Ethanol Blended Petrol (EBP) programme was launched in 2003, aiming to promote the use of environmentally friendly alternative fuels and reduce import dependency for energy requirements. Pilot programs were launched in 2001 at 3 locations i.e., at Miraj, Manmad (Maharashtra) and Bareilly (Uttar Pradesh), wherein 5% blended petrol was supplied to retail outlets. The success of the field trials paved way for the sale of 5% ethanol blended petrol in nine states and four UTs under EBP program 2003.

Under the EBP program, the government undertook several measures like re-introducing administered price mechanism, exploring alternate routes to ethanol production and differential pricing mechanism for ethanol products. The government also introduced several schemes to reduce the price of ethanol blended petrol like reduction in GST on ethanol for EBP and interest subvention scheme. Furthermore, the government has released long term procurement targets for ethanol.

In 2019, the targets were revised to selling 10% ethanol blended petrol by 2022 and 20% by 2030. However, the government achieved its 2022 stated targets and has taken several measures to prepone the existing target of 20% blending in 2030 to 2025.

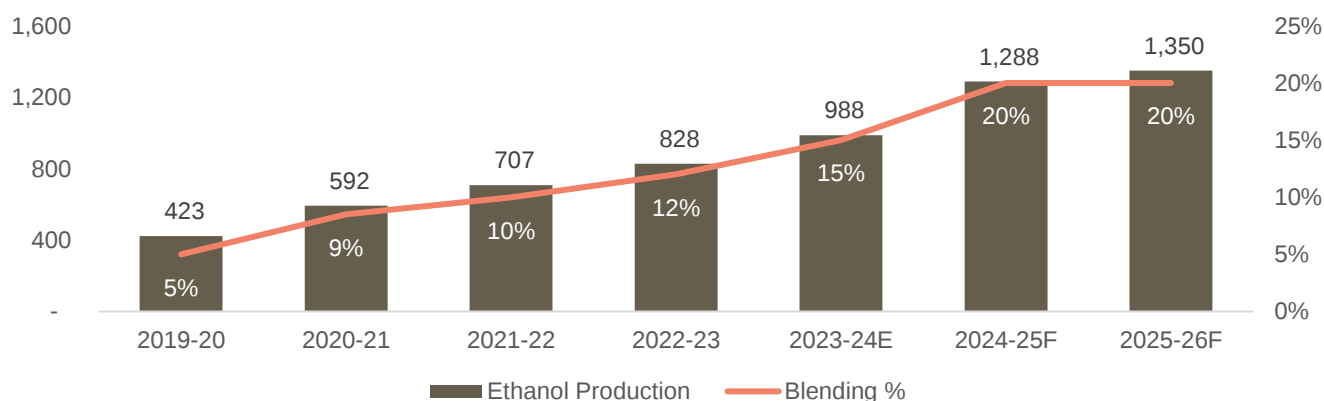
Table 13: Ethanol blending targets under EBP program (in crore litre)

ESY	Ethanol in blending	Ethanol in other usage	Blending %	Total Ethanol
2019-20	173	250	5%	423
2020-21	332	260	9%	592
2021-22	437	270	10%	707
2022-23	548	280	12%	828
2023-24	698	290	15%	988
2024-25	988	300	20%	1288
2025-26F	1,016	334	20%	1,350

Source: Ministry of petroleum and natural gas

In addition to these efforts the Government is also using taxes and duties to encourage ethanol usage and boost the market for ethanol. For instance, an additional basic excise duty of INR 2/ litre is being levied on unblended petrol (not blended with ethanol or methanol) intended for retail sale with effect from 01 November 2022 showcasing the Government's commitment towards bringing ethanol to the forefront.

Figure 44: Ethanol production and blending targets trend (FY20-FY26)

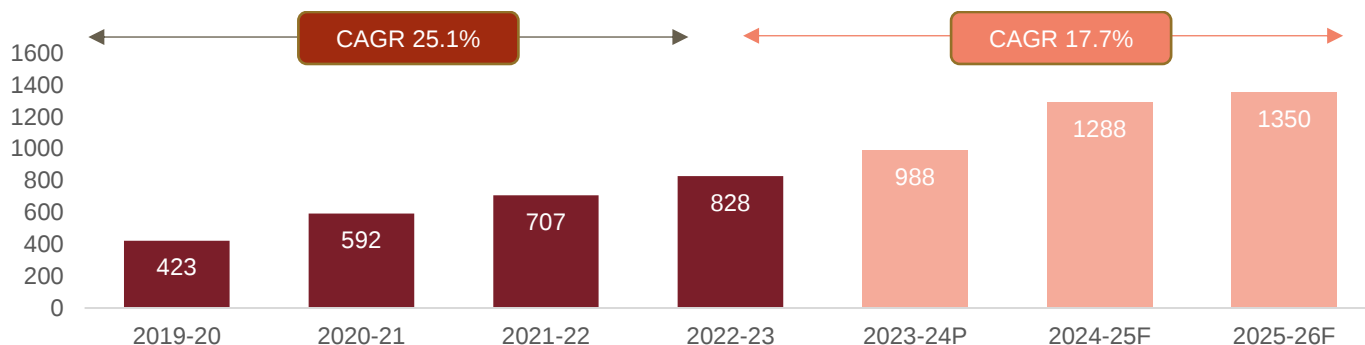


Source: Ministry of petroleum and natural gas
E: Estimated and F: Forecasted

5.4 India ethanol market

The government has been implementing ethanol-blended petrol (EBP) programme throughout the country except Union Territories of the Andaman Nicobar and Lakshadweep islands. As part of EBP, oil marketing companies (OMCs) sell petrol blended with an average 19.05% ethanol as of July 2025, which will be increased to 20.00% by ESY 2025-26. By ESY 2025-26, at 20% blending level, ethanol demand will increase to 1,016 crore litres. Therefore, the worth of the ethanol industry will jump by over 500% from around INR 9,000 crore to over INR 50,000 crore

Figure 45: India ethanol market demand and outlook (crore litre)



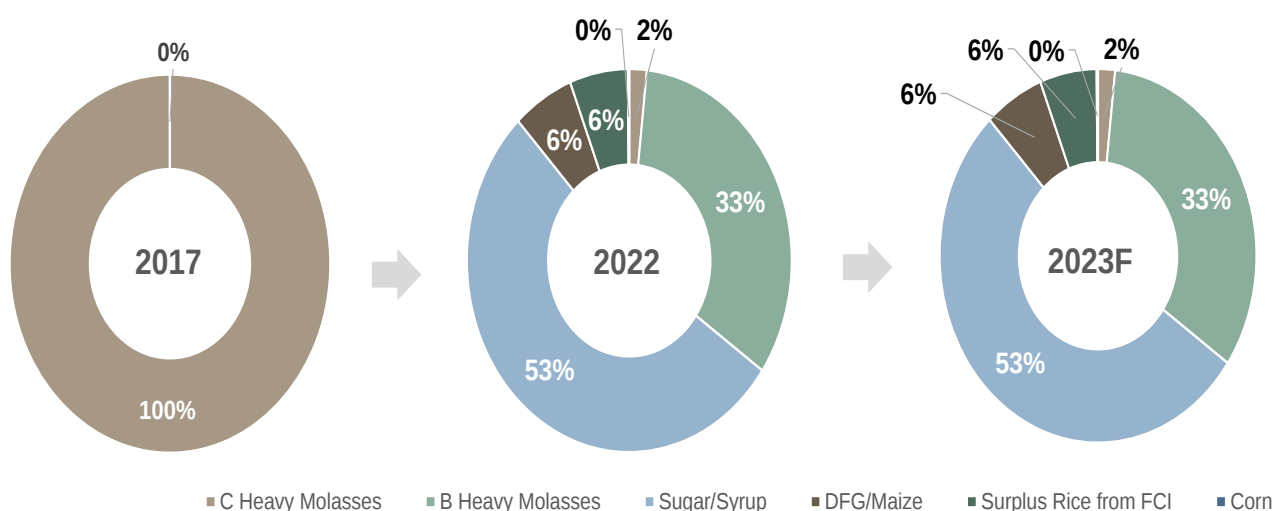
Source: NITI Aayog and ministry of petroleum and natural gas

P: Projected F: forecasted

Ethanol demand India is expected to grow at a CAGR of 17.7% till fiscal 2026. The Government has already begun planning for the future by exploring goals beyond the 20% blending target. Apart from the advancing of the 20% blending target to 2025 from 2030, the Government has also shifted focus towards second-generation ethanol which will further help the sector. The Government of India and certain State Governments have also included Ethanol projects under their priority sector lending criteria, which has encouraged banks to sanctions loans for Ethanol projects to achieve priority sector lending thresholds.

5.4.1 India ethanol market by source / feedstock

Figure 46: Ethanol percentage contribution from different Feedstock (2018-23P)



Source: Ministry of Petroleum and Natural Gas

F: Forecasted

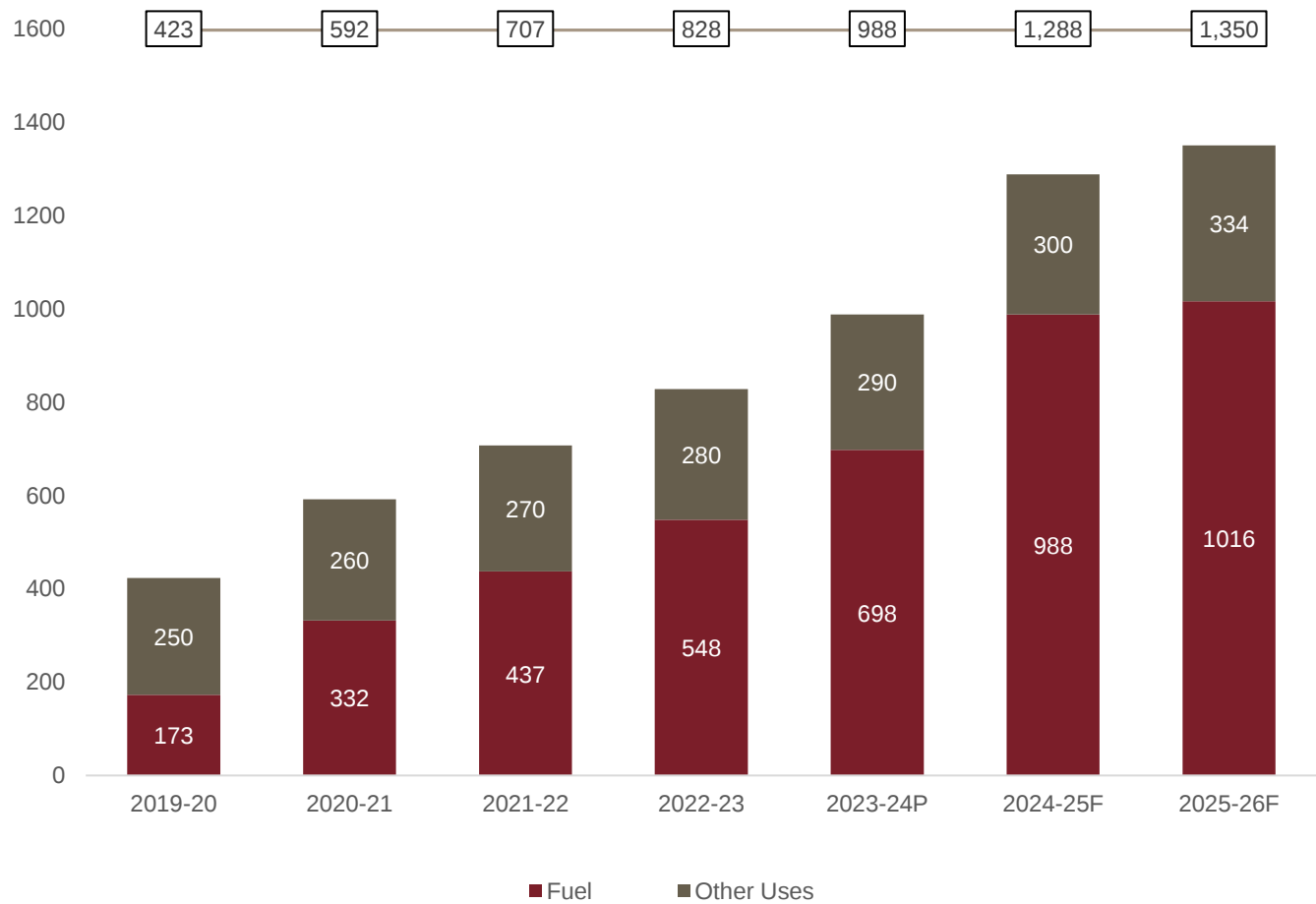
DFG; Damaged Food Grains; FCI: Food Corporation of India

During 2017, nearly all the ethanol was produced from C-Heavy Molasses. However, post implementation of the National Biofuel policy in 2018, industries started adopting B Heavy Molasses as the primary feedstock. Several alternatives to the feedstocks were identified, currently four feedstocks (sugar, molasses, damaged food grains, and maize) contribute to the production of ethanol in India. Over the years, sugarcane has become the most important source of biofuels.

5.4.2 India ethanol market by application

In the fiscal year 2022-2023, the overall Ethanol market, including Ethanol for diverse uses, is estimated to be at 828 crore litres and is anticipated to expand significantly, reaching 1,350 crore litres by the year 2026. This upward trajectory underscores the nation's robust commitment to increasing Ethanol utilization, higher blending targets under the EBP Program, potential utilisation of Ethanol as bio-diesel, for flex fuel vehicles, cooking fuel and SAF, reinforcing sustainable energy practices, and fostering a greener future. Keeping in line with the green theme, carbon dioxide may be captured while producing Ethanol is also being proposed to be used for producing methanol and calcium carbonate, which have multiple applications of their own.

Figure 47: Indian ethanol market share by application trend (in crore litre)



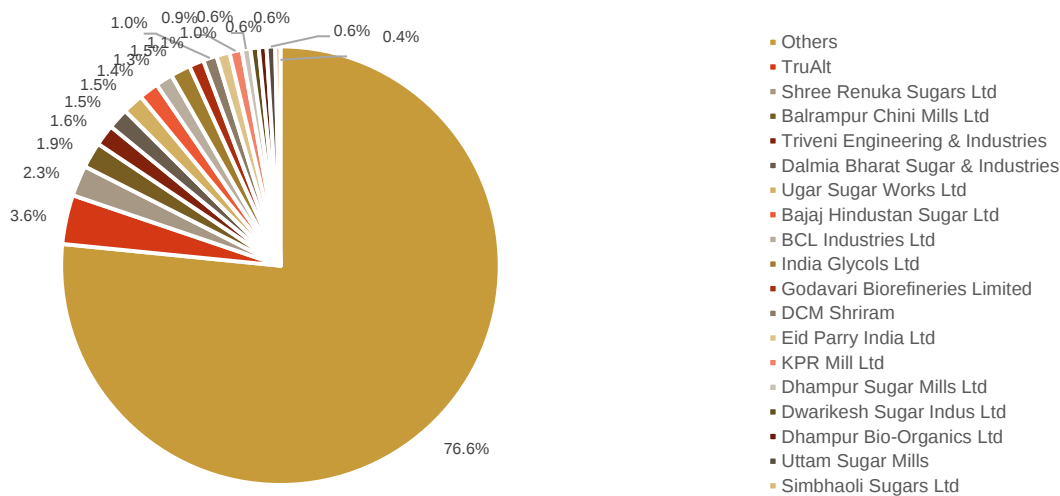
Source: NITI Aayog and ministry of petroleum and natural gas

Other usage of ethanol includes industrial solvents, pharmaceuticals and medical products, cosmetic and personal care, etc.

P: Projected F: forecasted

5.4.3 India ethanol market share by production capacity

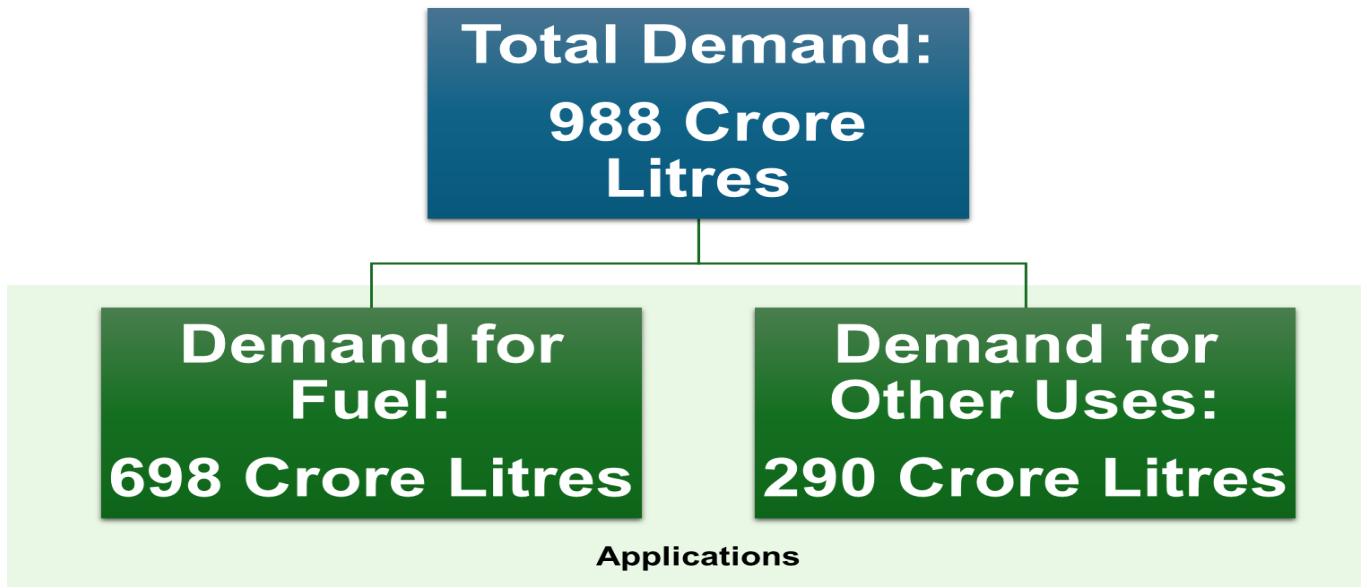
Figure 48: Indian ethanol market share by installed production capacity (FY25)



Source: Company annual reports

The India Ethanol market is characterized by a high degree of fragmentation, with numerous players contributing to its dynamic landscape. Among the leading players in this sector, TruAlt Bioenergy stands out with a highest market share of 3.6% by capacity during FY 2025, driven by its robust capacity expansion. Shree Renuka Sugars Ltd follows closely, underlining the competitive nature of the market, while Balrampur Chini Mills Ltd also plays a significant role. This diversity not only ensures a broad range of options for consumers but also stimulates innovation and the development of advanced technologies in ethanol production.

Figure 49: Indian ethanol market share by application overview



Source: Ministry of Petroleum and Natural Gas

Earlier, ethanol was majorly consumed in the development of industrial chemicals like ethylene, acetic acid, and ethyl acetate, however, after the initiation of blending programs by the government, ethanol is majorly used for fuel consumption. This trend is expected to continue and increase with the government setting 20% blending targets for 2025. Furthermore, the government is exploring alternative feedstock and 2G ethanol production standards to prevent the food vs fuel conflict. At the same time, demand for industrial ethanol is also likely to rise in coming years in tandem with the expansion of its domestic chemical and healthcare sectors.

5.4.4 India ethanol price by feedstock

The production of ethanol requires voluminous amounts of sugarcane juice, sugarcane syrup, and molasses as raw material. Raw material procurement and pricing is critical in the ethanol industry, where the price of ethanol is regulated by the Government of India through the purchase prices state OMCs pay for sourcing ethanol. End users of OMCs include retail fuel consumers.

In addition, owing to the seasonal variation in sugarcane supply, there is heavy fluctuation in the price at which ethanol producers are able to obtain sugarcane juice and molasses, although the Government of India sets floor prices for ethanol sourced from various feedstocks, as indicated below:

Table 14: Feedstock procurement prices for ethanol in INR/ Litre

ESY (Dec-Nov)	Feedstock for ethanol production					
	Sugarcane juice/ syrup/ sugar	B-Heavy molasses	C-heavy molasses	Damaged foodgrains	Maize	Surplus rice
2018-19	59.19	52.43	43.46	47.13	Introduced from ESY 2020-21	
2019-20	59.48	54.27	43.75	50.36		
2020-21	62.65	57.61	45.69	51.55	51.55	56.87
2021-22	63.45	59.08	46.66	52.92	52.92	56.87
2021-22 (including relief w.e.f. 01 June 2022)	65.05	60.57	47.84	55.26	55.26	58.31
2022-23 (Dec to Oct)	65.61	60.73	49.41	64.00*	66.07*	58.50
2023-24 (Nov to Oct)	65.61	60.73	56.58**	64.00*	71.86**	58.50
2024-25 (Nov to Oct)	65.61	60.73	57.97	64.00	71.86	58.50

*OMCs have increased the incentive on Maize-based ethanol by 9.72 to Rs. 66.07 per litre and DFG-based ethanol by Rs. 8.46 to Rs. 64.00 per litre with effect from 07.08.2023

**OMCs have increased the incentive on Maize-based ethanol from Rs. 66.07 to Rs. 71.86 per litre from 05.01.2024 and C-heavy molasses-based ethanol prices from Rs. 49.41 to Rs. 56.58 per litre for ESY 2023-24 (it has further increased to Rs. 57.97 per litre for ESY 2024-25)

Source: Department of Food & Public Distribution

After the production of feedstock, certain cost drivers are associated with the production and final price of the E100 fuel which include processing cost for OMCs which differs from distillery to distillery across the country. In October 2023, GST on molasses has been revised from 28% to 5%, which is beneficial to the industry as tax on raw material has been reduced significantly. There is no excise duty on the price to dealers on any type of ethanol for blending. Dealer commission is also fixed which is decided by the governments mandate. A VAT of 30% is levied on this price in Delhi which ultimately gets to the final price of E100 in the country.

Government has advanced the target of 20% ethanol blending in petrol from earlier 2030 to ESY 2025-26 and a "Roadmap for ethanol blending in India 2020-25" has been put in public domain. As a step in this direction, OMCs plan to achieve 18% blending during the ongoing ESY 2024-25. Other recent enablers include enhancement of ethanol distillation capacity to 1,814 crore litre per annum; Long Term Off-take Agreements (LTOAs) to set up Dedicated Ethanol Plants (DEPs) in ethanol deficit States; encourage conversion of single feed distilleries to multi feed; availability of E-100 and E-20 fuel; launch of flexi fuel vehicles etc. All these steps also add to ease of doing business and achieving the objectives of Atmanirbhar Bharat.

The Government has been promoting blending of ethanol in petrol under the Ethanol Blended Petrol (EBP) Programme wherein Public Sector Oil Marketing Companies (OMCs) sell ethanol blended with petrol. During the ongoing ESY 2024–25, OMCs have achieved an average ethanol blending of 19.05% as on 31.07.2025. In the month of July 2025, Ethanol blending of 19.93% has been achieved.

In order to ensure availability of feedstock for ethanol production to achieve 20% Ethanol blending target by the Ethanol Supply Year (ESY) 2025-26, the Government have taken several steps which inter-alia includes:

- i. Expansion of feedstock for Ethanol production as per the National Policy on Biofuels, as amended in 2022.
- ii. Development of Maize Cluster around ethanol plants by Department of Agriculture and Farmers Welfare (DAFW) and a Project by ICAR-Indian Institute of Maize Research (IIMR) titled "Enhancement of maize production in catchment areas of ethanol industries" to increase the production of maize in catchment area of grain-based distilleries.
- iii. Approval by Government for allocation of 52 Lakh Metric Tonne (LMT) of surplus Food Corporation of India (FCI) rice for ethanol production, each for the ESY 2024-25 (from 1st November 2024 to 31st October 2025) and ESY 2025-26 up to 30.06.2026.
- iv. Diversion of 40 LMT of sugar for ethanol production allowed for the ESY 2024-25.

5.4.5 Yield comparison of ethanol based on the type of feedstock

Table 15: Ethanol yield based on feedstock

Feedstock	Quantity of ethanol per MT of feedstock	Realisation / MT of feedstock (Rs.)	Realisation per litres of Ethanol (RS/Litre)	ESY 24-25 (Rs/Litre)
Sugarcane	70 litres	3,446	49.2	65.61
Sugarcane Syrup (55 Brix)	290 litres	14,335	49.4	65.61
B-Heavy Molasses	298 litres	13,750	46.1	60.73
C-Heavy Molasses	255 litres	11,700	45.9	57.97
Damaged Foodgrains#	400 litres	28,000	70.0	64.00

Feedstock	Quantity of ethanol per MT of feedstock	Realisation / MT of feedstock (Rs.)	Realisation per litres of Ethanol (RS/Litre)	ESY 24-25 (Rs/Litre)
Surplus Rice (FCI)	450 litres	22500	50	58.50
Corn (Maize)#	380 litres	23,500	61.8	71.86

Source: CRISIL MI&A consulting

Note: Price of sugarcane calculated at 10.5% sugar recovery. Price of surplus rice for total quantity not exceeding 1.2MT

#The rates vary from region to region and in accordance with demand/supply or quality.

While sugarcane, sugarcane syrup, and maize are high-yielding feedstocks for ethanol production; however, their broader acceptability may be challenged by the conflict of food vs fuel. This calls for the adoption of 2G ethanol feedstock to preserve food security of India. The Government has recently launched the “Innovation Roadmap of the Mission Integrated Biorefineries”, standards for setting up 2G Ethanol refineries in the country. The mission aims at greater international collaboration and the need for increased financing for energy research, development, and demonstration during the next five years through public-private investment.

Sugarcane and Maize have been used for ethanol production in India and around the globe. However, with recent mandates of government allowing alternatives feedstock for ethanol production, allowing of rice from Fertilizer Corporation of India and damaged grains to be used for production. Rice, Sugarcane and Maize has the highest yield making them an optimum feedstock for ethanol production.

The 'off-season' for sugarcane crushing, between April to September, witnesses a steep increase in the price of molasses in the open market, in addition to reduced availability. During the off-season of sugar cane production, grain-based feedstock, such as corn or wheat, is harvested and processed at ethanol production facilities. The grains are milled to extract starch, which is then converted into fermentable sugars through enzymatic processes and fermented to produce ethanol. Distillation and dehydration steps separate and purify the ethanol, making it suitable for various applications. This strategic use of grain-based feedstock allows ethanol production to continue year-round, ensuring a consistent supply of bioethanol for fuel and industrial purposes while complementing the production cycle of sugar cane.

5.5 Note on 2nd generation ethanol

Studies indicate that Lignocellulosic surplus biomass availability in India is around 12-16 crore tons per annum. If exploited, this has potential to yield 2500 to 3000 crore litres of Ethanol per annum and has potential to reduce India's dependence on imported crude oil considerably. 2G Ethanol Biorefineries, apart from producing Cellulosic Ethanol, also produces Pellets (from surplus lignin); Biogas (which can be upgraded to Bio CNG); liquid CO₂/ Dry Ice (for supplies to Poly Houses & Cold Storages, which would support Horticulture activity) & assured quality Compost (which will increase farm yields & reduce chemical fertilizer consumption). Thus 2nd Generation Bio-refineries would be integrated Bioenergy projects. A 100 KL per day plant can utilize 2 lakh tonne per annum of agricultural residue to generate around 3 crore litres of ethanol per annum, to put things into perspective, we have 8,00,000 MT available to utilise.

Burning of crop residues is also a health hazard in Northern India which is adversely affecting the environment by adding to GHG emissions. Similarly, Landfills and Municipal Solid waste also add to the Environment problems by causing Soil and water pollution. Setting up of these 2G Ethanol Biorefineries will also help in addressing the above issues and will aid in improving health of citizens. 2G Ethanol Biorefineries will also contribute to socio-economic development of rural India by providing remunerative income to farmers for their otherwise waste agriculture residues. It will also create a large number of direct and indirect jobs, in the Biomass Supply Chain & Bio Refinery. 2G Ethanol

Biorefineries also present significant potential to manufacture high value by-products such as Furfural, Xylitol, L-Arabinose, high fructose syrup etc. which may increase profitability in the processes involved.

Growing awareness and adoption of biofuels in the domestic market present significant opportunities for 2G ethanol producers to cater to local fuel requirements. The aviation sector is increasingly looking towards sustainable aviation fuels (SAF) to reduce its carbon footprint. 2G ethanol can be a key component in the production of SAF, opening up new avenues for market growth and collaboration with the aviation industry. This can be seen in reality as well, as on January 2025, 17,400 PSU outlets are dispensing E20 Ethanol Blended MS. The government has also said that by 2025 the entire country will have special fuel stations retailing E20 petrol, drawing confidence from the faster rollout of such fuel stations.

Additionally, 2G ethanol can be used as an additive to enhance the performance of conventional fuels. It helps in reducing emissions and improving fuel efficiency in internal combustion engines, making it an attractive option for the automotive industry. Utilizing 2G ethanol for electricity generation provides a renewable and sustainable alternative to fossil fuels. This application contributes to energy security and grid stability, supporting the transition to greener energy sources.

Furthermore, 2G ethanol serves as a valuable feedstock for the production of bioplastics and biochemicals. This supports the shift towards environmentally friendly and sustainable manufacturing practices, reducing the reliance on petroleum-based products. The production process of 2G ethanol generates high-value by-products such as furfural, xylitol, L-arabinose, and high fructose syrup. These by-products offer additional revenue streams and enhance the economic viability of 2G ethanol plants, contributing to a more sustainable and profitable bioeconomy. The government has taken note of the same and has been working towards boosting the viability of 2G ethanol in India through schemes such as the PM JI-VAN Yojana.

Prospective Product Applications

- As a fuel additive, 2G Ethanol improves combustion efficiency, boosts octane ratings, and lowers emissions, making it a valuable component in cleaner gasoline formulations.
- For electricity generation, 2G Ethanol offers a renewable power source that can be utilized in power plants and cogeneration systems, providing both electricity and heat efficiently.
- In the realm of bioplastics and biochemicals, 2G Ethanol acts as a sustainable feedstock, reducing reliance on petroleum-based products. It facilitates the production of biodegradable polymers for packaging, agriculture, and medical applications, and supports green chemistry initiatives by contributing to the synthesis of environmentally friendly products.
- 2G Ethanol can be converted into high-value by-products such as furfural, xylitol, L-arabinose, and high fructose syrup, each finding significant applications in bio-based chemicals, food, and pharmaceutical industries.
- 2G Ethanol further can be applied to produce elastomers, specialty fuels and SAF molecules. The production of MVL from 2G Ethanol opens avenues in biotechnology and pharmaceuticals, serving as a precursor for isoprenoids and cholesterol synthesis. This versatility extends to advanced materials and specialty chemicals. Beyond these applications, 2G Ethanol can be transformed into bio-based elastomers for tires and industrial uses, specialty fuels meeting specific performance criteria, and SAF, contributing to the aviation industry's efforts to reduce its carbon footprint. Overall, the diverse applications of 2G Ethanol underscore its importance in fostering a more sustainable and eco-friendly future.

5.6 Molecular grade ethanol

Molecular grade ethanol refers to a highly purified form of ethanol which is specifically refined to meet stringent standards for use in laboratory and scientific applications. It typically possesses a purity level exceeding 99%, with minimal impurities such as water, denaturants, or other contaminants. This exceptional purity ensures that molecular grade ethanol provides consistent and reliable results in various scientific processes, including molecular biology, biochemistry, pharmaceutical research, and analytical chemistry.

The market for molecular grade ethanol exhibits significant potential, driven by increasing demand across multiple sectors. Research and development activities, particularly in biotechnology, molecular biology, and pharmaceuticals, are major contributors to the market's growth. Additionally, the healthcare industry relies on molecular grade ethanol

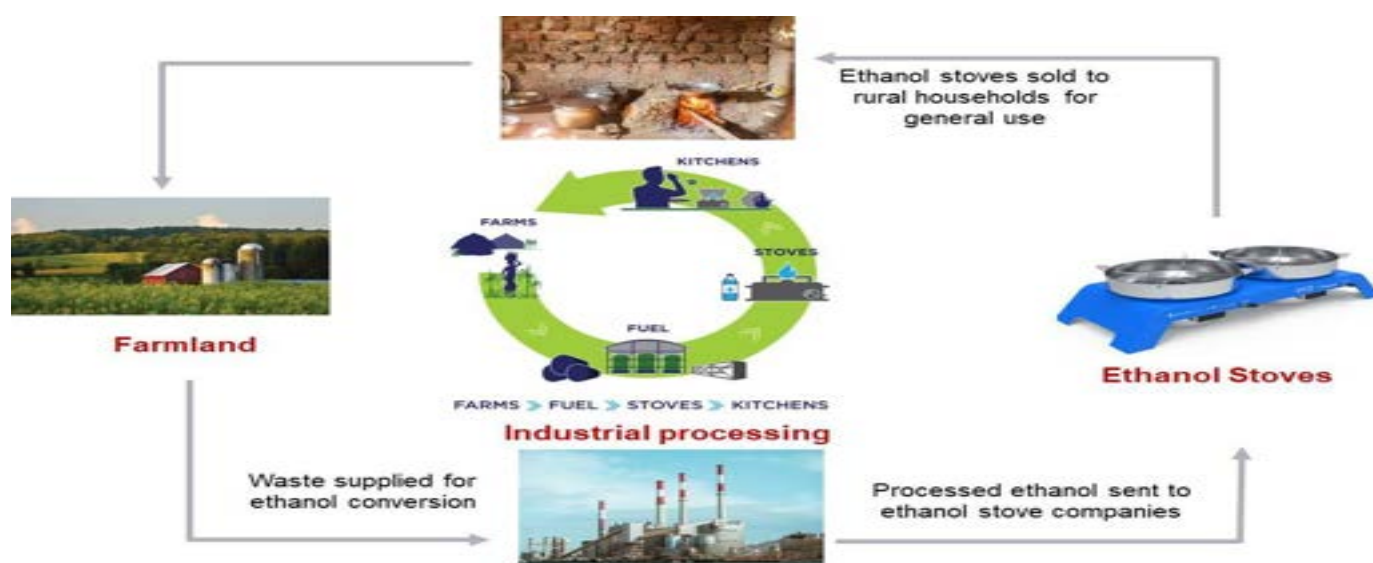
for its antiseptic and disinfectant properties, further augmenting market demand. Moreover, the cosmetics and personal care sector increasingly values high-purity ingredients, creating additional avenues for market expansion.

5.7 Use of Ethanol as a cooking fuel

Ethanol burns with a slow, steady, and slightly visible flame. It is required to be stored in closed containers due to its combustible nature and increased evaporation speed. Special care needs to be taken in households to fully extinguish the flame while filling ethanol stoves.

Recently, HPCL, one of the biggest oil companies of India, has partnered with IIT Guwahati, to develop ethanol cooking stove which is expected to see a pilot soon. HPCL also plans to launch ethanol ATMs for users to procure ethanol canisters for the ethanol stove. Several African nations like Ethiopia, Nigeria, Kenya, Mozambique, Madagascar, etc. are either using or exploring the use of ethanol as a cooking fuel to diversify their options and prevent issues in times of supply disruptions or price increases.

Figure 50: Ethanol used as a cooking fuel



Source: Project Gaia and CRISIL MI&A consulting

5.8 Distiller's Dried Grains with Solubles (DDGS)

Distillers' dried grains with solubles (DDGS) are a significant by-product of the ethanol production process, particularly from starch-rich grains like corn, wheat, or barley. Following fermentation, which converts grains into ethanol, the resulting residues are transformed into distiller's dried grains (DDG). Through subsequent drying procedures and the reintegration of liquid solubles, DDGS is formed, offering enhanced protein and energy content compared to DDG alone. The market for DDGS has seen heightened supply as a result of increased grain-based ethanol distilleries from Maize DDGS and Rice DDGS, both standing at a current price of Rs.16,000 per MT as of first week of June 2025.

Functioning as a pivotal protein source within animal feed formulations, DDGS serves as an economically viable alternative to conventional protein supplements like soybean meal. However, there is an opportunity to improve its digestibility, thus, increasing its value. Further processing can enhance DDGS digestibility from approximately 50% to over 70%, yielding a high-value product suitable for fisheries and poultry industries. Additionally, refinement can yield High Protein DDGS, elevating its protein content from around 45% to over 60%.

While DDGS is primarily utilized in cattle feed, rice protein can be used for human consumption. Rice protein is a premium grade product and its high value in the market makes it an attractive commodity. Establishing rice protein

production alongside grain-based distillery operations, where rice serves as a feedstock, presents a promising opportunity.

5.9 Mevalonolactone (MVL)

Mevalonolactone, a chemical compound derived from mevalonic acid, finds various applications particularly in the pharmaceutical and biochemical industries. It serves as a precursor in synthesis of essential compounds like cholesterol, which is crucial for cellular function and hormone production. In pharmaceuticals, mevalonolactone is integral to the manufacturing of statins, a class of drugs used to lower cholesterol levels. Additionally, its role extends to research and development in biochemical studies, contributing to advancements in understanding metabolic pathways and drug discovery. Its versatile applications underscore its significance in both industrial and scientific areas.

It is possible to synthesize mevalonolactone from ethanol, though not directly. The process involves several biochemical steps using engineered microorganisms or chemical synthesis routes. These methods leverage ethanol as a starting material taking advantage of its availability and relatively low cost to produce more complex and valuable bio-compounds like mevalonolactone. Advances in metabolic engineering and synthetic biology continue to improve the efficiency of these conversion processes.

5.10 Extra-Neutral Alcohol (ENA)

ENA is the primary raw material in the production of alcoholic beverages. The production process of ENA is similar to ethanol and requires the same raw materials, but the cost of production of ENA is typically slightly lower than ethanol although the selling price may be higher.

ENA is subject to price volatility and unavailability caused by external conditions such as government interventions like allocation for fuel blending, commodity price fluctuations within India and globally, weather conditions, supply and demand dynamics, logistics and processing costs, inflation and governmental regulations and policies. Further, companies are required to pay import duty when they procure ENA from states other than those where their facilities are located. This could lead to reduced demand for ENA from companies based in states outside Karnataka.

Further, the unavailability of raw materials such as sugarcane for ENA production can also be caused by other conditions, such as pandemics, seasonality, inflation and general economic and political conditions, civil disruptions in the region, or changes in the policies of the state or local government of the region or the Government of India, including restrictions by the relevant state government on selling of ENA outside that particular state. Other seasonal factors such as irrigation, area of sugarcane production, and amount of rainfall also play a role in determining the quantity and quality of sugarcane produce.

5.11 India ethanol capacity overview and outlook

5.11.1 Existing ethanol capacity in India

The Annual Production capacity in India of Ethanol has been constantly rising due to a number of factors, including not limited to, amendments in EBP program, rising adoption of Ethanol Blending in India, changes in pricing mechanism, and experimentation of new feedstock. India's ethanol capacity has jumped more than four times in the last 11 years reach 1,814 crore litres annually (this has surged from 410 crore litres in 2013) with the help of favourable policy initiatives. Of the 1,814 crore litres of installed capacity, 816 crore litres is molasses based, 136 crore litres is dual feed capacity while the remaining 858 crore litres is grain-based capacity. With an enhanced installed production capacity, the blending of ethanol with petrol has surged to 19.93% in July 2025 from 1.53% in 2013, leading to huge savings in foreign exchange of more than INR 1.10 lakh crore as well as benefits to sugarcane and food grain farmers.

During the last 11 years, the total revenue generated by sugar distilleries/ mills has been around INR 2 lakh crore (this figure includes grain-based distilleries). Of this figure, INR 1.22 lakh crore has been generated by sugarcane-based distilleries alone.

5.11.2 Ethanol capacity required to achieve blending targets and beyond

Government has notified Pradhan Mantri JI-VAN (Jaiv Indhan - Vatavaran Anukool fasal awashesh Nivaran) Yojana for promoting Second Generation (2G) ethanol production from cellulosic and lignocellulosic biomass including petrochemical route in the country by providing financial support for setting up 2G ethanol bio-refineries. Oil CPSEs are setting up 2G ethanol bio-refineries in the country at Panipat (Haryana), Bathinda (Punjab), Numaligarh (Assam), Bargarh (Odisha) and one demonstration project at Panipat. This upward trajectory underscores the India's robust commitment to increasing ethanol utilization, reinforcing sustainable energy practices, and fostering a greener future. India aims to take ethanol blending percentage beyond 20% to augment the benefits being received at present. This will require further increases in the ethanol capacity of India which presents a massive opportunity for players operating in the ethanol industry.

5.12 India biofuel dispensing stations

As of February 2025, India has made substantial progress in achieving its ethanol blending target, reaching a blending rate of ~18%. This accomplishment is a significant stride toward the national objective of achieving a 20% ethanol blending target by 2025. Furthermore, as of January 2025 the total number of Ethanol fuel dispensing stations across the country dispensing E20 fuel has surged to about 17,400 outlets and E100 is dispensed at over 400 retail outlets. India is closer to achieving the target of 20% Ethanol blending by 2025-26 and this highlights the growing infrastructure to support Ethanol-blended fuels while marking a significant milestone in the country's transition towards more environmentally conscious fuelling options.

In addition to E85 ethanol, another notable ethanol blend gaining traction in India is E93. This advanced fuel technology offers a blend containing approximately 93% ethanol and 7% gasoline. Upcoming vehicles equipped with E93 ethanol flex fuel technology, such as the Toyota Innova, signify a growing trend towards sustainable fuel options in the automotive industry. Additionally, TVS has already made strides in this direction by launching the Apache RTE 200Fi E100 in 2019, which utilizes E93 ethanol as a primary fuel source.

Tata Motors has said that it will be adding the flex fuel variant of the Punch. The Punch flex fuel was showcased at the recently concluded Auto Expo 2025. Additionally, Suzuki Motor Corporation (SMC), parent company of Maruti Suzuki, recently released its new mid-term management plan where the Japanese auto giant curbed its EV ambitions. Instead, Suzuki will be working on introducing more hybrids and flex-fuel models in the future. Hyundai has also increased its interest towards this segment by showcasing the Flex Fuel variant of its popular model Creta which will be 100% compatible ethanol. Honda Motors has also been active in this segment with all Honda cars manufactured in India since 1 Jan 2009 being E20 Material Compatible, i.e., customers can use the E20 fuel in their existing Honda cars without the need of changing any part in their cars.

Historically, the blending of ethanol and petrol was completed by the OMC. However, current dynamics for E93 fuel may lead to ethanol and motor spirits (MS) blending at the distilleries. During the last 10 years these ethanol blending initiatives have enhanced farmer incomes, increased rural employment, reduced CO2 emissions equivalent to planting 1.75 crore trees and resulted in savings of Rs 85,000 crore worth of foreign exchange.

In other major developments in this space, the Indian government approved the Review of Guidelines for Granting Authorization to market Transportation Fuels. This marks a major reform of the guidelines for marketing of petrol and diesel. The policy for granting authorization to market transportation fuels had not undergone any changes for the last 22 years since 2002. It has now been revised to bring it in line with the changing market dynamics and with a view to encourage investment from private players, including foreign players, in this sector. The new Policy will give a fillip to 'Ease of Doing Business', with transparent policy guidelines. It will boost direct and indirect employment in the sector. Setting up of more retail outlets (ROs) will result in better competition and better services for consumers.

Salient features and major impact of the revision

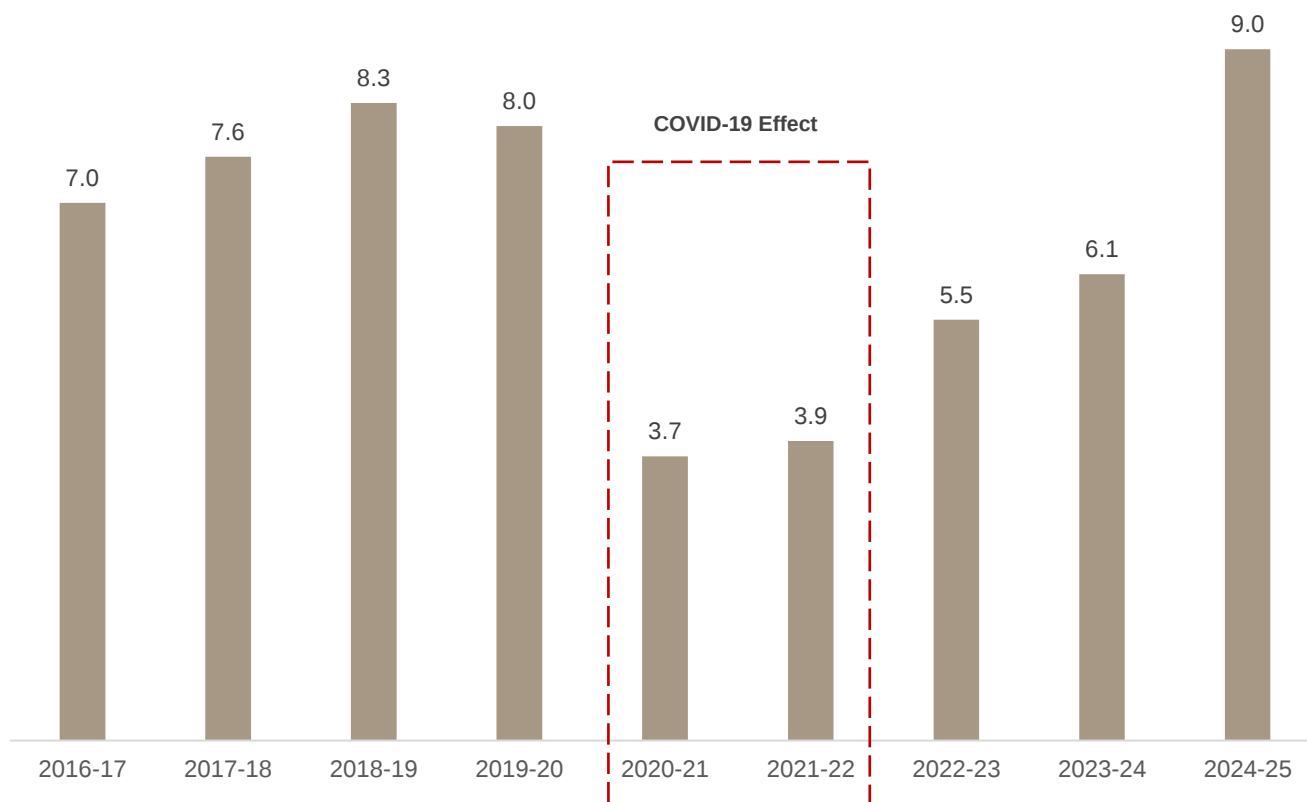
- Much lower entry barrier for private players, the entities seeking authorisation would need to have a minimum net worth of Rs.250 crore vis-à-vis the current requirement of Rs. 2000 crore prior investment.

- Non – Oil Companies can also invest in the retail sector. Requirement of prior investment in Oil and Gas Sector, mainly in exploration and production, refining, pipelines/terminals etc., has been done away with.
- The entities seeking market authorisation for petrol and diesel are allowed to apply for retail and bulk authorisation separately or both.
- The companies have been given flexibility in setting up a Joint Venture or Subsidiary for market authorisation.
- In addition to conventional fuels, the authorized entities are required to install facilities for marketing at least one new generation alternate fuel, like CNG, LNG, biofuels, electric charging, etc. at their proposed retail outlets within 3 years of operationalization of the said outlet.
- More private players, including foreign players, are expected to invest in retail fuel marketing leading to better competition and better services for consumers.
- The new entities will bring in latest technology for marketing of fuels and also encourage digital payments at the ROs.
- Entities will also encourage employment of women and ex-servicemen at the retail outlets.
- The authorised entities are required to set up minimum 5% of the total retail outlets in the notified remote areas within 5 years of grant of authorisation. A robust monitoring mechanism has been set up to monitor this obligation.
- An individual may be allowed to obtain dealership of more than one marketing company in case of open dealerships of PSU OMCs but at different sites.

6 Sustainable Aviation Fuel (SAF)

6.1 Scope for SAF in India & government mandate's towards SAF

Figure 51: Consumption trend of ATF in India, 2017-2025 (MMT)



Source: PPAC

India's consumption of ATF has seen a robust increase in consumption as the Indian middle class takes to the skies with an increasing disposable income. ATF consumption saw a sharp decline in 2020-21 as air travel became severely restricted due to restrictions imposed on account of the COVID-19 pandemic, however, the demand has since recovered and has reached and even exceeded pre-pandemic levels. As per IBEF estimates, with India's population nearing 1.4 billion, it will be home to the fastest-growing air passenger market in the world, driven by infrastructure developments and expected passenger numbers rising annually from 158 million in 2017 to an estimated 572 million by 2037, largely due to the expanding middle-class demographic. India was among the top 5 developing countries in aviation emissions as per a study conducted by the Norwegian University of Science and Technology, this necessitates the need to decarbonize the sector. Environmental imperatives are driving the aviation industry towards sustainable alternatives. Stringent global regulations and sustainability goals are pressuring airlines to reduce their carbon emissions. As a result, there is an increasing demand for SAF, which can be blended with traditional fuels to help airlines meet these targets.

Currently, the SAF market in India is in nascent stages. A lot of companies are researching and developing aircraft for SAF. On May 2023, Air Asia tested its flight between Pune and Delhi completely on SAF, produced using indigenous feedstock. As per government targets, India is looking to achieve a 1% blending rate for SAF by 2027 and 2% by 2028 both for international flights initially which will translate to around 14 crore litres. Airbus CEO has also confirmed the firm's effort to stimulate changes needed to transform India into a SAF marketplace.

There are several reasons for SAF to become a mainstay of India's aviation sector, the foremost being India's abundance of feedstock potential. India takes pride in its wealth of biomass resources, which are crucial for the production of Sustainable Aviation Fuel (SAF). These resources include a variety of agricultural residues and waste products that are abundant and sustainable. Key biomass feedstocks include agricultural residues, bagasse, non-edible oils, forest residues, and municipal solid waste.

This abundance provides a strong foundation for developing a sustainable SAF industry. By investing in infrastructure, technology, and sustainable practices, India can build a robust supply chain that supports scalable SAF production. This not only enhances India's role in the global biofuels market but also contributes to economic growth, energy security, and environmental sustainability. This will help India's rapidly growing aviation industry adhere to sustainability goals and help India achieve its net-zero targets.

As per the International Air Transport Association (IATA), globally, the cost to the industry of achieving its 2050 Net Zero CO₂ ambition is estimated to be in the order of USD 4.7 trillion or USD 174 billion per year on average. Additionally, further capital investment needed for energy transition is estimated between USD 3.8 and USD 8.1 trillion. A key lever for this transition is the production and use of SAF where some 3,000-6,600 new production facilities likely to be required globally. With ~10% of the global bio-feedstock available for SAF production, India has substantial opportunity for developing its SAF production ecosystem, with potential to produce ~40 million tonnes of SAF annually by 2050. India can become a global hub for SAF which can in turn revolutionize its rural economy. Public investment and fiscal incentives along with broader initiatives to help create a supportive operating environment will play an important role in catalysing development of the SAF ecosystem.

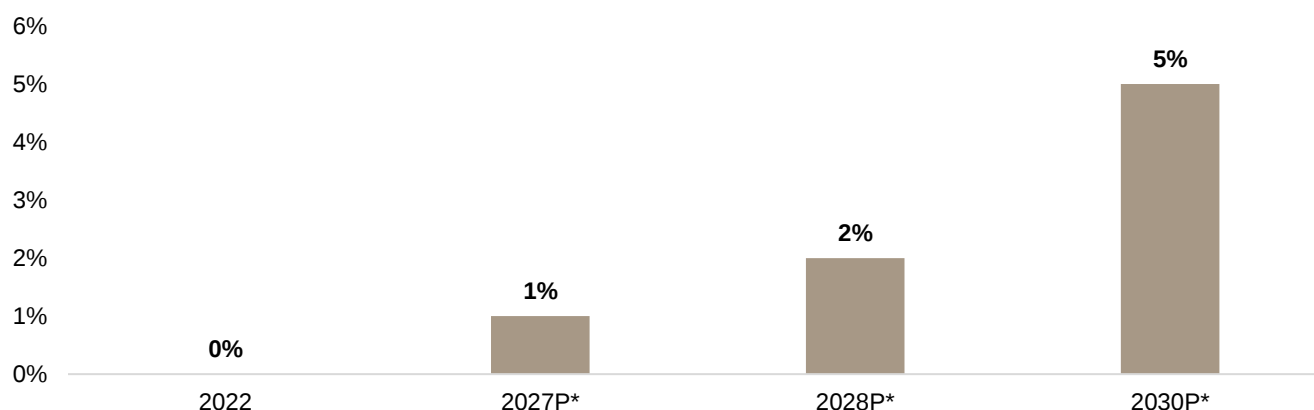
The Indian government is also committed to playing a leading role in the biofuels sector, as evidenced by its initiative to launch the Global Biofuels Alliance. This commitment is part of India's broader mission to reduce carbon emissions and promote sustainable energy. With a strong dedication to environmental sustainability, India is taking significant steps to integrate biofuels into its energy mix.

To support this transition, the Indian government has introduced several supportive policies aimed at encouraging the production and adoption of biofuels, and for Sustainable Aviation Fuel (SAF), it will be no different. The industry is optimistic that the policy framework will be designed to create a conducive environment for SAF adoption, positioning India as a key player. SAF also gives India export opportunities if it utilises its geographical advantages. Countries like the United Arab Emirates and Singapore face significant geographical limitations that hinder their ability to produce SAF on a large scale. Their limited agricultural land and natural resources constrain their capacity to cultivate the necessary feedstocks for biofuel production. This presents a unique opportunity for India to step in and lead the way in the SAF sector. By capitalizing on this opportunity, India can drive economic growth, promote environmental sustainability, and set international standards for the future of aviation fuel, this will also enable India to strengthen its political influence on the international stage.

Lastly, the development of a SAF industry presents significant economic growth and investment potential for India. The SAF industry can generate substantial employment opportunities across various sectors, including agriculture, research and development, manufacturing, and logistics. This can lead to the creation of thousands of new jobs. Promoting biofuel crops can spur rural development by providing farmers with additional revenue streams.

The promising SAF sector can attract significant investments from domestic & international players, including agricultural businesses, energy companies, and manufacturing firms. These investments can drive technological advancements and increase production capacity.

Figure 52: India SAF blending percentage over the years



Source: Press Information Bureau

*For international flights initially

P: Projected

During 2022, several domestic airlines in India, including Indigo, Air India, Air Asia India, and Vistara, entered into agreements with the Council of Scientific and Industrial Research–Indian Institute of Petroleum. The aim of these collaborations was to jointly work on the development of Sustainable Aviation Fuel (SAF) blends.

Furthermore, Indian Oil Corporation Limited (IOCL) is actively engaged in the establishment of a SAF plant at the Panipat refinery in Haryana. This endeavour involves an investment of \$122 million (INR 1000 crore). IOCL's ambition is to produce an annual output of 88,000 MT of SAF, which would constitute 2 percent of the total ethanol production by the year 2030. IOCL has also announced plans to accelerate the adoption of SAF. The company aims to achieve at least 1% SAF blending in jet fuel by July-September 2025, surpassing the government's target of 2027.

In a groundbreaking move for India's clean energy ambitions, BPCL announced its plans to establish the country's first major SAF production facility by 2027, BPCL is expected to invest USD 1.6 billion towards its SAF efforts in the aforementioned plant and beyond.

HPCL has recently partnered up with Boeing help advance India's SAF ecosystem and support the Indian Government's environmental goals. They will explore opportunities to scale SAF production in India, support the certification of domestically produced SAF, and advocate for policies to develop a robust SAF ecosystem in the country. They will also collaborate to implement sustainability standards and practices across the entire SAF supply chain, explore opportunities for training programs, and share leading practices with SAF

In 2018, SpiceJet, an Indian airline, achieved a significant milestone by operating a fully biofuel-powered flight. The historic flight utilized a blend of Jatropha and sugarcane-based biofuels, demonstrating the airline's commitment to reducing its carbon footprint and promoting sustainable aviation practices in India.

Table 16: Product Applications (Present and Prospective)

Present Applications	Prospective Applications
SAF is a lower-carbon alternative to normal jet fuel that can be used to fuel existing aircraft without making significant modifications to the aircraft and its engines.	Bio-naphtha is currently used for two major downstream applications - fuel blending and bioplastics production - in major markets such as Europe
Several airlines around the globe have started using SAF blends in their commercial flights as part of their	Biodiesel is used in conjunction with the petroleum-based diesel, i.e., biodiesel is blended with the petro-diesel in different proportions depending on the availability of biodiesel as well as its

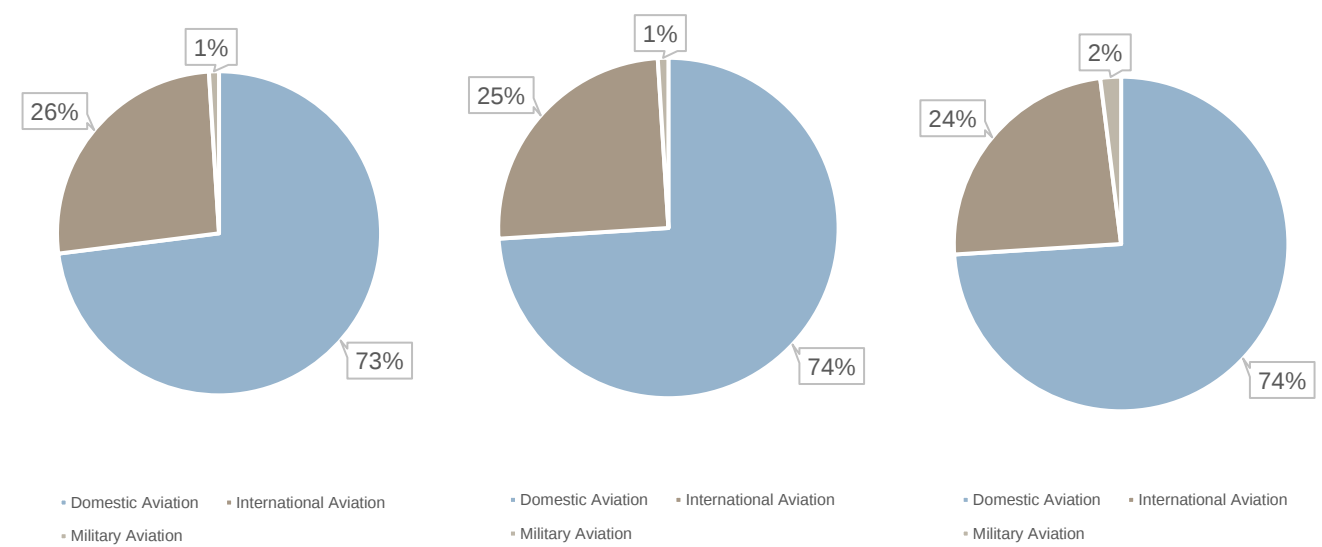
Present Applications	Prospective Applications
sustainability initiatives.	costing, the engines or equipment in which the blend is to be used as fuel, and the desired performance.

6.2 Regulations governing SAF

6.3.1 Blending mandate for SAF

The Centre has set an indicative target of 1% for blending sustainable aviation fuel (SAF) with conventional jet fuel for all international flights by 2027, marking a major step towards reducing carbon emission. This is expected to double to 2% by 2028 and become 5% by 2030, according to an order issued by the ministry of petroleum and natural gas.

Figure 53: Sector-wise ATF consumption for FY25 (9.0 MMT), FY24 (8.2 MMT), & FY23 (7.4 MMT) respectively



Source: PPAC

The Ministry estimates that with the target being set at 5% SAF blend, India would potentially require around 700 million litres (70 crore litres) of SAF per annum which creates a robust market demand for SAF in the country and provides ample offtake avenues for the players that will operate in the sector.

6.3.2 Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)

CORSIA is the first global market-based measure for any sector and represents a cooperative approach that moves away from a “patchwork” of national or regional regulatory initiatives. It offers a harmonized way to reduce emissions from international aviation, minimizing market distortion, while respecting the special circumstances and respective capabilities of ICAO (International Civil Aviation Organization) Member States.

CORSIA complements the other elements of the basket of measures by offsetting the amount of CO2 emissions that cannot be reduced through the use of technological improvements, operational improvements, and sustainable aviation fuels with emissions units from the carbon market.

CORSIA is implemented in three phases: a pilot phase (2021-2023), a first phase (2024-2026), and a second phase (2027-2035). For the first two phases (2021-2026), participation is voluntary. From 2027 onwards, participation will be determined based on 2018 RTK data. As of 1 January 2023, 115 States had announced their intention to participate in CORSIA. 11 more States announced their intention to participate in CORSIA from 1 January 2024, bringing the total number of participating States to 126.

Under CORSIA, airlines are entitled to claim emissions reductions from fuels that meet defined sustainability criteria and are certified by an approved certification scheme. These “CORSIA eligible fuels” (CEF) include SAF, which are renewable or waste-derived fuels, as well as LCAF, which are fossil-based fuels.

Additionally, to meet CORSIA's sustainability criteria, a specific CEF needs to achieve net greenhouse gas emission reductions of at least 10% compared to conventional jet fuel on a life cycle basis. Furthermore, a CORSIA eligible fuel must not be made from biomass obtained from land with high carbon stock. Additional sustainability criteria applicable for CORSIA eligible SAF from certified fuel producers on or after 1 January 2024 were recently adopted by the ICAO Council, considering broader social and environmental impacts in addition to carbon reduction.

It is expected that from 2027; all international flights will be subject to offsetting requirements under the mandatory stage of the Carbon Offsetting and Reduction Scheme for International Aviation. The Indian Government has also announced a 1% SAF indicative blending target for 2027.

Figure 54: CORSIA Explained

Pre-Inception Phase (2019-2020)	Pilot Phase (2021-2023)	First Phase (2024-2026)	Second Phase (2027-2035)
Monitoring, reporting, and verification to set the baseline	Voluntary – States are volunteering to be part of the Scheme from 2021 (More States are encouraged to volunteer) <i>Operators flying routes between volunteering States will offset emissions based on the average CO2 growth of the aviation sector</i>	Voluntary – States are volunteering to be part of the Scheme from 2021 (More States are encouraged to volunteer) <i>Operators flying routes between volunteering States will offset emissions based on the average CO2 growth of the aviation sector</i>	Mandatory – With exemptions for: Small islands, Least Developed Countries, Land-locked Developing Countries, and States which have less than 0.5% of air traffic (Although they can still volunteer) 2027-2029: Operators will offset based on average CO2 growth of the sector. 2030-2032: Offset obligations shift to include over 20% of individual operator growth 2033-2035: Offset obligations shift to be over 70% based on individual operator growth
OVER 80% OF THE GROWTH IN AIR TRAFFIC CO2 AFTER 2020 WILL BE OFFSET			

Source: Aviation – Benefits Beyond Borders

6.3.3 European Union’s Emissions Trading System (EU ETS)

CO2 emissions from aviation have been included in the European Union’s Emissions Trading System (EU ETS) since 2012. Under the EU ETS, all airlines operating in Europe, European and non-European alike, are required to monitor, report, and verify (MRV) their emissions, and to surrender allowances against those emissions. They receive tradeable allowances covering a certain level of emissions from their flights per year.

SAF under EU ETS are considered to have zero emissions and are exempt from the obligation to surrender CO2 allowances, if they are certified as compliant with the European Union’s Renewable Energy Directive (EU RED). To provide a further incentive to airlines, between 2024 and 2030, 20 million ETS allowances will be made available to airlines for the use of SAF to bridge the price difference between the use of fossil fuels and SAF.

6.3 Iso-Butanol

6.2.1 Production process of iso-butanol

Table 17: Iso-butanol production process

Step	Description
Fermentation	Fermentation of sugar to produce gas-phase isobutene
Purification	Extraction of Isobutene from gas produced
Processing	Processing (oligomerization) of isobutene produced
Fractionation	Distillation process to remove impurities
Hydrogenation	Conversion of distilled product into final product (SAF)

Source: INEA Global Bioenergy

Raw feedstock, i.e., sugar, is derived from 1st generation material like sugarcane, sugar beet etc. or 2nd generation feedstock of wood and agri residue. The feedstock undergoes several phases of processing to finally get converted into end material which is primarily SAF in the energy space.

6.3.1.1 End Uses of iso-butanol

Iso-Butanol is used to manufacture plasticizers, which are used in the production of PVC Resins. Iso Butanol is similar to n- Butanol and can be used as a solvent in coating application and can be used as an emulsifier in the paint industry. Additionally, it is also used to produce iso butyraldehyde which is further used in the manufacturing of neopentyl glycol. Moreover, the demand for Iso Butanol is rising from pharmaceuticals, dyes, inks and paint industries, thereby further fuelling growth in the market. Iso-butanol is a second-generation biofuel with several properties, making it an attractive biofuel. It produces relatively high energy density (98% of that of gasoline), does not readily absorb water from air, and can be mixed at any proportion with gasoline.

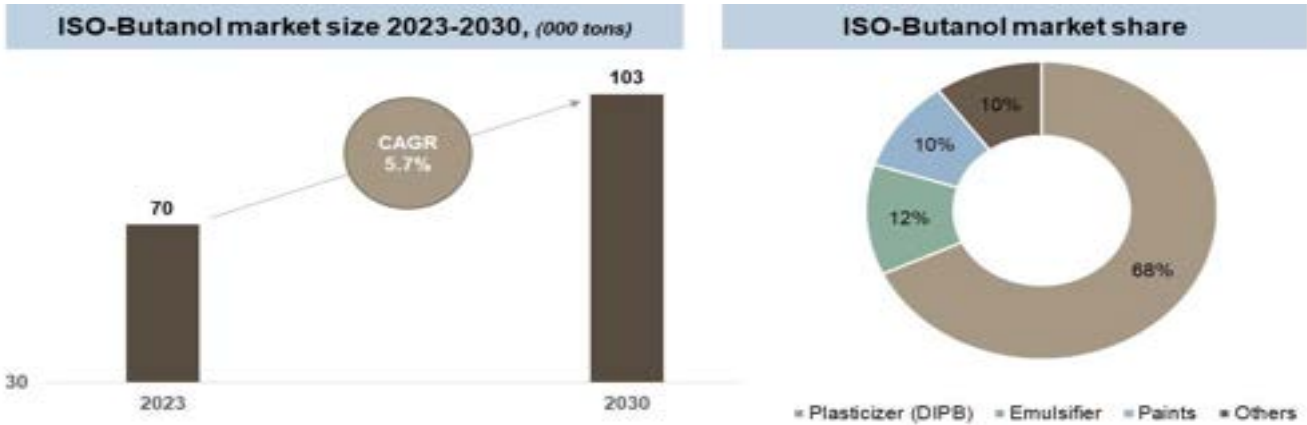
6.3.1.2 Role of Iso-butanol in SAF production

Market for Iso-butanol as a feedstock for SAF production is in a very nascent stage. Butanol is a four-carbon alcohol suited to produce road and jet fuel. The ATJ-SPK (alcohol-to-jet synthetic paraffinic kerosene) pathway aims to obtain paraffinic kerosene from C2-C4 alcohols. The ASTM already approved the pathway for iso-butanol and ethanol with a blending certification of up to 30% and 50%, respectively. However, the industry is expected to grow in the coming years, due to increased awareness of the benefits of iso-butanol over ethanol as a feedstock for SAF production. Furthermore, Iso-butanol is a 2nd generation biofuel, which makes it all the more lucrative for adoption to prevent the conflict of food vs fuel.

6.3.1.3 India Iso-Butanol market & government measures

Indian Iso-butanol/SAF market is in a very nascent stage and is expected to catch up by 2025 with SAF production reaching minimum volumes. Currently, only Praj Industries and Gevo Industries provide renewable iso-butanol, SAF and renewable premium gasoline. Gevo Industries and Praj Industries together handle the commercialization of renewable iso-butanol and convert the end product into SAF for aviation sector. These are the only known entities to operate ASTM approved Alcohol-to-Jet pathways in the country. Recently, Praj Industries has signed an MoU with Axxens to produce SAF through Alcohol-to-Jet pathway in the country, further aiding the production capacity and demand of iso-butanol in India.

Figure 55: India Iso-butanol market overview and outlook



Source: CRISIL MI&A consulting

ISO butanol market is 70,000 tons which is expected to grow at a CAGR of 5.7% during 2023-2030. Plasticizer is identified as biggest application holding lion's share of 68% in FY 2023. The market is expected to pick up the pace with governments increased regulations towards Net Zero emission targets and increased understanding of the benefits of SAF in the aviation industry.

7 Biodiesel

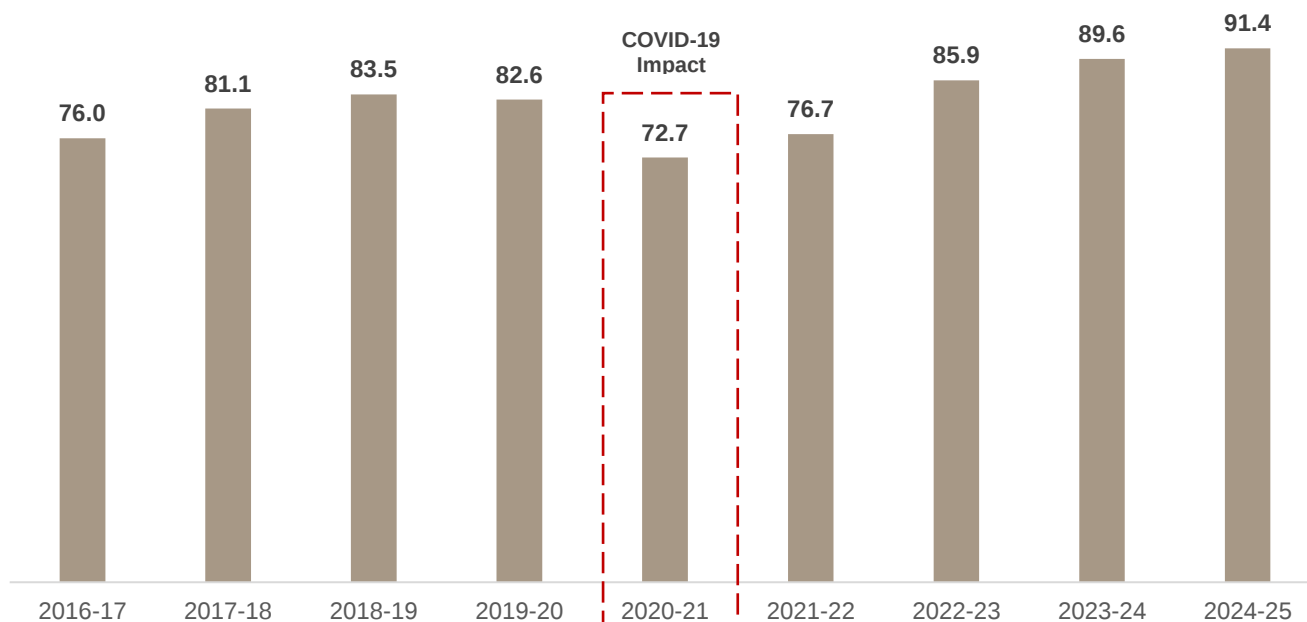
7.1 Indian biodiesel market

Biodiesel is a domestically produced, clean-burning, renewable substitute for petroleum diesel. Using biodiesel as a vehicle fuel increases energy security, improves air quality and the environment, and provides safety benefits. The raw materials for biodiesel production are vegetable oils, animal fats, and short-chain alcohols. Since cost is the primary concern in biodiesel production and trading (fundamentally due to oil prices), the utilization of non-edible vegetable oils is typically considered to be beneficial. Other than its lower cost, one more evident benefit of non-edible oils for biodiesel production lies in the fact that no foodstuffs are spent to produce fuel. Animal fats are also an interesting option, especially in countries such as India with plenty of livestock resources, although it is necessary to carry out preliminary treatment since they are solid; furthermore, highly acidic grease from cattle, pork, poultry, and fish can be also used. Methanol is the most frequently used alcohol although ethanol can also be used.

MoPNG announced a Biodiesel Purchase Policy which became effective 1st January 2006. On 10.08.2015, Government allowed direct sale of Biodiesel (B100) for blending with diesel to Bulk Consumers such as Railways, State Road Transport Corporations. On 29.06.2017 Government allowed sale of biodiesel to all consumers for blending with diesel.

Government has notified Guidelines for sale of biodiesel for blending with High-Speed Diesel for transportation purposes on 30.4.2019. Through this Notification Government has granted permission exclusively for sale of biodiesel (B-100) only and not for any mixture thereof of whatever percentage.

Figure 56: Consumption trend of HSD, 2017-2025 (MMT)



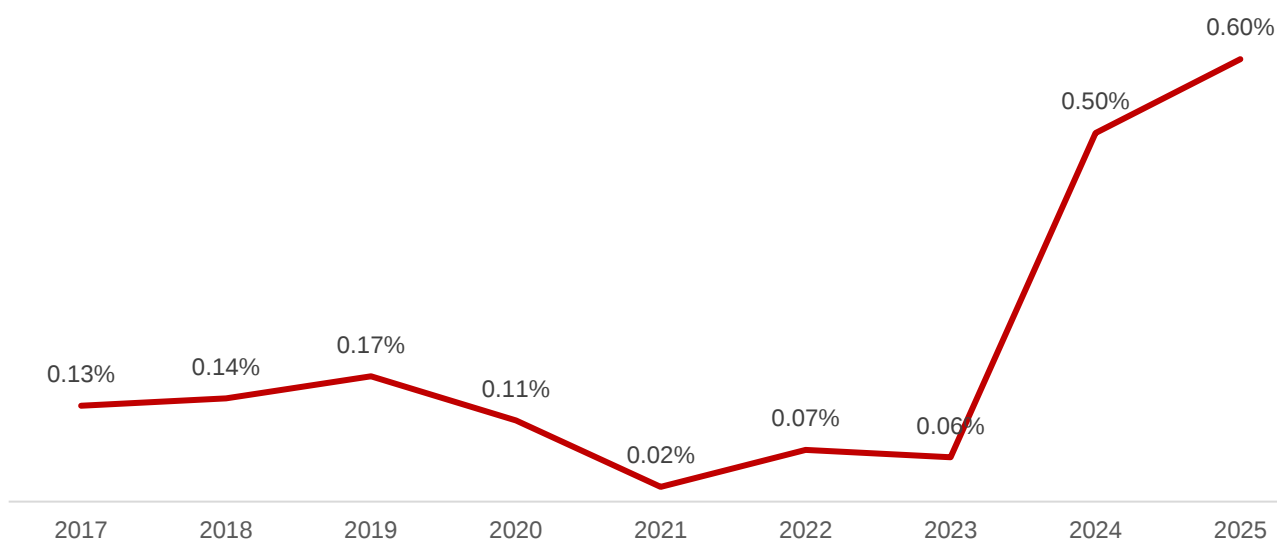
Source: PPAC

In spite of diesel being on the more polluting conventional fuels prevalent in the market, we can see that its usage has increased considerably over the years. This calls for quick and decisive action on this front to curb usage of diesel. Biodiesel is the need of the hour; however, its blending rates have been significantly low, especially when you compare them to what has been achieved in ethanol blending.

To meet its biodiesel blending goal by 2030, India would need to invest in new plants substantially to enhance the production capacity from its current effective capacity of 520 million litres (as of 2021) and form a supply chain infrastructure for UCO; while imposing some essential collection mechanisms. In India, the entrepreneurs who are

typically fuel traders with comparatively better access to the domestic fuels market dominate biodiesel manufacturing and operate micro, small, and medium enterprises, in contrast to other countries that mostly rely on manufacturing units set up by vegetable oil refineries or large oil companies. It is important for the government to encourage and/or induce noticeably greater biodiesel production.

Figure 57: Blend rate for biodiesel in India, 2017-2025



Source: TERI; United States Department of Agriculture's FAS; MoPNG

India has an aspirational target of blending 5 percent of biodiesel (for on-road use) by 2030, which would require 4.5 BL of biodiesel per year. The national average blend rate in India grew slightly from 0.06 percent from 2023 to an expected rate of 0.60 percent in 2025, Indian Oil managed to achieve a biodiesel blending ratio of 0.73% for which they have received recognition as well. Biodiesel production in India primarily relies on sources such as animal fats, non-edible oils, used cooking oil (UCO), and imported palm oil and palm stearin. But the marginal growth in the blending rate reflects challenges like import restrictions and a shortage of feedstocks in India. India's UCO market is expanding slowly from 3 MMT in 2022 to 3.2 MMT in 2023 and is expected to reach 4.5 MMT by 2030. However, almost 80 percent of costs are associated with UCO procurement and processing, coupled with inconsistent availability of feedstocks and an unorganized supply chain. The rise in biodiesel blending that can be seen is primarily due to the push towards sustainability.

Table 18: India Biodiesel Production from Multiple Feedstocks

Calendar Year	2017	2018	2019	2020	2021	2022	2023	2024
Feedstock Use (1,000 MT)								
Animal fats	6	7	10	6	12	7	6	8
Recycled oils (UCO)	56	60	70	45	65	65	70	125
Other (Mostly palm stearin)	100	110	140	140	95	105	115	83
Total	162	177	220	191	172	177	191	216

Source: United States Department of Agriculture's FAS

India, with its large transportation fleet, holds significant potential for the biodiesel market. Several schemes and policies by the Indian government supporting biodiesel capacity building are in place. However, the sector's expansion is hindered by factors, including a lack of viable feedstocks, limited investments, and inadequate infrastructure for storage and delivery. Owing to exorbitant feedstock costs and deflationary policies, few countries sustain B5 biodiesel blends, with some operating at B10 or above.

Indian OMCs between April to November 2024, have procured 36.68 crore litres of biodiesel for the biodiesel blending programme as against 29.25 crore litres during April to November 2023. India maintains more than 12 biodiesel plants with a production capacity of 820 ML. Non-edible industrial oils, UCO, animal fats, and tallows are essential feedstocks for biodiesel production. However, their availability can be inconsistent, leading to intermittent production cycles. The Food Safety and Standards Authority of India (FSSAI) initiated the RUCO (Repurpose Used Cooking Oil) initiative in 2018 to prevent the reuse of cooking oil and turning UCO into biofuel. India uses approximately 24 BL of cooking oil yearly and 60 percent of it goes back to the food value chain which poses a health threat. This 60 percent (1.8 BL) of UCO can be collected from the hotel industry and converted into 1.3 BL biodiesel annually.

Given India's situation, using vegetable oil sources for biodiesel production is a hurdle for the country's food security. It will result in food vs fuel debates, as palm stearin is one of the most common imported feedstocks used for biodiesel production. Instead, increasing domestic production using non-edible domestic sources will result in less dependency on imports. Non-edible sources are some of the country's most promising sources of biodiesel production. In response to rapid population growth, urbanization, and industrialization, food production has been impacted by decreased land availability. Proper land distribution is required for agriculture, urbanization, commercial application, and forest reserve distribution. It will burden the land area for food production if edible oil crops are used as feedstock for biodiesel production. However, nonedible crops can be grown in non-fertile land— like saline, sandy soil, and even on wastelands that are unsuitable for crop production. India has a major chunk of land that will require crop cultivation to meet B5 till 2030.

Table 19: Annual production and oil yield of potential non-edible oil crops

Non-Edible Oil Crops	Major Crop	Yield (Kg/Ha/Yr.)	Oil Content (wt. %)
Jatropha	Seed	2,500	40-60
Mahua	Seed	20-200 (per tree)	35-50
Candlenut	Seed	16,000	60-65
Rubber	Seed	100-150	40-50
Soapnut	Seed	-	23-30
Jojoba	Seed	500-5,000	40-50
Tobacco	Seed	1,170	35-49
Neem	Seed	2,670	25-45
Karanja	Seed	900-9,000	30-50
Castor	Seed	450	45-50
Polanga	Seed	3,700	65-75
Cotton	Seed	649	17-23
Kusum	Seed	-	51-62
Yellow Oleander	Seed	52,000	60-65
Sea Mango	Seed	1,900-2,500	40-50
Tung	Seed	450-600	30-40
Bottle Tree	Seed	250-300	50-60

Source: TERI

National Policy on Biofuels, 2018 also promotes using non-edible sources like jatropha, karanja, mahua, etc., because of their growth potential, wasteland availability, yield, among other reasons. Major challenges and barriers with the non-edible source are its current unavailability, proper cultivation, regularization, high polyunsaturated fatty acids, low unsaturated fatty acids content, etc. However, this could be taken care of with technological advancements.

High-potential second-generation feedstock for biodiesel production uses cooking oil, acid oil, and animal tallow. A high conversion and yield percent from raw material to biodiesel, cheap rates, and availability are some positives for these feedstocks. The major barriers include the poor collection mechanism, disrupted supply-chain network, proper regulation mechanism, etc. Used cooking oil has been a potential feedstock in India because of its availability and high procurement. Though the potential is very high, the supply-chain network, proper regulations in line, and other policy loopholes make achieving the target difficult, proper regulations and a robust implementation framework will be needed to tackle this issue.

7.2 Biodiesel market: Policy initiatives

7.2.1 National Biofuels Policy 2018

National Biofuels Policy 2018 was formulated with the primary objective of reducing India's dependency on fossil fuels, promoting cleaner energy, and ensuring sustainable energy security. The policy encompasses various types of biofuels, including Ethanol, biodiesel, and advanced biofuels such as cellulosic Ethanol and algal biofuels. Key features of the 2018 policy include:

- **Blending Targets:**
 - Ethanol Blending: The policy set a target of achieving 20% Ethanol blending with petrol by 2030. The same was revised to 2025 from 2030 in the 2022 Amendment of the Policy.
 - Biodiesel Blending: A target of 5% biodiesel blending with diesel by 2030 was established.
- **Feedstock Utilization:**
 - The policy encouraged the use of various feedstocks for biofuel production, including sugarcane, sugar beet, sweet sorghum, starches, and other biomass.
 - It aimed to utilize non-food feedstocks to avoid compromising food security.
 - The 2022 Amendment allowed for a broader range of feedstocks, including agricultural residues, forestry residues, and industrial wastes. Inclusion of advanced biofuels such as 2G Ethanol, CBG, and third-generation ("3G") biofuels also happened at this stage.
- **Incentives and Financial Support:**
 - Financial incentives were provided to biofuel producers, including subsidies and tax reductions.
 - Viability gap funding, interest subvention, and financial assistance for setting up biofuel plants were introduced.
 - The 2022 amendment provided additional financial incentives to encourage private investment in biofuel production and also the introduction of new schemes for viability gap funding, increased capital subsidies, and more attractive loan terms.
- **Research and Development:**
 - The policy emphasized the importance of R&D to develop efficient technologies for biofuel production.
 - Collaboration with international agencies and organizations was encouraged to adopt best practices.
- **Waste to Energy:**
 - Promotion of the use of urban and industrial waste for biofuel production was highlighted.
 - The policy aimed to convert waste into energy, thereby addressing waste management issues.

This goal is to be achieved by:

- Reinforcing ongoing biodiesel supplies through increasing domestic production.
- Setting up Second Generation (2G) bio refineries.
- Development of new feedstock for biodiesel.
- Development of new technologies for conversion to biodiesel.
- Creating suitable environment for biodiesel and its integration with HSD.

The policy identifies the following as potential domestic raw materials for production of biodiesel in the country:

- Non- edible Oilseeds
- Used Cooking Oil (UCO)
- Animal tallow
- Acid Oil
- Short Gestation non-edible oil rich crops
- Algal feedstock, etc.

The policy encourages augmenting indigenous feedstock supplies for biofuel production utilizing the wastelands for feedstock generation. However, depending upon availability of domestic feedstock and blending requirement, import of feedstock for production of bio diesel would be permitted to the extent necessary. Feedstock import requirements will be decided by the National Biofuel Coordination Committee (NBCC) proposed under this Policy.

The amendments reflect India's commitment to achieving a cleaner, more sustainable energy mix. By advancing blending targets and promoting advanced biofuels, the policy aims to reduce greenhouse gas emissions, enhance energy security, and support rural economies through the use of agricultural residues and waste. The comprehensive approach also seeks to attract private investment and foster innovation in the biofuels sector, aligning with global sustainability goals and the Paris Agreement commitments.

7.2.2 Biodiesel Purchase Policy

The Bio-diesel Purchase Policy sets out measures to support activities for blending of biodiesel in diesel and marketing of such blended fuel. The policy states that it is imperative that the biodiesel offered for blending in diesel is of standard quality. Therefore, it would be necessary that only those biodiesel manufacturers who get their samples approved and certified by the oil companies and get registered as authorised suppliers would be eligible for assured purchase of the product. Also, the biodiesel purchase centres should be equipped with minimum testing facilities for ensuring purchase of biodiesel of requisite specification.

With effect from January 2006, the public sector oil marketing companies shall purchase, through its select purchase centres, biodiesel (BI 00), which meet the fuel quality standard prescribed in the Bureau of Industrial Standards (BIS) specification formulated vide PCD3 (2242) C- dated 26.7.2004, and as may be notified and modified from time to time. The oil marketing companies shall make available the comprehensive industry guideline "Operations, Quality and Safety Manual on Bio-diesel- HSD BIOO and HSD B05max" for information and guidance of the biodiesel industry. The purchase centres have been identified in consultation with the oil marketing companies, viz the Indian Oil Corporation (IOC), Hindustan Petroleum Corporation (HPC) and Bharat Petroleum Corporation (BPC), on the basis of availability of minimum testing facilities for BIOO and for blending in HSD to the extent of five per cent. Depending on response, felt need, and preparedness in testing and accepting biodiesel, more purchase centres would be identified subsequently.

Biodiesel manufacturers interested in supplying biodiesel to public sector oil marketing companies should approach the state level co-ordinator (SLC) pertaining to the state, and after assessment of production capacity and credibility of the prospective supplier by joint evaluation / certification by the industry team, samples would be tested and if these meet the prescribed BIS specifications, the supplier shall be registered as an authorized supplier.

The Indian government's biofuel agenda has received a significant boost with the initiation of a substantial biodiesel procurement programme for the financial year 2025-26 by Indian Oil Corporation Limited (IOCL), Bharat Petroleum Corporation Limited (BPCL), and Hindustan Petroleum Corporation Limited (HPCL). As part of this endeavour, a tender was floated on March 13, 2025, to procure 200 million litres of biodiesel for the first quarter of the fiscal year, marking the inaugural cycle of procurement for 2025-26. This tender has already yielded results, with Letters of Intent (LOIs) being awarded to various suppliers, including Rajputana Biodiesel Limited and its subsidiary Nirvaanraj Energy Private Limited, highlighting the increasing contribution of private biodiesel producers in fulfilling the country's energy requirements. This development is in line with the National Policy on Biofuels, which targets a 5% biodiesel blending ratio by 2030, and demonstrates the growing participation of private players, such as Kotyark Industries, Emami Agrotech, Universal Biofuels, Muenzer Bharat Pvt. Ltd., and Altret Greenfuels, in India's biodiesel supply chain.

7.2.3 Sale of Biodiesel for blending with HSD for transportation purposes-2019

- Application for permission for retail sale of Biodiesel (B-100) through an outlet by an entity shall be made to the Food and Civil Supplies Department/any other Department authorised for the same by the State/UT Government of the concerned State/UT, where the Retail Outlet is to be set up.
- The permission will be granted exclusively for sale of biodiesel (B-100) only and not for any mixture thereof of whatever percentage.
- Permission for setting up the retail outlet for sale of biodiesel would be subject to the Registration/Approvals/No Objection Certificates as per the prescribed format from the respective Central/State/UT/Local Government/Authorities in which the retail outlet is located and other concerned authorities mentioned therein.
- Biodiesel to be sold in pursuance of aforesaid permission should be indigenously produced and not imported.
- Owner/Operator shall maintain the material balance along with supplier details. The biodiesel retail outlet owner/operator shall make available the same at the retail outlet at all times for inspection by any authority authorised for the purpose either by the concerned State/UT Government and /or Central Government.

- Biodiesel retail outlet owner/operator shall retain samples of at least last three supplies received by them from their suppliers for inspection and/ or testing by any authority authorised for the purpose.
- To avoid entry of unscrupulous biodiesel suppliers, a suitable registration system for biodiesel manufactures, suppliers and sellers will be devised at the State/UT Level. Further, State/UT Governments shall maintain a register of all Retail Outlets selling Biodiesel in their respective State/UT.
- The biodiesel retail outlet owner/operator shall maintain a permanent record of each and every sale of biodiesel made by it in a register which would be updated on a daily basis and be available for inspection at all times.

7.2.4 Repurpose Used Cooking Oil (RUCO) initiative

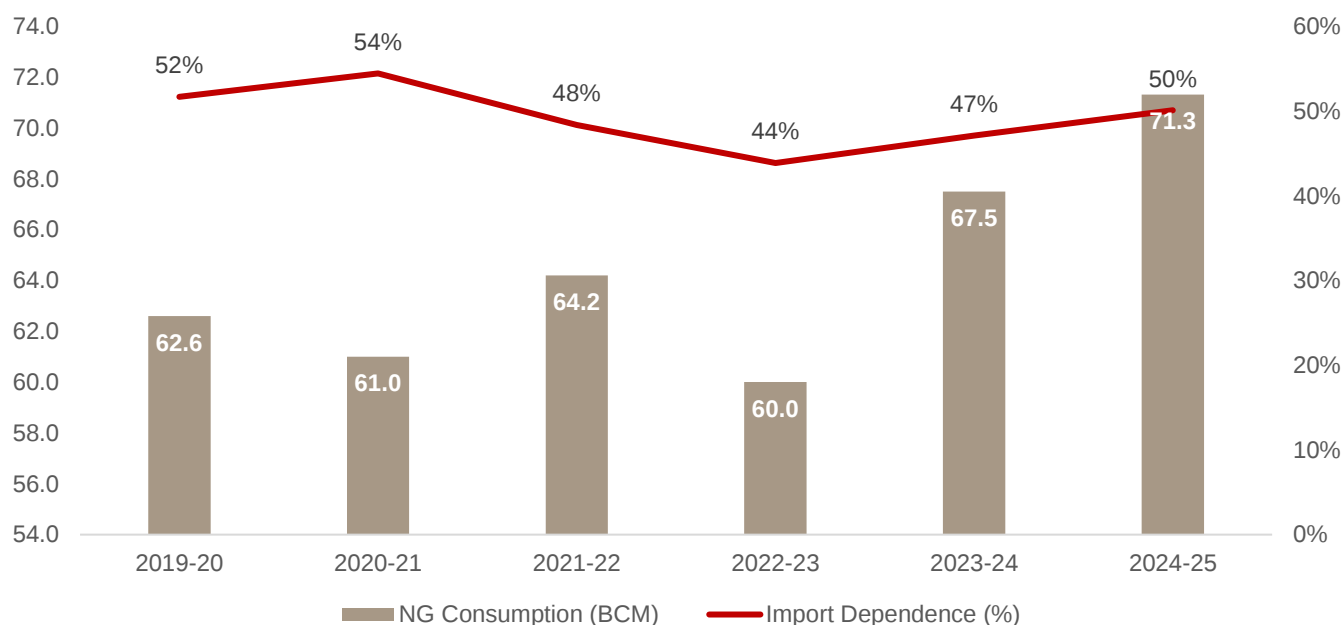
During frying, several properties of oil are altered, Total Polar Compounds (TPC) are formed on repeated frying. The toxicity of these compounds is associated with several diseases such as hypertension, atherosclerosis, Alzheimer's disease, liver diseases. Therefore, it is essential to monitor the quality of vegetable oils during frying. In order to safeguard consumer health, FSSAI has fixed a limit for Total Polar Compounds at 25 percent beyond which the vegetable oil shall not be used. From 1st July, 2018 onwards, all Food Business Operators (FBOs) are required to monitor the quality of oil during frying by complying with the said regulations. FSSAI is implementing an EEE (Education, Enforcement, Ecosystem) Strategy to divert Used Cooking Oil from the food value chain and curb current illegal practices. The EEE Strategy approach ensures good health and welfare for all 130–crore citizens, aiding energy security, climate change mitigation, and leading to environmentally sustainable development.

There is a need to ensure that the used cooking oil does not enter the food chain and that oil is disposed or used in a sustainable manner. Thus, the FSSAI launched the RUCO initiative. A network of aggregators has been formed who collect used cooking oils from the manufacturers/FBOs which are then passed on to biodiesel manufacturers and/or soap manufacturers.

8 Compressed Biogas

8.1 Indian CBG Market

Figure 58: Natural gas consumption in India (BCM) and import dependence (as a % of consumption)



Over the past few years, CBG has emerged as a viable alternative to imported fossil natural gas, offering nearly net-zero emissions and enhancing energy security (given the high dependence on imported natural gas). Various waste and biomass sources, such as cattle dung, agricultural waste, distillery spent wash, press mud, organic fraction of municipal solid waste (OFSMW) and sewage treatment plant sludge, undergo anaerobic decomposition to produce biogas. CBG is progressively also proposed to be used as a cooking fuel, and for household purposes. Only 97 CBG plants have been commissioned in India as of June 2024, out of the planned 5,000 plants expected to be operational by the end of 2024-25 under the Sustainable Alternative Towards Affordable Transportation (SATAT) scheme. The industry is gaining momentum, as evidenced by 2,061 active letters of intent to various stakeholders.

India's compressed biogas potential to be around 40 to 60 MMTPA (million metric tons per annum) with current installed capacity at <1%. Currently, India has already made significant strides in the CBG sector, having sold 31,423 tons of CBG. The SATAT (Sustainable Alternative Towards Affordable Transportation) initiative's ambitious target is to produce 15 million metric tonnes per annum (MMTPA) of Compressed Biogas (CBG) and a remarkable 50 MMTPA of bio-manure. Achieving this target would not only reduce the dependency on fossil fuels but also promote a circular economy where waste materials are transformed into valuable resources, benefiting both the environment and the economy. It underscores the importance of renewable energy and sustainable practices in addressing energy security and environmental challenges on a global scale. Additionally, CBG projects are categorised as agricultural infrastructure as per RBI guidelines. Loans pertaining to agricultural infrastructure are being classified as priority sector lending, which has encouraged banks to sanction loans for CBG projects.

Table 20: CBG Product Application (Present and Prospective)

Present Applications	Prospective Applications
CBG is compressed and used as a fuel for vehicles, particularly in city transport fleets.	Bio-CNG, which is primarily CBG compressed for use in CNG vehicles, is likely to see significant expansion.

CBG is blended with natural gas or used directly for cooking and heating purposes in households and industries connected to city gas networks.	CBG can play a crucial role in this shift by fuelling buses, taxis, and other public transport vehicles.
CBG is used in gas turbines or engines to generate electricity, either for direct use or for feeding into the grid.	CBG can be used in microgrid systems to provide reliable electricity, supporting rural electrification efforts and enhancing energy security.
Cities and municipalities are setting up Bio-CNG stations where vehicles equipped to use compressed natural gas.	CBG can contribute to grid stability by providing a dispatchable and reliable source of power. Its use can help balance fluctuations in renewable energy generation.
Organic Manure - Liquid Fermented Organic Manure - Fermented Organic Manure - Phosphorate Rich Organic Manure	CBG can be utilized in combined heat and power systems, where it not only generates electricity but also provides heat for industrial processes or district heating. This enhances overall energy efficiency and reduces emissions.

Driving factors for CBG sector:

- **Mandate for gas marketing entities to sell 5% CBG by volume:** In a move that is likely to change the face of the CBG sector, the government will gradually mandate 5% CBG for all organizations marketing natural and biogas by 2028-29; for collection of biomass and distribution of bio-manure, appropriate fiscal support will be provided.
- **Policy for mandatory bio-manure sale**
- **₹10,000 crore outlay for 200 CBG plants**

8.2 Government Initiatives to promote CBG in India

8.2.1 SATAT Scheme

Figure 59: SATAT vision

Sustainable Alternative Towards Affordable Transportation (SATAT) was launched on 01.10.2018



**5000 CBG Plants
by 2024**



15 MMT of CBG



50 MMT of Bio-Manure

**CBG Plants to be set up by Entrepreneurs and off take by Oil & Gas Companies
(IndianOil, BPCL, HPCL, GAIL & IGL)**

Source: MoPNG and CRISIL MI&A Consulting

SATAT scheme was launched in October 2018 in sync with Swachh Bharat Mission and COP 21 commitments; the scheme is future-ready and even complements the main tenet of the Atmanirbhar Bharat Abhiyan launched in 2020, i.e., self-reliance. It is aimed at reducing India's carbon footprint by spearheading a shift to cleaner fuels and also offering a means to dispose agricultural waste in a beneficial and non-polluting manner.

The Government of India has undertaken initiatives towards encouraging CBG, including the Sustainable Alternative Towards Affordable Transportation (SATAT) initiative launched in October 2018 envisages setting up of 5,000 Compressed Biogas (CBG) plants for production of 15 million metric ton (MMT) per annum of CBG by 2024-25 (earlier 2023-24), with an envisaged initial outlay of ₹ 30,000 crore for setting up of 900 plants in the first phase.

Under SATAT, as of March 2025, total number of active Letters of Intent (LOIs) is 2,277. A total of 94 CBG plants have been commissioned across the country. SATAT scheme invites individuals or corporations to set up CBG plants, produce & supply CBG to Oil Marketing Companies (OMCs). As per the GOBARDhan Portal, India has 143 functional CBG plants while 215 plants are under various stages of construction.

Table 21: Pricing for CBG under SATAT Scheme

S. No.	Lower RSP of CBG in Slab	Higher RSP of CBG in Slab	Procurement price of CBG	Procurement Price of CBG
	Including tax	Including tax	Without GST	With GST
	Rs./ Kg	Rs./ Kg	Rs./ Kg	Rs./ Kg
1	RSP of CBG up to Rs. 70/ Kg		54.00	56.70
2	70.01	75.00	55.25	58.01
3	75.01	80.00	59.06	62.01
4	80.01	85.00	62.86	66.01
5	85.01	90.00	66.67	70.01
6	90.01	95.00	70.48	74.01
7	95.01	100.00	74.29	78.01

Source: IOCL Notice on "Purchase Price of CBG under SATAT Scheme"

Policy for mandatory bio-manure sale:

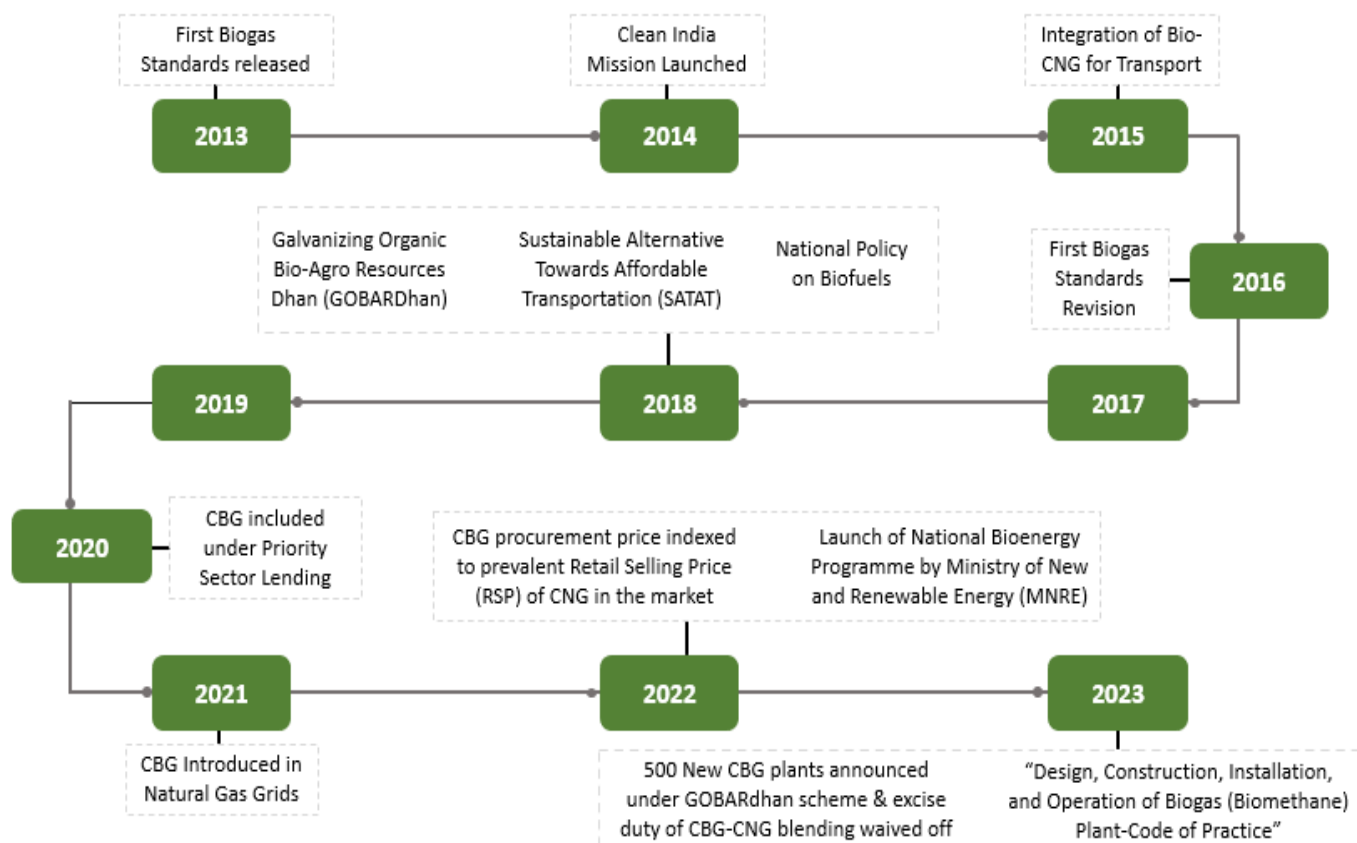
Bio-manure has traditionally been difficult to market due to the sheer dominance of traditional chemical fertilizers in the market; the government is working out a policy for mandatory sale of bio-manure by fertilizer entities in what would be a major boost for CBG players.

₹10,000 crore outlay for 200 CBG plants

500 new 'waste to wealth' plants under GOBARDhan scheme will be established for promoting circular economy; These will include 200 CBG plants, including 75 plants in urban areas, and 300 community or cluster-based plants at total investment of ₹10,000 crore.

Regulation of fermented organic manure in the context of Compressed Biogas (CBG) production involves ensuring the quality, safety, and compliance with environmental standards for the use of organic waste materials in the biogas production process. It typically includes guidelines for feedstock sources, fermentation processes, and the handling of resulting organic manure to promote sustainability and minimize environmental impacts.

Figure 60: India Roadmap to Compressed Biogas



Source: CRISIL MI&A Consulting

8.2.2 CBG Blending Obligation (CBO)

In November 2023, the Government of India made it mandatory for the City Gas Distribution (CGD) Sector to blend Compressed Bio-Gas (CBG) into the CNG (Transport) and PNG (Domestic) segments. This significant move aims to promote sustainable energy practices nationwide. Under the CBG Blending Obligation (CBO), CGD entities are required to mix CBG with natural gas, with the blending percentages gradually increasing over time. Initially starting as a voluntary effort until FY 2024-2025, the CBO mandates blend percentages of 1%, 3%, and 4% for FY 2025-26, 2026-27, and 2027-28, respectively. By FY 2028-29, this obligation rises to 5%. Furthermore, until the CGD network is fully operational across the country, CBG marketed separately by all CGD entities will also count towards meeting the blending obligation.

The latest notification emphasizes the strategic importance of Feedstock Optimization Model in the context of Compressed Biogas (CBG) production. The mandatory CBG blending initiative ensures a significant market for CBG, offering assured offtake for producers. The pricing mechanism, as outlined in the notification, provides a favourable framework for producers, contributing to the economic viability of CBG projects. Noteworthy advantages include exemptions from City Gas Distribution (CGD) restrictions, allowing for broader market access and sales of CBG. The notification highlights that CBG shall be promoted as the green fuel by guaranteeing its renewable origin and which could be sustainably monetized through tradability of green certificate system. Mechanism like open access, book and claim, mass balancing etc. may be used for transfer and trading of energy and green certificates.

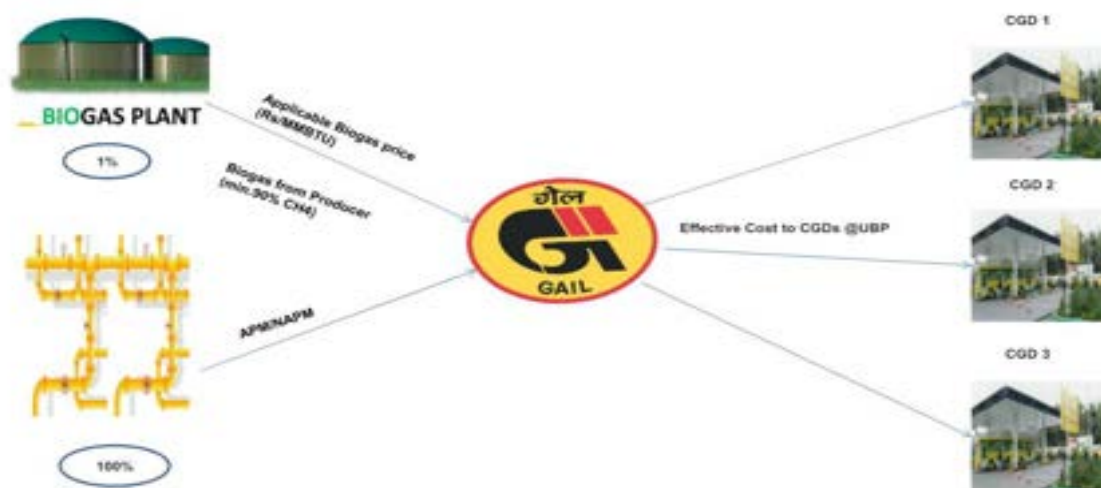
It's crucial to highlight that major companies, including Reliance and other Oil Marketing Companies (OMCs), have committed to ambitious targets in setting up CBG plants. This underscores the industry's confidence in the CBG sector's potential for growth and aligns with broader national objectives related to renewable energy, sustainability,

and reducing carbon emissions. The combined impact of these factors positions CBG production as a lucrative and environmentally friendly venture, supported by regulatory measures and industry leaders' proactive investments.

8.2.3 CBG-CGD Synchronisation Scheme

MoPNG has issued policy guidelines dated. 09.04.2021 and 26.10.2021 for synchronisation of CBG produced by plants in CGD networks. GAIL has been mandated to operationalize the Synchro Scheme and supply Biogas/CBG co-mingled with domestic gas at Uniform Base Price (UBP) to all CGD entities for use in CNG(T) & PNG(D) segments of CGD network. The term of CBG-CGD Synchro Scheme has been further extended by 10 years. GAIL has successfully implemented the Synchro scheme on pan India basis, and it is open to every CBG producer for supply of their Biogas/CBG to nearby CGD networks.

Figure 61: Biogas/CBG mixing under CBG/CGD Synchronization



Source: GAIL (India) Limited

After the 12th CGD bidding round, 308 GAs would be authorized to various entities covering 100% of India's geographical area (except the islands) spread over 600 districts in over 30 states/UTs. Widespread access to CGD networks will bring demand centres close to CBG plants, thereby enabling a gas-based economy and there is an increasing demand for Biogas due to shortfall in domestic gas supply for PNG(D) & CNG(T) segment. CGD sector will become an anchor customer for Biogas/CBG.

8.2.4 National Biomass Programme for FY2021-22 to FY 2025-26 (Phase-I)

The Ministry of New and Renewable Energy has notified Central Financial Assistance (CFA) of Rs. 4 crores per 4,800kg of CBG per day generated from 12,000 cubic meters of biogas per day, with a maximum of Rs.10 crore per project. Furthermore, it has announced the national bioenergy programme in November 2022, which is continued for the period from FY 2021-22 to 2025-26. The Programme has been recommended for implementation in two Phases and Phase-I of the Programme has been approved with a budget outlay of Rs. 858 crores.

It will comprise of the following sub-schemes:

- **Waste to Energy Programme:** This programme will aim to support the setting up of large Biogas, Bio-CNG and Power plants, and will be implemented under the Indian Renewable Energy Development Agency (IREDA)
- **Biomass Programme:** This scheme aims to support manufacturing of briquettes & pellets and promotion of biomass (non-bagasse) based cogeneration in Industries.
- **Biogas Programme:** To support setting up of family and medium size biogas units in rural areas.

For obtaining a bank loan for Compressed Biogas (CBG) projects, the financing structure typically involves a contribution of 15-30% of the project cost, which includes various components, including margin money for working capital, as per each bank's specific guidelines for term loans or project loans. Additionally, working capital requirements are typically set at 15-25% of the project cost or in accordance with the policies of each respective bank.

There is also a working capital subsidy of 3%, with a cap of ₹ 2 crore per project for CBG production, as this has been designated a priority sector by the Government of India.

In February 2023, in an effort to prevent the stacking of taxes on blended Compressed Natural Gas (CNG), the Ministry of Finance (MoF) has granted an exemption from excise duty on the portion equivalent to the GST paid on Compressed Biogas (CBG) when mixed with CNG.

Also, the carbon credits earned from producing a tonne of Bio-CNG fall within the range of 16 to 25 credits, depending on the feedstock utilised. CBG initiatives have the potential to produce carbon credits via the Clean Development Mechanism (CDM) established by the United Nations Framework Convention on Climate Change. These carbon credits can be marketed to organizations and governments seeking to neutralize their carbon emissions, offering an extra income stream for CBG projects.

As per the notification released on 15th March 2024, the Government's approval of the Scheme for Development of Pipeline Infrastructure (DPI) represents a significant stride in facilitating the injection of Compressed Bio-Gas (CBG) into the City Gas Distribution (CGD) network. With a substantial financial outlay of Rs.994.50 crore allocated for FY 2023-24 to FY 2025-26, this scheme aims to provide financial assistance for creating CBG-CGD grid connectivity and supporting 100 CBG projects. By fostering an ecosystem conducive to the seamless offtake of CBG, the DPI scheme is poised to reduce logistical costs and promote sustainable energy practices on a large scale.

MoPNG on August 27, 2025 released a revised scheme guideline for Development of Pipeline Infrastructure for facilitation of Compressed Biogas (CBG) Offtake with the aim of:

- i. Supporting pipeline infrastructure for injection of CBG from CBG plant into City Gas Distribution (CGD) network by providing systematic financial assistance (FA). FA shall be based on the pre-condition that plants should have an installed CBG production capacity of at least 2 TPD and are registered on GOBARDhan platform.
- ii. Injection of CBG by gas pipeline operators (GPO) into gas pipeline network. For this, financial (FA) assistance shall be provided to the GPO under a phased manner. FA shall be based on the pre-condition that GPO should be engaged in development/ laying/ operating either of the following. First, Natural gas pipeline authorized by PNGRB. Second, dedicated pipeline for natural gas transportation. Third, captive pipeline for natural gas transportation.

The primary objective of the policy is to facilitate cost-effective transportation of CBG from production facilities to demand centres.

Several other subsidies provided by various Government Departments to promote Compressed Bio-Gas (CBG) include:

1. Department of Fertilizers: Market Development Assistance

The Department of Fertilizers has introduced a Market Development Assistance (MDA) scheme with an outlay of Rs. 1,451.82 crore for 3 years (FY24 to FY26). Under this scheme, an MDA of Rs. 1500/MT will be granted for the sale of Fermented Organic Manure (FOM)/ Liquid Fermented Organic Manure (LFOM)/ Phosphate Rich Organic Manure (PROM) produced at BG/CBG plants under the GOBARDhan initiative. Registration of manufacturing plants on the Unified GOBARDhan portal of the DDWS and adhering to Fertilizer Control Order (FCO) specifications for organic fertilizers are pre-requisites for MDA eligibility. In a further boost, the Indian Council for Agricultural Research has facilitated development of Package of Practices (PoP) for FOM/ LFOM application for various crops.

2. Department of Drinking Water & Sanitation: Swachh Bharat Mission – Gramin 2.0

Financial support of up to Rs. 50 lakh per district is available for setting up at least one model community biogas plants at the village/ block/district level to achieve safe management of cattle and biodegradable waste. The Department of Drinking Water and Sanitation's Unified Registration Portal has streamlined efforts for one to avail benefits of any of the CBG schemes of the Government of India. They have launched a Unified Registration Portal for CBG/ Biogas plants which will likely have a significant positive impact on the sector as a whole.

3. Department Ministry of Housing and Urban Affairs: Swachh Bharat Mission - Urban 2.0

Under the Scheme of Swachh Bharat Mission Urban 2.0, additional Central Assistance is provided to States and Union Territories for solid waste management by Ministry of Housing and Urban Affairs, as per scheme guidelines. Additional Central Assistance of 25% /33%/50% (based on ULB population) for MSW based CBG plants (subject to max. cost of Rs.18 crore per 100 TPD).

4. Department of Agriculture, & Farmers Welfare: Agri-Infra Fund

The Department of Agriculture & Farmers Welfare has introduced a new Scheme under the National Agriculture Infra Financing Facility called Agriculture Infrastructure Fund (AIF). The Agricultural Infrastructure Fund (AIF) offers financial assistance for investments in viable projects related to post-harvest management infrastructure and community farming assets. Compressed Bio-Gas (CBG) is among the eligible projects under the community farming assets project. All loans obtained through this financing facility will benefit from a 3% per annum interest subvention, capped at a loan amount of Rs. 2 crores. This subvention will be applicable for a maximum duration of 7 years.

5. Department of Animal Husbandry and Dairying: Animal Husbandry Infrastructure Fund

The Animal Husbandry Infrastructure Development Fund (AHIDF) is a central sector scheme with a package of Rs.15,000 crore. The project under the AHIDF is eligible for a loan up to 90% of the estimated/ actual project cost from the Scheduled Banks based on the submission of viable projects by eligible beneficiaries. All eligible entities under AHIDF will be provided with interest subvention of 3% on loans up to INR 2 crore. Production of Bio-CNG & production of Phosphate Rich Organic Manure (PROM) was included as eligible activities under Animal Waste to Wealth Management (including Agri waste management) component of AHIDF in April 2022. The inclusion of bio slurry in the Fertilizer Control Order has also been promised.

6. The Government of India intends to facilitate biomass aggregation, preventing the burning of surplus biomass and generating extra income for farmers. This scheme aims to support biomass collection for initial 100 biomass-based CBG plants by providing financial assistance to CBG producers for procurement of biomass aggregation machinery (BAM). MoPNG sanctions amounting to almost INR 38 crore have been issued to date.

Additionally, in 2023, India introduced the 2023 Carbon Credit Trading Scheme (CCTS), encompassing both compliance and voluntary sectors. However, while the compliance segment is scheduled to commence in 2025-26 and there is no set timeline for the launch of the voluntary carbon market. Nevertheless, it shows the intent towards sustainability. Under India's revised carbon market scheme, obligated entities have the flexibility to purchase additional credits or sell surplus ones. Meanwhile, businesses can trade CCCs to offset their emissions. Such schemes will further boost green fuels and energies once they are brought into action.

8.3 CBG and CNG

8.3.1 Process Comparison

CNG and CBG are both methane-based gases. CNG is processed from the seabed, however, CBG is made from fermented waste or other biological material, then compressed and processed to remove carbon dioxide and hydrogen sulphide content, making it a CO₂ neutral fuel. Chemically, both the fuels are alike with similar calorific value, the basic difference lies in their production process and composition, where CNG is derived from fossil fuels and CBG is derived from decomposition of waste materials. This makes CBG a commercially viable option to replace CNG as a transport fuel in vehicles. Just like CNG, CBG is also transported through gas pipelines, requiring no additional infrastructural requirements.

CBG holds the potential for minimizing India's import bill for fuels. The solid by-products of CBG can be used as bio-manure, and as per the experts, it can potentially lead to a 20% increase in crop yield. Other by-product of CBG is CO₂, which has a high demand in food preservation and in fire extinguishers production. CBG further enhances the country's utilization of agricultural residue, cattle dung and municipal solid waste (MSW) and thus to achieve reduction in emissions and pollution. CBG also acts as a buffer against the energy security concerns and crude/gas price fluctuations. CBG is expected to provide an additional source of income to the farmers, rural employment and amelioration of the rural economy.

8.3.2 Compatibility of CBG in existing CNG Vehicles

In FY23, India's demand for Compressed Natural Gas (CNG) stands at 19.2 million metric standard cubic meters per day (mmscmd), CBG and CNG have similar properties and hence a vehicle running on CNG can be straightway filled with CBG without any prior modifications. Ministry of Road transport and Highways, Government of India, as per its recent notifications has permitted the usage of CBG for motor vehicles as an alternate of CNG.

As per MOPNG, the potential customers for CBG are vehicles and industries towards replacement of petrol, diesel and CNG. CBG is also sold to end customers as a replacement for LPG. Furthermore, the Indian Biogas Association has also guided the committee under SATAT towards the policy for injection of CBG to City gas distribution (CGD) and replacement of LPG cylinders under Ujjawala Yojna with bio-CNG under SATAT initiative. Furthermore, under the CBG-CGD synchronisation scheme of SATAT, there is a provision for injecting CBG in the city gas distribution (CGD) network. Additionally, the government allows the sale of CBG even in authorized areas of CGD entities through separate retail outlets, in other words, there is no PNGRB permission required for selling CBG in any part of India.

8.4 Other Use Cases of CBG apart from fuel

Biogas, after anaerobic production, can be converted into electricity through fuel cells. However, the process is only practical in the theoretical sense, as it requires very clean gas and expensive fuel cells. Therefore, direct conversion of biogas into electricity is still under research phase.

Whereas conversion of biogas to electric power by a generator set is more practical. In contrast to natural gas, biogas is characterized by a high knock resistance and hence can be used in combustion motors with high compression rates.

During the production of compressed biogas, bio-slurry is produced as a waste, which can be processed and used as a bio-fertilizer in the field. The bio-fertilizer thus produced has less noticeable odor and no hazardous microbes.

8.5 Why CBG as a product is feasible for ethanol player

The upgraded form of biogas, known as compressed biogas (CBG) or bio- CNG (biomethane in Europe and renewable natural gas in the United States), contains over 98 per cent methane and is generated through anaerobic digestion from organic waste streams. These waste materials arise from diverse industrial, economic, agricultural and household activities. The CBG cycle serves as an ideal representation of circularity, as it is derived from various

wastes generated by human activities and is subsequently utilized as a resource in the form of clean energy and biofertilizer. Implementing CBG projects in India offers multiple advantages. It reduces the need for CNG imports, promotes in-house clean energy production, enhances waste management, strengthens the rural economy, and expands the non-chemical fertilizer sector. This aligns with the Indian government's goal of transitioning to a gas-based economy, aiming to increase its gas share from the current 6.7 per cent (as of December 2023) to 15 per cent by 2030.

CBG and ethanol as a product are a form of waste-to-fuel energy. Both require processing of biomass to convert them into fuel. However, ethanol is produced in the liquid form whereas compressed biogas is produced in the gaseous form. CBG is feasible for an ethanol player as it provides an infrastructural advantage. Both CBG and Ethanol are produced from maize/ sugar and other farm waste. However, after the pre-treatment and initial processing, both follow a completely different procedure, where waste material has to be processed into an anaerobic chamber for a certain time to produce CBG, and for ethanol production, waste is required to be processed further for blending production.

Gail (India), India's leading natural gas company, and TruAlt Bioenergy Limited signed a Term Sheet for GAIL's equity participation in TruAlt Bioenergy's joint venture company Leafiniti Bioenergy Limited which owns and operates India's second CBG plant. TruAlt Bioenergy and GAIL India hold 51% and 49% shareholding respectively in the JV. The investment for establishing the CBG plants is expected to surpass US\$72 million, financed through a blend of debt and equity, contingent upon successful due diligence and necessary approvals. The JV company plans to process more than 600 million kilograms of organic waste annually, including agricultural residue, sugarcane press mud, spent wash from ethanol production, and other biodegradable waste. This initiative aims to produce over 33 million kilograms of CBG, nearly 20 million kilograms of Solid Fermented Organic Manure (SFOM), and more than 30 million kilograms of Liquid Fermented Organic Manure (LFOM) each year. Each unit will operate at a capacity of 10 tonnes per day (TPD), leading to a daily production of 100,000 kilograms of CBG. This will provide a substantial economic boost to local agriculture, creating jobs for over 600 people, and offering considerable environmental advantages. The joint venture aims to establish a strong production system for CBG using diverse waste and biomass sources, in line with the growing demand for CNG.

9 Carbon credits market

A carbon credit is a tradable permit representing one ton of carbon dioxide (CO₂) removed from the atmosphere. These arise from projects that reduce, avoid, or capture greenhouse gas emissions like renewable energy generation, forest conservation, or carbon capture and storage. Verified and certified projects generate credits that companies, organizations, or even individuals can purchase.

The concept of carbon credits emerged in the 1997 Kyoto Protocol, the first international agreement to combat climate change. It established a cap-and-trade system, limiting the total greenhouse gas emissions allowed for participating countries. Each country received an initial allocation of "allowances" (essentially carbon credits) that they could trade amongst themselves. This created a market incentive for reducing emissions, as countries with excess allowances could sell them to those exceeding their limits.

The Paris Agreement in 2015 further solidified the role of carbon markets. It encouraged countries to establish Nationally Determined Contributions (NDCs), ambitious national climate plans that often involve carbon trading schemes.

The global carbon credits market is a mechanism designed to reduce greenhouse gas emissions by allowing countries, companies, or organizations to buy carbon credits as a way to offset their own emissions. The primary goal of the carbon credits market is to incentivize and finance projects that reduce or remove greenhouse gases from the atmosphere. This can include renewable energy projects, reforestation efforts, or energy efficiency improvements.

Carbon credits represent the right to emit one ton of carbon dioxide or its equivalent. These credits are traded on various platforms and exchanges, with prices fluctuating based on supply and demand dynamics. The market operates under various regulatory frameworks, including the Kyoto Protocol's Clean Development Mechanism (CDM) and the Paris Agreement's mechanisms for voluntary carbon markets. Participants in the market include governments, multinational corporations, financial institutions, and project developers. They buy credits to meet regulatory requirements, offset their emissions voluntarily, or as part of corporate social responsibility initiatives.

The market faces challenges such as ensuring the environmental integrity of credits, avoiding double counting, and maintaining transparency in transactions. There is ongoing debate about the effectiveness of carbon markets in achieving emission reduction targets. Over time, the market has evolved with new initiatives and standards emerging to address shortcomings and improve transparency. Efforts are underway to create more robust market mechanisms under international agreements like the Paris Agreement. The global carbon credits market plays a significant role in the fight against climate change by financially supporting emission reduction projects. However, its effectiveness hinges on robust regulation, transparency, and continued evolution to meet global climate goals.

9.1 Carbon credits market – Compliance and voluntary markets

Compliance markets are regulated by national or international legal frameworks. Notable examples include the European Union Emissions Trading System (EU ETS), the California Cap-and-Trade Program, and mechanisms established under the Kyoto Protocol such as the Clean Development Mechanism (CDM). Participants are typically large emitters such as power plants, industrial facilities, and airlines that are mandated by law to cap their emissions. These entities must purchase carbon credits to cover any emissions above their allotted cap.

Compliance markets have strict rules for the types of projects that can generate credits, and there is rigorous monitoring and verification to ensure the integrity of the credits. Prices in these markets can be influenced by regulatory changes and the overall cap on emissions set by authorities. Compliance markets are designed to ensure that countries or regions meet their emission reduction targets. They create a financial incentive for companies to reduce their emissions and invest in cleaner technologies.

Voluntary markets allow companies, organizations, and individuals to purchase carbon credits voluntarily, often driven by corporate social responsibility, sustainability goals, or consumer demand for greener products. These markets are not regulated by law but operate based on standards developed by various organizations. Participants

include businesses looking to offset their carbon footprint, NGOs, individuals, and governments that want to demonstrate leadership in climate action. There are several standards in the voluntary market, such as the Verified Carbon Standard (VCS), Gold Standard, and Climate Action Reserve. These standards ensure that projects are real, additional (beyond business-as-usual scenarios) and verified by third parties.

Voluntary markets support a wide variety of projects, including reforestation, renewable energy, methane capture, and community-based initiatives. The flexibility allows for innovation and diverse approaches to emission reductions. Prices in voluntary markets can vary widely based on the type of project, location, and co-benefits (e.g., social, environmental benefits beyond carbon reduction). The market is often influenced by corporate sustainability commitments and public awareness of climate issues. Voluntary markets provide additional avenues for funding climate projects and raise awareness about carbon offsetting. They play a critical role in engaging private sector participation and driving climate action beyond regulatory requirements.

9.2 Indian carbon markets (ICM)

India has established a new National Designated Authority (NDA) on August 22, 2025 to handle all of India's commitments under Article 6 of the Paris Agreement superseding the earlier NDA dated May 30, 2025. Chaired by the Secretary of Ministry of Environment, Forest and Climate Change and comprising representatives from 20 key ministries/agencies, the new NDA's role is to evaluate, approve, and authorize carbon market and non-market projects, maintain a national registry through the Indian Carbon Market framework, facilitate migration of pre-2020 CDM Certified Emission Reductions (CERs) into new article 6 framework, and ensure projects align with India's sustainable development goals and NDC targets. It can set eligibility criteria, fees, guidelines, and procedures; assess projects for technical, financial, and sustainability soundness; prioritize proposals with higher national benefits; and co-opt experts or form sub-committees as needed. It also ensures proper monitoring, stakeholder consultation, and compliance with international requirements while reporting to the Apex Committee for Paris Agreement Implementation (AIPA) and the Central Government.

This development is in line with the Paris Agreement Rulebook, which emphasizes carbon trading through bilateral and cooperative approaches, as well as international market mechanisms. India has taken the necessary steps, including the inclusion of fuels like Compressed Biogas (CBG) and Sustainable Aviation Fuel (SAF) in the list of greenhouse gas (GHG) mitigation activities.

In 2023, India introduced the Carbon Credit Trading Scheme (CCTS), which encompasses both compliance and voluntary sectors. Although the compliance segment is set to commence in 2025-26, a specific timeline for the launch of the voluntary carbon market has not been established. Under the revised carbon market scheme, obligated entities have the flexibility to purchase additional credits or sell surplus ones, while businesses can trade carbon credits to offset their emissions.

However, sectors facing challenges in meeting reduction targets, particularly those with hard-to-abate emissions, are exploring the possibility of trading energy-saving certificates (ESCerts) and renewable energy certificates (RECs) as offsets. Following the successful hosting of the G20 Summit, India has emerged as a favorable destination for energy transition investments, with the addition of approximately 17 GW of capacity, of which 13.8 GW consists of non-fossil additions.

The government plans to further develop the Indian Carbon Market (ICM), which will establish a national framework aimed at decarbonizing the Indian economy by pricing GHG emissions through the trading of Carbon Credit Certificates. The Bureau of Energy Efficiency, in conjunction with the Ministry of Environment, Forest, and Climate Change, is developing the Carbon Credit Trading Scheme for this purpose. A stakeholder consultation on Accredited Carbon Verifiers under the ICM was recently held in New Delhi, attended by key stakeholders, including Accredited Energy Auditors, Carbon/Energy Verifiers, and sector experts.

As India currently has an energy savings-based market mechanism, the new Carbon Credit Trading Scheme will enhance energy transition efforts with an increased scope covering potential energy sectors in India. For these

sectors, GHG emissions intensity benchmarks and targets will be developed, aligned with India's emissions trajectory as per climate goals. The trading of carbon credits will be based on performance against these sectoral trajectories. Furthermore, a voluntary mechanism is envisioned to encourage GHG reduction from non-obligated sectors.

The ICM will enable the creation of a competitive market that provides incentives for climate actors to adopt low-cost options by attracting technology and finance towards sustainable projects that generate carbon credits. It can serve as a vehicle for mobilizing a significant portion of the investments required by the Indian economy to transition towards low-carbon pathways. Additionally, it will provide guidance for developing the Monitoring, Reporting, and Verification (MRV) process and define eligibility criteria for Accredited Carbon Verifiers (ACVs).

The ICM will develop methodologies for estimating carbon emissions reductions and removals from various registered projects and stipulate the required validation, registration, verification, and issuance processes to operationalize the scheme. MRV guidelines for the emissions scheme will also be developed after consultation. A comprehensive institutional and governance structure will be established with specific roles for each party involved in the execution of the ICM. Capacity building of all entities will be undertaken to up-skill in the subject matter.

The ICM will mobilize new mitigation opportunities through demand for emission credits by private and public entities. A well-designed, competitive carbon market mechanism would enable the reduction of GHG emissions at the least cost, both at the entity level and the overall sector, driving faster adoption of clean technologies in a growing economy like India.

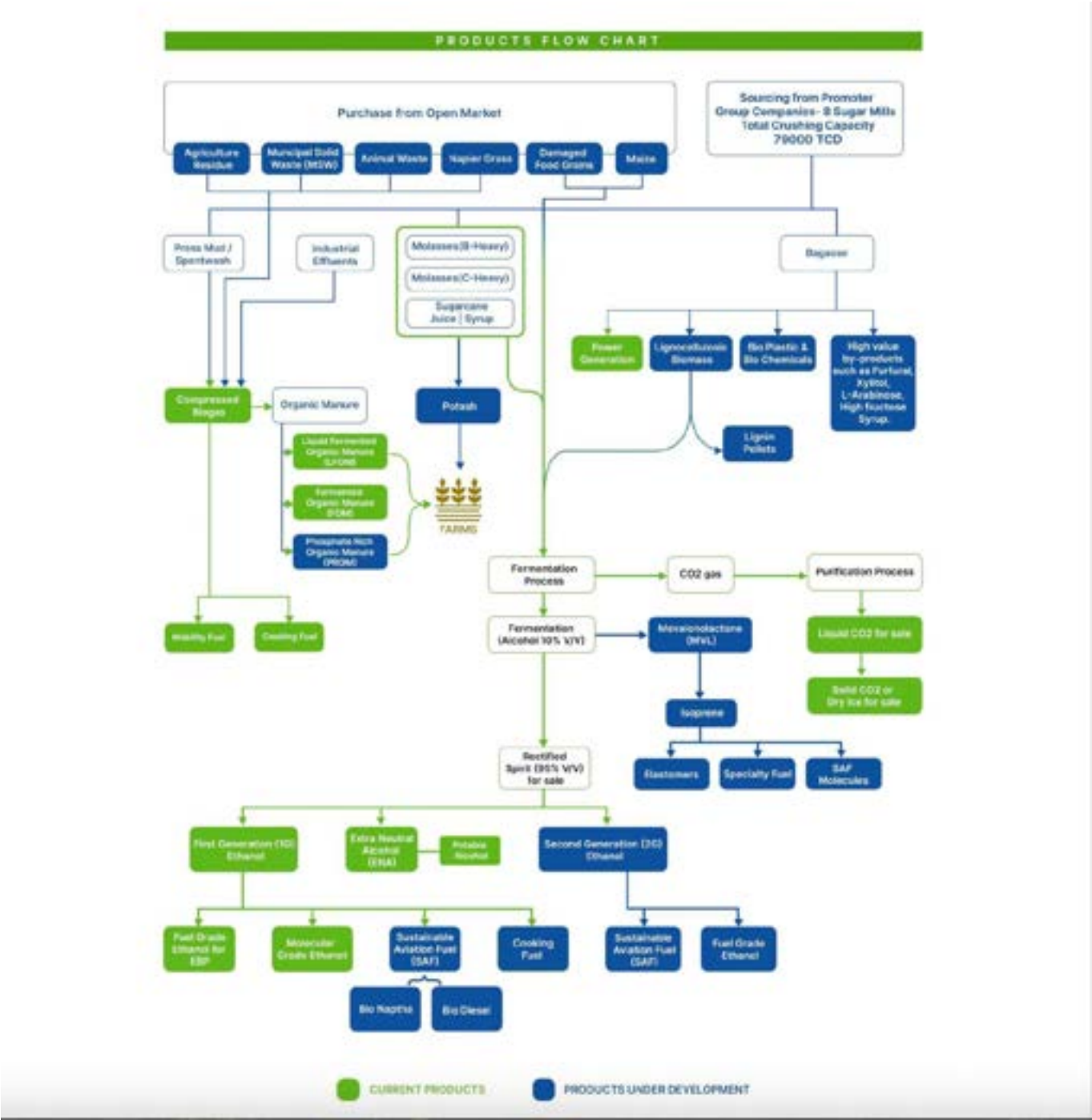
India has been at the forefront of climate action to meet climate goals through its ambitious Nationally Determined Contributions (NDC). To facilitate the achievement of India's enhanced climate targets and meet future goals, the government is developing the ICM. By accelerating the transition to a low-carbon economy, the ICM will facilitate the achievement of the NDC goal of reducing the Emissions Intensity of GDP by 45% by 2030 against 2005 levels.

The government has already begun work in this regard, with the Ministry of Environment proposing legally binding GHG emission targets for over 460 industrial units as part of India's first compliance-based carbon market. The draft rules, titled Greenhouse Gas Emission Intensity Target Rules, 2025, were issued by the ministry in June 2025. The Bureau of Energy Efficiency will set targets for two compliance years, 2025-26 and 2026-27, based on 2023-24 as baseline data. Sectoral benchmarks and each company's past performance will guide these targets. Unused credits can be banked for future years, offering some flexibility to industries.

This development will be particularly beneficial for biofuel producers in India, considering Article 6 of the Paris Agreement, which focuses on the development of carbon markets and enables countries to transfer carbon credits earned from the reduction of greenhouse gas emissions to help one or more countries meet their climate targets. CBG and SAF have been finalized as GHG mitigation activities in India, while biofuels, in general, will be considered valid under GHG removal activities. This will give impetus to the development of biofuels in India once the ICM is operational.

10 TruAlt Bioenergy: A diversified biofuel player

Figure 62: TBL products flow chart



TruAlt Bioenergy Limited is a green energy company steadfastly pursuing its objectives through a harmonious amalgamation of various policies laid out by the Government of India in its transition towards sustainable growth. From the foundational National Biofuels Policy to the strategic Ethanol Blending Program, the Pradhan Mantri JI-VAN Yojana, the Sustainable Alternative Towards Affordable Transportation (SATAT) initiative, to the cutting-edge

forays into Green Hydrogen and the globally significant Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), TruAlt Bioenergy's operations seamlessly align with an extensive spectrum of governmental policies. Strategic investments and collaborations are at the heart of TruAlt Bioenergy's growth strategy, wherein the company actively seek partnerships with industry leaders, research institutions, and governmental bodies to amplify our impact and accelerate the adoption of sustainable energy solutions. These alliances enable TruAlt Bioenergy to leverage collective expertise, share resources, and expand market reach, driving significant value creation for stakeholders. TruAlt Bioenergy's forays into CBG with companies like GAIL as partners are examples of these.

TruAlt Bioenergy stands as one of India's largest biofuels producers, having strategically positioned itself as a prominent and diversified player in the biofuel industry, particularly in the ethanol sector. TruAlt Bioenergy holds the distinction of being the largest ethanol producer in India based on installed capacity, with an aggregate installed capacity of 2,000 kilo litres per day (KLPD) and an operational capacity of 1,800 KLPD as of March 31, 2025. The company is a leading entity in the market and has amongst the largest market share in terms of ethanol production capacity in (Fiscal 2025) at 3.6%. This 3.6% market share is based on the combined share in both sugar/molasses-based and grain-based ethanol. Specifically, in sugar-based ethanol, TruAlt Bioenergy holds a market share of 7.0%.

TruAlt Bioenergy has strategically established its presence with five distillery units that operate on molasses and syrup-based feedstocks. The company further intends to commission dual-feed capabilities totalling 1,300 KLPD, aimed at enhancing operational flexibility and optimizing feedstock utilization. These units will be capable of running on diverse feedstocks, including damaged food grains, broken rice, and maize. Typically, dual feed integration facilities operate approximately from 330 to 340 days. In parallel bagasse-based cogeneration plants offer a cost advantage over coal-based cogeneration plants, resulting in lower fuel expenses and reduced power generation costs.

As of August 2024, the world's first commercial ethanol-to-SAF refinery is operational with a capacity of 110 KLPD, TruAlt Bioenergy has ambitions of setting up a 310 KLPD facility to produce 10 crore litres of SAF, which is intended to position it as one of the world's largest producers of SAF from Ethanol.

TruAlt Bioenergy also produces extra-neutral alcohol (ENA) which is a primary raw material in the production of alcoholic beverages. During the manufacturing processes, the company also captures CO₂ which is in turn used to produce dry ice and liquid CO₂. The CO₂ market in India is primarily driven by its use in various industries such as food and beverages, healthcare, chemicals, and oil and gas. The CO₂ market is growing in India driven by increasing industrialisation and rising standards of living.

TruAlt Bioenergy, through its subsidiary Leafiniti Bioenergy Private Limited, is one of the first producers of compressed biogas ("CBG") under the Sustainable Alternative Towards Affordable Transportation (SATAT) scheme introduced by the Government of India in 2018 and operated at 10.2 TPD. TruAlt Bioenergy is rapidly expanding its CBG capacity with multiple plans and is set to become one of India's leading CBG/ Bio-CNG producers.

A distinct advantage that sets TruAlt Bioenergy apart from other biofuel players lies in its robust network of raw material sources, majority of which are internally generated. This vertically integrated approach to sourcing raw materials contributes significantly to the company's competitive edge by having direct control over the supply of raw material via supply arrangement with promoter group entities. Thus, TruAlt Bioenergy is at a position to ensure reliability, consistency, and quality in its ethanol production processes.

This strategic alignment of resources positions TruAlt Bioenergy to effectively cater to the burgeoning demand for ethanol in India's dynamic market. As countries increasingly shift towards more sustainable and environmentally friendly energy solutions, the demand for biofuels, including ethanol, continues to rise. TruAlt Bioenergy's strategic foresight in expanding its distillation capacity and securing its raw material supply bodes well for its ability to meet this growing market demand. In line with this TruAlt Bioenergy is also progressing towards the fuel retail business. TruAlt Bioenergy has been officially granted authorisation as an Oil Marketing Company (OMC), allowing it to directly market clean fuels like ethanol and Bio-CNG, along with retailing Motor Spirit (Petrol) and High-Speed Diesel (HSD) across India. This marks a strategic entry into the country's fuel retailing network. The company will be recognized as a private Oil Marketing Company (OMC) in India, alongside established players such as Reliance Industries – BP,

Shell and Nayara Energy. As part of its commitment to inclusive fuel access, TruAlt Bioenergy aims to establish at least 5% of the retail outlets in notified remote areas, supporting the government's vision of last-mile energy connectivity. In the initial rollout, TruAlt Bioenergy plans to launch over 100 strategically located fuel stations, building a robust network that caters to both conventional fuels and next-generation blended alternatives such as ethanol and Bio-CNG.

TruAlt Bioenergy's long-term growth strategy entails reducing its reliance on a single feedstock and diversify its range of raw materials. The diversification aims to enhance operational efficiency while positioning TruAlt Bioenergy as a carbon-neutral entity. Primary focus is on second-generation biofuels, which encompass a wide variety of feedstocks, with an emphasis on non-edible biomass like wood chips, agricultural and forest residues, and municipal solid waste. Second-generation biofuels present numerous advantages, including superior environmental sustainability, enhanced energy efficiency, and the potential for utilizing more cost-effective resources. Additionally, the company intends to progressively commence the production of second generation (2G) ethanol, bioplastics, sustainable aviation fuel (SAF), biochemicals, and set up biofuel dispensing stations.

The company meets its steam and power requirements through integrated captive power generation. Each distillery is equipped with bagasse-fired cogeneration plants, comprising high-efficiency boilers and turbines, thereby ensuring minimal reliance on external energy sources. This approach not only enhances operational sustainability but also delivers a significant cost advantage over conventional coal-based power systems, aligning with both economic and environmental objectives. Furthermore, TruAlt Bioenergy's in-house raw material sourcing for ethanol production, particularly from a sister concern/ promoter group company, strategically fosters vertical integration. This ensures a seamless supply chain, granting the promoter group company direct control over raw material quality. Leveraging the sister concern/ promoter group resources enhances efficiency, reduces external dependency, and boosts overall operational stability, providing a distinct strategic advantage.

10.1 TruAlt Bioenergy: Potential threats to products and services

1. Competition with Fossil Fuels:
Biofuels face strong competition from cheaper and more established fossil fuels, which can limit market share and profitability.
2. Food vs. Fuel Debate:
The use of agricultural feedstocks for biofuel production can lead to conflicts with food supply, impacting public perception and policy support.
3. Climate Variability:
Climate variability and extreme weather events can affect the availability and reliability of feedstocks, disrupting biofuel production.
4. Regulatory and Policy Changes:
Uncertainty and changes in government regulations and policies can impact the biofuel industry's growth and stability.
5. Technological Advancements in Electric Vehicles:
The rapid advancement and adoption of electric vehicles pose a significant threat to the biofuel market by reducing demand for liquid fuels.
6. Global Economic Instability:
Economic instability can affect investment in the biofuel sector and disrupt global supply and demand dynamics.
7. Infrastructure Limitations:
Insufficient infrastructure for biofuel production, distribution, and storage can hinder market expansion and accessibility.

11 Competitive Landscape

11.1 Level of industry fragmentation and key player overview

Ethanol market in India is relatively fragmented, with numerous players including sugar mills, distilleries, and ethanol manufacturers. The Indian government has promoted ethanol blending in gasoline, which has encouraged a wider range of entities to enter the ethanol production market. Both large corporate players and smaller regional producers are involved in ethanol production.

TruAlt Bioenergy invested significantly in expanding its production capacity, allowing it to produce ethanol on a larger scale compared to its competitors. This move enabled them to meet the growing demand for ethanol, especially due to the Indian government's emphasis on ethanol blending. TruAlt Bioenergy has a successful track record of increasing the distillation capacity from 390 KLPD to 2,000 KLPD in around 4 years to become India's largest ethanol producer by installed capacity as of December 31, 2024.

The company currently operates four Ethanol production distilleries on molasses and syrup-based feedstocks, with production capacity (installed operational capacity) as follows:

Table 22: Ethanol Capacity

Sr. No.	Unit Type	Capacity* (KLPD)
1	Unit 1	700
2	Unit 2	500
3	Unit 3	400**
4	Unit 4	200***
	Total	1,800

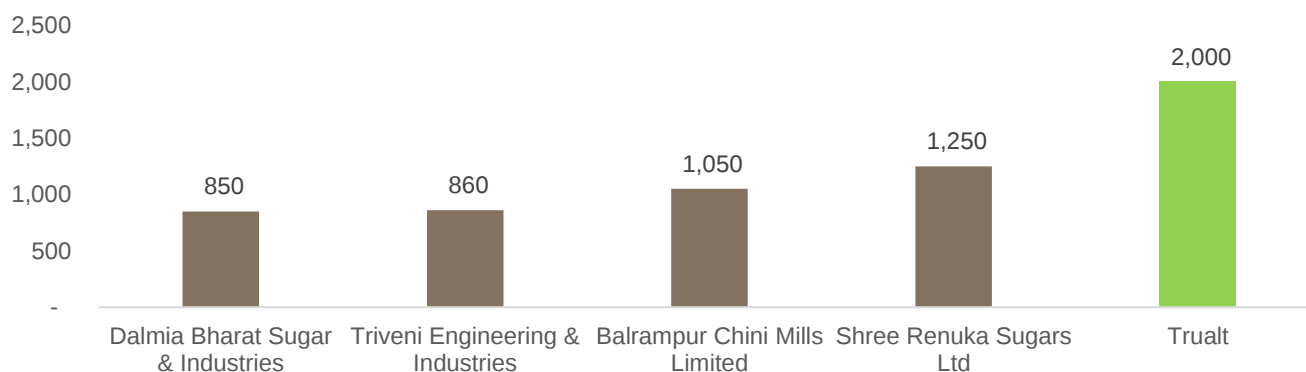
*As of March 31, 2025.

** TBL Unit 3 capacity was increased from 200 KLPD to 400 KLPD from November 1, 2024.

*** TBL Unit 4 received consent to operate on December 24, 2024 and was capitalised on March 30, 2025 post completion of trial run on March 29, 2025.

Note: In addition, the company has established TBL Unit 5 with an installed capacity of 200 KLPD as of March 31, 2025.

Figure 63: Top 5 installed distillation capacity (in KLPD), India – FY25



KLPD: thousand litre per day

Source: CRISIL MI&A consulting

11.2 Porter's five forces analysis

Table 23: Porter's Five Forces Assessment

Bargaining power of buyer (High)	- India ethanol market, buyers hold a significant amount of bargaining power due to the presence of numerous buyers such as oil marketing companies, sugar mills, and distilleries. - The buyers have the option to switch to other fuels like gasoline if the price of ethanol becomes too high. - Refineries and distributors have some leverage over ethanol producers as ethanol is a vital component of gasoline blends. - However, the competition among ethanol suppliers helps to balance this power dynamic.
Bargaining power of suppliers (Low to Moderate)	- The bargaining power of suppliers is relatively low in the India ethanol market. This is because there are a limited number of suppliers of ethanol, and they are all located in India. Buyers are also able to produce their own ethanol if the price becomes too high. - Ethanol production relies on agricultural feedstocks (sugarcane, corn). Suppliers have some power due to their importance, but options exist for sourcing raw materials.
Threat of new entrants (Moderate to High)	- There are various rules and regulations that are to be followed to produce ethanol like Environment Clearance from MoEFCC/SEIAA, license from Petroleum and Explosive Safety Organization of India (PESO), IEM license, and must meet the BIS standards for ethanol production. - Setting up the ethanol production plants requires high capital requirements.
Threat of substitutes (Moderate)	- There are several alternative fuels that can be used in gasoline, such as methanol and biodiesel. However, ethanol is a relatively cost-competitive fuel, and it has several environmental benefits that make it a desirable alternative to other products. - The by-products of ethanol hold immense value and can be utilized in a multitude of beneficial ways. For example, one of the by-products is distilled grains which are the leftover grains from the fermentation process. The other one is Co2 which can be used in carbonation of beverages.
Industry Rivalry (High)	- The rivalry among existing firms is relatively high in the India ethanol market. This is because there are a limited number of players in the market, and they all compete for a share of the same customers. - Intense competition among ethanol producers due to government mandates for blending and increasing demand. Established players and potential capacity expansions contribute to rivalry.

Source: CRISIL MI&A consulting

11.3 Operational benchmarking

Table 24: Ethanol Plant – Operational benchmark - Indian Players (FY25)

Sr. No.	Company Name	No. of distilleries	Ethanol/ Distillery capacity (KLPD)	Production (KLPD)	\$ Capacity Utilisation %
1	TruAlt Bioenergy	4	1800	628	45%
2	Bajaj Hindustan Sugar Ltd	6	800	NA	NA
3	Dhampur Sugar Mills Ltd	1	350	223	64%
4	Triveni Engineering & Industries	5	860	658	77%
5	Balrampur Chini Mills Ltd	5	1,050	716	68%
6	Shree Renuka Sugars Ltd	3	1,250	NA	NA
7	Eid Parry India Ltd	5	537	NA	NA
8	Dwarikesh Sugar Indus Ltd	2	337.5	181	54%

Sr. No.	Company Name	No. of distilleries	Ethanol/ Distillery capacity (KLPD)	Production (KLPD)	\$ Capacity Utilisation %
9	Dalmia Bharat Sugar & Industries	4	850	NA	NA
10	India Glycols Ltd	3	810	NA	NA
11	Simbhaoli Sugars Ltd	3	210	NA	NA
12	KPR Mill Ltd	2	500	NA	NA
13	DCM Shriram	4	560	NA	NA
14	Uttam Sugar Mills	2	350	219	63%
15	BCL Industries Ltd	2	700	743	106%
16	Godavari Biorefineries Limited	1	600	276	46%
17	Ugar Sugar Works Ltd	3	845	NA	NA
18	Dhampur Bio-Organics Ltd	1	312.5	201	64%

Source: Company regulatory filings and CRISIL MI&A consulting

Unit 4 has an installed operational capacity of 200 KLPD from 24th December 2024. Unit 5 has an installed capacity of 200KLPD as on 31 December 2024.

Table 25: Ethanol Plant – Operational benchmark - Indian Players (FY24)

Sr. No.	Company Name	No. of distilleries	Ethanol/ Distillery capacity (KLPD)	Production (KLPD)	\$ Capacity Utilisation %
1	TruAlt Bioenergy	3	1,400	598	43%
2	Bajaj Hindustan Sugar Ltd	6	800	586	73%
3	Dhampur Sugar Mills Ltd	1	350	413	118%
4	Triveni Engineering & Industries	5	860	606	71%
5	Balrampur Chini Mills Ltd	5	1,050	921	88%
6	Shree Renuka Sugars Ltd	3	1,250	514	41%
7	Eid Parry India Ltd	5	417	415	99%
8	Dwarikesh Sugar Indus Ltd	2	337.5	326	97%
9	Dalmia Bharat Sugar & Industries	4	850	580	68%
10	India Glycols Ltd	3	510	N.A.	N.A.
11	Simbhaoli Sugars Ltd	3	210	118	56%
12	KPR Mill Ltd	2	500	310	62%
13	DCM Shriram	4	560	534	95%
14	Uttam Sugar Mills	2	300	225	75%
15	BCL Industries Ltd	2	700	434	62%
16	Godavari Biorefineries Limited	1	600	N.A.	N.A.
17	Ugar Sugar Works Ltd	3	845	N.A.	N.A.
18	Dhampur Bio-Organics Ltd	1	312.5	306	98%

Source: Company regulatory filings and CRISIL MI&A consulting

Note for TruAlt Bioenergy: TruAlt Bioenergy increased capacity in Unit 1 by 550 KLPD and Unit 2 by 260 KLPD 26th Jan 2023 and 15th Nov 2022 respectively. As a result, TruAlt Bioenergy's total capacity increased from 590 KLPD in FY22 to 1,400 KLPD in FY23 and 2,000 in FY24. The sudden increase in capacity by 1,410 KLPD has resulted in lower utilization which is likely to increase from this year onwards. Installed capacity represents the installed capacity as of the last date of the relevant period. The installed capacity is based on various assumptions and estimates, including standard capacity calculation practice in the Indian ethanol industry and capacity of other machinery installed at the relevant distillery unit. Assumptions and estimates taken into account for measuring capacity utilization is calculated on a weighted average basis.
\$ Capacity Utilization – [Production (KLPD)]/[Ethanol Capacity (KLPD)].

Table 26: Ethanol Plant – Operational benchmark - Indian Players (FY23)

Sr. No.	Company Name	No. of distilleries	Ethanol/ Distillery capacity (KLPD)	Production (KLPD)	\$ Capacity Utilisation %
1	TruAlt Bioenergy	3	1,400	597	70% #
2	Bajaj Hindustan Sugar Ltd	6	800	517	65%
3	Dhampur Sugar Mills Ltd	1	350	284	81%
4	Triveni Engineering & Industries	4	660	496	75%
5	Balrampur Chini Mills Ltd	5	1,050	589	56%
6	Shree Renuka Sugars Ltd	3	1,250	538	43%
7	Eid Parry India Ltd	5	417	294	71%
8	Dwarikesh Sugar Indus Ltd	2	337.5	233	69%
9	Dalmia Bharat Sugar & Industries	4	710	485	68%
10	India Glycols Ltd	3	350	NA	NA
11	Simbhaoli Sugars Ltd	3	210	92	44%
12	KPR Mill Ltd	2	360	188	52%
13	DCM Shriram	4	560	NA	NA
14	Uttam Sugar Mills	2	200	151	76%
15	BCL Industries Ltd	2	600	287	48%
16	Godavari Biorefineries Limited	1	600	NA	NA
17	Ugar Sugar Works Ltd	2	845	250	30%
18	Dhampur Bio-Organics Ltd	1	312.5	269	86%

Source: Company regulatory filings and CRISIL MI&A consulting

Note for TruAlt Bioenergy: TruAlt Bioenergy increased capacity in Unit 1 by 550 KLPD and Unit 2 by 260 KLPD 26th Jan 2023 and 15th Nov 2022 respectively. As a result, TruAlt Bioenergy's total capacity increased from 590 KLPD in FY22 to 1,400 KLPD in FY23. The sudden increase in capacity by 810 KLPD has resulted in lower utilization which is likely to increase from this year onwards. In Fiscal 2023 capacity in Unit 1 has increased from 150 KLPD to 700 KLPD from Feb 23 and in Unit 2 has increased from 240 KLPD to 500 KLPD from Nov 22. Installed capacity represents the installed capacity as of the last date of the relevant period. The installed capacity is based on various assumptions and estimates, including standard capacity calculation practice in the Indian ethanol industry and capacity of other machinery installed at the relevant distillery unit. Assumptions and estimates taken into account for measuring capacity utilization is calculated on a weighted average basis. The corresponding capacity utilization has been considered on a weighted average basis. In Fiscal 2023 capacity in Unit 1 has increased from 150 KLPD to 700 KLPD from Feb 23 and in Unit 2 has increased from 240 KLPD to 500 KLPD from Nov 22. The corresponding capacity utilization has been considered on a weighted average basis.

\$ Capacity Utilization – [Production (KLPD)]/[Ethanol Capacity (KLPD)].

Table 27: Ethanol Plant – Operational benchmark - Indian Players (FY22)

Sr. No.	Company Name	No. of distilleries	Ethanol/ Distillery capacity (KLPD)	Production (KLPD)	\$ Capacity Utilisation %
1	TruAlt Bioenergy	3	590	372	63%
2	Bajaj Hindustan Sugar Ltd	6	800	475	59%
3	Dhampur Sugar Mills Ltd	1	250	221	88%
4	Triveni Engineering & Industries	3	520	262	50%

Sr. No.	Company Name	No. of distilleries	Ethanol/ Distillery capacity (KLPD)	Production (KLPD)	\$ Capacity Utilisation %
5	Balrampur Chini Mills Ltd	4	560	447	80%
6	Shree Renuka Sugars Ltd	3	720	452	63%
7	Eid Parry India Ltd	5	297	213	78%
8	Dwarikesh Sugar Indus Ltd	1	162.5	152	94%
9	Dalmia Bharat Sugar & Industries	4	600	321	52%
10	India Glycols Ltd	3	NA	NA	NA
11	Simbhaoli Sugars Ltd	3	210	85	40%
12	KPR Mill Ltd	2	360	93	26%
13	DCM Shriram	4	350	NA	NA
14	Uttam Sugar Mills	2	200	139	70%
15	BCL Industries Ltd	2	400	197	49%
16	Godavari Biorefineries Limited	1	400	NA	NA
17	Ugar Sugar Works Ltd	2	200	74	37%
18	Dhampur Bio-Organics Ltd	1	312.5	125	40%

Source: Company regulatory filings and CRISIL MI&A consulting

Note for TruAlt Bioenergy: Installed capacity represents the installed capacity as of the last date of the relevant period. The installed capacity is based on various assumptions and estimates, including standard capacity calculation practice in the Indian ethanol industry and capacity of other machinery installed at the relevant distillery unit. Assumptions and estimates taken into account for measuring capacity utilization is calculated on a weighted average basis.

\$ Capacity Utilization – [Production (KLPD)]/ [Ethanol Capacity (KLPD)].

Table 28: Ethanol Plant – Operational benchmark - Indian Players (FY21)

Sr. No.	Company Name	No. of distilleries	Ethanol/ Distillery capacity (KLPD)	Production (KLPD)	\$ Capacity Utilisation %
1	TruAlt Bioenergy	3	390	233	60% #
2	Bajaj Hindustan Sugar Ltd	6	800	249	31%
3	Dhampur Sugar Mills Ltd*	2	400	308	77%
4	Triveni Engineering & Industries	2	320	293	92%
5	Balrampur Chini Mills Ltd	4	520	468	90%
6	Shree Renuka Sugars Ltd	3	720	372	52%
7	Eid Parry India Ltd	4	237	173	73%
8	Dwarikesh Sugar Indus Ltd	1	130	84	65%
9	Dalmia Bharat Sugar & Industries	3	305	231	76%
10	India Glycols Ltd	3	NA	NA	NA
11	Simbhaoli Sugars Ltd	3	210	93	44%
12	KPR Mill Ltd	1	130	64	49%
13	DCM Shriram	4	350	NA	NA
14	Uttam Sugar Mills	2	200	82	41%
15	BCL Industries Ltd	1	200	190	95%
16	Godavari Biorefineries Limited	1	400	NA	NA
17	Ugar Sugar Works Ltd	2	75	NA	NA

Sr. No.	Company Name	No. of distilleries	Ethanol/ Distillery capacity (KLPD)	Production (KLPD)	\$ Capacity Utilisation %
18	Dhampur Bio-Organics Ltd*	NA	NA	NA	NA

Source: Company regulatory filings and CRISIL MI&A consulting

*NOTE: In FY21 Dhampur Sugar Mills Ltd and Dhampur Bio-organics were one entity and the number taken from the FY21 annual Report reflect the same

Note for TruAlt Bioenergy: Installed capacity represents the installed capacity as of the last date of the relevant period. The installed capacity is based on various assumptions and estimates, including standard capacity calculation practice in the Indian ethanol industry and capacity of other machinery installed at the relevant distillery unit. Assumptions and estimates taken into account for measuring capacity utilization is calculated on a weighted average basis.

\$ Capacity Utilization – [Production (KLPD)]/ [Ethanol Capacity (KLPD)].

Table 29: Ethanol Plant – Indian Players – Miscellaneous information

Sr. No.	Company Name	Upcoming plant	Cane crushing capacity (TCD)	Product Portfolio
1	TruAlt Bioenergy	1300 KLPD dual-feed integration in existing installed capacity of 2000 KLPD.	79,000***	Fuel-grade Ethanol
2	Bajaj Hindustan Sugar Ltd	NA	1,36,000	Fuel-grade Ethanol, Pharmaceutical and industrial grades, beverages production and Disinfectants and Sanitizers
3	Dhampur Sugar Mills Ltd	Recently expanded	24,000	Fuel-grade Ethanol
4	Triveni Engineering & Industries	Announced expansion to 1110 KLPD	61,000	Produce potable alcohol and fuel-grade Ethanol
5	Balrampur Chini Mills Ltd	NA	80,000	Fuel-grade Ethanol, and industrial application
6	Shree Renuka Sugars Ltd	NA	46,000	Fuel grade ethanol that can be blended with petrol
7	Eid Parry India Ltd	165 KLPD, expansions in its Haliyal and Nellikuppam plants are under progress. Would reach to 582 KLPD by April 2024.	40,800	Fuel-grade Ethanol
8	Dwarikesh Sugar Indus Ltd	NA	21,500	Fuel-grade Ethanol
9	Dalmia Bharat Sugar & Industries	The Company is expanding the 110 KLPD Jawaharpur distillery to 250 KLPD during FY2023-24. The Company will install another 300 KLPD grain-based distillery in Nigohi, which is expected to be commissioned in FY2024-25	43,200	Fuel-grade Ethanol
10	India Glycols Ltd	Plan for further Grain Capacity expansion to 720 KLPD by Q2FY25	5,500	Fuel-grade Ethanol
11	Simbhaoli Sugars Ltd	NA	19,500	Fuel-grade Ethanol
12	KPR Mill Ltd	NA	20,000	Fuel-grade Ethanol
13	DCM Shriram	120 KLD multi-feed distillery with 260 KLD grain attachment at Ajbapur	41,000	Fuel-grade Ethanol
14	Uttam Sugar Mills	In January 2024, 100 KLPD was added, taking the total capacity to 300 KLPD	27,000	Fuel-grade Ethanol
15	BCL Industries Ltd	Plans to take up the total group distillery capacity to 850 KLPD over the next two years.	NA	Producers of grain based potable alcohol and bottled alcohol

Sr. No.	Company Name	Upcoming plant	Cane crushing capacity (TCD)	Product Portfolio
16	Godavari Biorefineries Limited	Recently completed expansion from 400 KLPD	20,000	Sugar, biofuel, ENA, perfumery grade ethanol, hand sanitizer, pharma grade ethanol
17	Ugar Sugar Works Ltd	The company is planning an investment of Rs. 151 crores. It will set up a 200 KLPD facility at Ugar Khurd	18,500	Rectified spirit, Indian made liquor, absolute alcohol, arrack, industrial alcohol
18	Dhampur Bio-Organics Ltd	250 KLPD greenfield expansion project announced	29,500	Fuel-grade ethanol

Source: Company regulatory filings and CRISIL MI&A consulting

***Through Promoter Group companies

Table 30: Ethanol Plant – Operational benchmark (Global Players)

Sr. No.	Company Name	No of plants	Ethanol capacity (KLPD)	Production (KLPD)	Capacity Utilisation %	Upcoming plant	Cane crushing capacity (TCD)	Product Portfolio
1	Valero Energy Corporation	12	16,594	14,634	88%	NA	NA	Ethanol is shipped primarily by rail to fuel providers who mix the ethanol with gasoline
2	Raizen Brazil	NA	11,223	NA	NA	NA	NA	Fuel-grade Ethanol, Pharmaceutical and industrial grades for chemical, cosmetic and beverages applications
3	Wilmar - Australia	1	164	NA	NA	NA	11,841	Fuel-grade Ethanol, industrial grades, organic ethanol (include beverages, flavours, perfumery and extraction) and Refrigeration brine
4	Petrobras	9	4,362	NA	NA	NA	NA	Fuel-grade Ethanol
5	Sao Martinho	4	3,562	NA	NA	NA	NA	Hydrated ethanol , used in the tanks of ethanol-powered cars; Anhydrous ethanol , which is mixed with gasoline as an additive to fill the tanks of gasoline-powered vehicles; and industrial

Sr. No.	Company Name	No of plants	Ethanol capacity (KLPD)	Production (KLDP)	Capacity Utilisation %	Upcoming plant	Cane crushing capacity (TCD)	Product Portfolio
								ethanol, mainly used in the production of paints, cosmetics, and alcoholic beverages.

Source: Company regulatory filings

11.4 Financial benchmarking

11.4.1 Domestic Players

Table 31: Revenue FY18 to FY25

Revenue (Rs. Lakh)	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	CAGR (FY18-25)	FY24 % revenue from ethanol
TruAlt Bioenergy	-	-	-	52,538	69,558	116,039	122,340	190,772	38.04%*	78.2%
Bajaj Hindustan Sugar Ltd	594,271	680,639	666,934	666,597	557,565	633,803	610,432	557,476	-0.91%	14.2%
Triveni Engineering & Indus	341,238	315,174	443,663	470,335	469,404	631,010	615,140	680,794	10.37%	35.8%
Dhampur Sugar Mills Ltd	339,581	295,406	352,513	223,297	216,298	287,402	264,683	265,638	-3.45%	30.7%
Balrampur Chini Mills Ltd	440,072	428,578	474,129	481,166	484,603	466,586	559,374	541,538	4.1%	30.2%
Shree Renuka Sugars Ltd	626,634	447,953	474,079	555,537	638,647	902,075	1,131,900	1,058,910	7.78%	7.6%
Dalmia Bharat Sugar and Industries	227,488	201,851	211,080	268,577	300,686	325,208	289,937	374,578	7.38%	37.7%
Dwarikesh Sugar Indus Ltd	145,828	108,412	133,613	183,885	197,871	210,296	170,957	135,888	-1.00%	34.1%
EID Parry India Ltd	1,543,758	1,656,539	1,712,892	1,858,745	2,352,106	3,524,380	2,941,311	N.A.	N.A.	2.7%

*CAGR is from FY21 to FY25

Source: Company regulatory filings

Table 32: EBITDA FY18 to FY25

EBITDA (Rs. Lakh)	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	CAGR (FY18-24)
TruAlt Bioenergy	-	-	-	9,974	10,877	15,480	18,809	30,914	32.68%*
Bajaj Hindusthan Sugar Ltd	27,211	29,618	45,294	16,293	17,141	26,285	24,723	28,874	0.85%
Triveni Engineering & Indus	27,588	30,886	54,318	55,821	63,441	61,591	62,659	47,620	8.11%
Dhampur Sugar Mills Ltd	3,545	48,010	36,121	27,672	29,139	30,333	26,631	16,954	25.05%
Balrampur Chini Mills Ltd	45,166	68,907	68,197	71,383	69,971	51,204	81,227	73,943	7.30%
Shree Renuka Sugars Ltd	-110,626	26,785	-12,089	51,079	34,679	56,370	67,400	60,140	-
Dalmia Bharat Sugar and Industries	23,419	23,705	33,662	47,143	46,440	43,653	41,185	46,891	10.43%
Dwarikesh Sugar Indus Ltd	14,249	12,905	13,607	20,125	29,073	21,455	20,495	11,347	-3.25%

EID Parry India Ltd	136,874	151,007	199,681	217,556	240,602	315,550	258,762	N.A.	N.A.
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(*) CAGR for FY21-25

Source: Company regulatory filings

Table 33: EBITDA margin FY18 to FY25

EBITDA Margin	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25
TruAlt Bioenergy	-	-	-	18.98%	15.64%	13.34%	15.37%	16.20%
Bajaj Hindusthan Sugar Ltd	4.58%	4.35%	6.79%	2.44%	3.07%	4.15%	4.05%	5.18%
Triveni Engineering & Indus	8.08%	9.80%	12.24%	11.87%	13.52%	9.76%	10.19%	6.99%
Dhampur Sugar Mills Ltd	1.04%	16.25%	10.25%	12.39%	13.47%	10.55%	10.06%	6.38%
Balrampur Chini Mills Ltd	10.26%	16.08%	14.38%	14.84%	14.44%	10.97%	14.52%	13.65%
Shree Renuka Sugars Ltd	-17.65%	5.98%	-2.55%	9.19%	5.43%	6.25%	5.95%	5.68%
Dalmia Bharat Sugar and Industries	10.29%	11.74%	15.95%	17.55%	15.44%	13.42%	14.20%	12.52%
Dwarikesh Sugar Indus Ltd	9.77%	11.90%	10.18%	10.94%	14.69%	10.20%	11.99%	8.35%
EID Parry India Ltd	8.87%	9.12%	11.66%	11.70%	10.23%	8.95%	8.80%	N.A.

Source: Company regulatory filings

Table 34: PAT FY18 to FY25

PAT (Rs. Lakh)	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	CAGR (FY18-25)
TruAlt Bioenergy	-	-	-	4,950	3,760	4,901	3,181	14,664	31.19%
Bajaj Hindusthan Sugar Ltd	-49,964	-13,657	-5,000	-29,082	-26,754	-13,474	-8,692	-2,478	-
Triveni Engineering & Indus	11,914	21,628	33,512	29,460	42,406	179,181	39,516	23,826	10.49%
Dhampur Sugar Mills Ltd	15,126	25,092	22,403	14,335	14,403	15,799	13,452	5,242	-14.05%
Balrampur Chini Mills Ltd	23,166	57,582	51,935	47,979	46,464	28,417	53,447	43,692	9.49%
Shree Renuka Sugars Ltd	-69,554	-36,505	-56,656	-11,652	-13,672	-19,667	-62,720	-29,990	-
Dalmia Bharat Sugar and Industries	12,230	17,515	19,319	27,034	30,786	24,832	27,247	38,675	17.88%
Dwarikesh Sugar Indus Ltd	10,145	9,511	7,345	9,154	15,522	10,481	8,352	2,334	-18.94%
EID Parry India Ltd	51,743	43,765	88,888	99,982	157,370	182,774	161,757	N.A.	N.A.

(*) CAGR for FY21-25

Source: Company regulatory filings

Table 35: PAT margin FY18 to FY25

PAT Margin	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25
TruAlt Bioenergy	-	-	-	9.4%	5.4%	4.2%	2.6%	7.69%
Bajaj Hindusthan Sugar Ltd	-8.41%	-2.01%	-0.75%	-4.36%	-4.80%	-2.13%	-1.42%	-0.44%
Triveni Engineering & Indus	3.49%	6.86%	7.55%	6.26%	9.03%	28.40%	6.42%	3.50%
Dhampur Sugar Mills Ltd	4.45%	8.49%	6.36%	6.42%	6.66%	5.50%	5.08%	1.97%
Balrampur Chini Mills Ltd	5.26%	13.44%	10.95%	9.97%	9.59%	6.09%	9.55%	8.07%
Shree Renuka Sugars Ltd	-11.10%	-8.15%	-11.95%	-2.10%	-2.14%	-2.18%	-5.54%	-2.83%

Dalmia Bharat Sugar and Industries	5.38%	8.68%	9.15%	10.07%	10.24%	7.64%	9.40%	10.32%
Dwarikesh Sugar Indus Ltd	6.96%	8.77%	5.50%	4.98%	7.84%	4.98%	4.89%	1.72%
EID Parry India Ltd	3.35%	2.64%	5.19%	5.38%	6.69%	5.19%	5.50%	N.A.

Source: Company regulatory filings

Table 36: Net worth FY18 to FY25

Net Worth (Rs. Lakh)	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25
TruAlt Bioenergy	-	-	-	7,209	10,975	24,049	26,461	76,900
Bajaj Hindusthan Sugar Ltd	295,725	279,239	269,701	237,222	225,909	443,480	448,519	423,117
Triveni Engineering & Indus	94,635	114,052	133,867	155,567	191,285	266,525	290,090	315,962
Dhampur Sugar Mills Ltd	100,254	122,582	136,190	156,006	88,498	104,304	110,101	115,335
Balrampur Chini Mills Ltd	161,706	211,779	241,569	261,915	276,971	289,558	340,096	379,550
Shree Renuka Sugars Ltd	-367,160	-556,115	-88,240	-66,414	-60,746	-88,064	-143,790	-167,510
Dalmia Bharat Sugar and Industries	150,456	153,170	151,875	214,269	238,571	270,495	293,216	323,451
Dwarikesh Sugar Indus Ltd	36,582	46,360	48,371	57,891	67,329	73,979	82,208	80,622
EID Parry India Ltd	423,642	445,246	522,628	682,869	809,987	953,899	1,121,200	N.A.

Source: Company regulatory filings

Table 37: Net debt FY18 to FY25

Net Debt (Rs. Lakh)	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25
TruAlt Bioenergy	-	-	-	33,751	75,005	114,532	166,133	139,990
Bajaj Hindusthan Sugar Ltd	601,541	533,261	504,192	532,835	476,006	427,767	378,783	350,346
Triveni Engineering & Indus	110,776	159,429	135,500	96,594	153,647	83,928	133,455	192,295
Dhampur Sugar Mills Ltd	131,469	166,278	160,759	106,940	83,457	68,746	96,033	79,558
Balrampur Chini Mills Ltd	87,374	167,179	139,746	113,419	120,931	187,831	200,793	262,583
Shree Renuka Sugars Ltd	307,610	269,695	287,191	439,291	519,241	538,159	573,460	580,380
Dalmia Bharat Sugar and Industries	66,191	94,972	113,961	84,461	72,390	38,828	95,953	71,074
Dwarikesh Sugar Indus Ltd	32,178	63,505	65,249	55,663	52,184	37,009	44,995	42,119
EID Parry India Ltd	3,47,897	4,71,401	3,65,964	-15,430	4,377	-24,853	9,005	N.A.

Source: Company regulatory filings

Table 38: ROE FY18 to FY25

ROE	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25
TruAlt Bioenergy	-	-	-	68.66%*	41.36%	26.31%	10.27%	28.27%
Bajaj Hindusthan Sugar Ltd	-16.90%	-4.75%	-1.82%	-11.47%	-11.55%	-4.03%	-1.95%	-0.6%
Triveni Engineering & Indus	12.59%	20.73%	27.03%	20.36%	24.45%	78.28%	14.20%	7.9%
Dhampur Sugar Mills Ltd	15.09%	22.52%	17.31%	9.81%	11.78%	16.39%	12.55%	4.7%
Balrampur Chini Mills Ltd	14.33%	30.83%	22.91%	19.06%	17.24%	10.03%	16.98%	12.1%
Shree Renuka Sugars Ltd	18.94%	7.91%	17.59%	15.07%	21.50%	26.43%	Not Meaningful	Not Meaningful
Dalmia Bharat Sugar and Industries	8.13%	11.54%	12.67%	14.77%	13.60%	9.76%	9.67%	12.5%
Dwarikesh Sugar Indus Ltd	27.73%	22.93%	15.51%	17.23%	24.79%	14.83%	10.69%	2.9%
EID Parry India Ltd	12.21%	10.07%	18.37%	16.59%	21.08%	20.72%	15.59%	18.5%

(*) For FY21, TruAlt's ROE figure is derived from closing equity, as opposed to average equity

Source: Company regulatory filings

Table 39: ROCE FY18 to FY25

ROCE	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25
TruAlt Bioenergy	-	-	-	18.89%*	12.96%	10.48%	7.42%	10.88%
Bajaj Hindusthan Sugar Ltd	0.8%	1.1%	3.0%	-0.7%	-0.6%	0.6%	0.29%	0.94%
Triveni Engineering & Indus	10.7%	10.5%	17.1%	18.2%	18.4%	14.8%	15.20%	6.83%
Dhampur Sugar Mills Ltd	-8.3%	8.2%	9.7%	8.1%	11.1%	14.2%	10.83%	5.22%
Balrampur Chini Mills Ltd	14.3%	18.9%	15.3%	15.9%	15.2%	8.7%	11.58%	8.83%
Shree Renuka Sugars Ltd	249.2%	-2.8%	45.9%	11.7%	3.3%	7.0%	9.06%	7.68%
Dalmia Bharat Sugar and Industries	8.1%	7.8%	10.7%	13.0%	11.8%	9.9%	7.68%	7.90%
Dwarikesh Sugar Indus Ltd	15.9%	10.7%	8.9%	14.1%	21.2%	14.3%	12.79%	4.93%
EID Parry India Ltd	13.5%	14.1%	18.3%	22.5%	25.4%	28.3%	18.67%	N.A.

(*) For FY21, TruAlt's ROCE figure is derived from closing capital employed, as opposed to average capital employed

Source: Company regulatory filings

Table 40: Net Debt/Equity FY18 to FY25

Debt/Equity	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25
TruAlt Bioenergy	-	-	-	4.68	6.83	4.76	6.28	1.82
Bajaj Hindusthan Sugar Ltd	2.03	1.91	1.87	2.25	2.11	0.96	0.84	0.83
Triveni Engineering & Indus	1.17	1.40	1.01	0.62	0.80	0.31	0.46	0.61
Dhampur Sugar Mills Ltd	1.31	1.36	1.18	0.69	0.94	0.66	0.87	0.69
Balrampur Chini Mills Ltd	0.54	0.79	0.58	0.43	0.44	0.65	0.59	0.69
Shree Renuka Sugars Ltd	-0.84	-0.48	-3.25	-6.61	-8.55	-6.11	-3.99	-3.46

Dalmia Bharat Sugar and Industries	0.44	0.62	0.75	0.39	0.30	0.14	0.33	0.22
Dwarikesh Sugar Indus Ltd	0.88	1.37	1.35	0.96	0.78	0.50	0.55	0.52
EID Parry India Ltd	0.82	1.06	0.70	-0.02	0.01	-0.03	0.01	N.A.

Source: Company regulatory filings

Table 41: Fixed Asset Turnover FY18 to FY25

Fixed Asset Turnover	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25
TruAlt Bioenergy	-	-	-	1.60*	1.70	1.40	1.01	1.29
Bajaj Hindusthan Sugar Ltd	0.8	0.9	0.9	0.9	0.8	0.9	0.8	0.75
Triveni Engineering & Indus	4.1	3.8	4.7	4.4	4.4	5.0	4.2	3.56
Dhampur Sugar Mills Ltd	2.1	1.9	2.2	1.4	1.7	2.9	2.5	2.37
Balrampur Chini Mills Ltd	3.0	3.0	3.1	3.0	3.0	2.2	2.1	2.05
Shree Renuka Sugars Ltd	1.0	0.9	1.2	1.5	1.6	2.2	2.6	2.42
Dalmia Bharat Sugar and Industries	1.8	1.5	1.6	2.0	2.1	2.0	1.7	2.07
Dwarikesh Sugar Indus Ltd	4.3	3.3	3.6	4.4	5.0	4.4	2.9	2.42
EID Parry India Ltd	5.0	5.4	5.4	5.8	7.4	10.6	7.9	N.A.

(*) For FY21, TruAlt's figure is derived from closing PPE, as opposed to average PPE

Source: Company regulatory filings

Table 42: Working Capital days FY18 to FY25

Working Capital Days	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25
TruAlt Bioenergy	-	-	-	59.83	26.09	-21.50	26.23	26.18
Bajaj Hindusthan Sugar Ltd	-28	-51	-95	-111	-122	-106	-98	-63.74
Triveni Engineering & Indus	167	231	172	142	197	165	210	211.73
Dhampur Sugar Mills Ltd	112	182	171	243	217	130	173	212.85
Balrampur Chini Mills Ltd	122	190	200	198	210	219	222	265.30
Shree Renuka Sugars Ltd	-114	-154	-79	-43	5	10	2	-2.32
Dalmia Bharat Sugar and Industries	81	154	241	219	193	160	223	202.68
Dwarikesh Sugar Indus Ltd	114	238	260	191	173	139	187	265.32
EID Parry India Ltd	25	48	63	36	16	8	8	N.A.

Source: Company regulatory filings

NOTE: High WC days in the industry can be attributed to its cyclic nature with production being concentrated in sugarcane crushing season which generally lasts for 4-5 months, leading to a mismatch between cashflows and expenses throughout the year, thus necessitating higher WC days to manage daily operations and inventory.

Table 43: Inventory days FY18 to FY25

Inventory Days	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25
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TruAlt Bioenergy	-	-	-	79.14*	65.29	57.36	70.34	51.77
Bajaj Hindusthan Sugar Ltd	212	178	184	175	219	189	200	224.62
Triveni Engineering & Indus	223	302	226	194	241	180	228	229.27
Dhampur Sugar Mills Ltd	158	248	220	329	290	147	182	220.13
Balrampur Chini Mills Ltd	189	246	240	247	242	240	242	283.63
Shree Renuka Sugars Ltd	57	137	154	170	160	111	134	164.14
Dalmia Bharat Sugar and Industries	161	239	314	270	224	179	261	229.38
Dwarikesh Sugar Indus Ltd	169	310	308	225	199	147	190	265.58
EID Parry India Ltd	134	150	152	116	98	76	124	N.A.

(*) For FY21, TruAlt's figure is derived from closing inventory, as opposed to average inventory

Source: Company regulatory filings

NOTE: High inventory days stem from the need to store raw material which primarily is syrup & molasses for usage during off season period which generally lasts for 6-9 months. During peak crushing seasons (lasting 4 to 5 months) when output surpasses demand the sugar manufacturing industry produces and stores final product (sugar / ethanol) and various byproducts like syrup, molasses. Thus, for Ethanol players, syrup is used as a raw material in crushing season and molasses are used in the off season. Additionally, evolving market conditions with respect to domestic and international markets may also play a role in inventory management decisions leading to prolonged storage periods.

Further the sale of ethanol is dependent on the bidding process of OMCs and supply of ethanol is as per the delivery schedules which is guided by OMCs pursuant to various market factors.

Further, for pure-play Ethanol companies, the raw material (syrup and molasses) prices increase in the off season due to which they are procured in the cane crushing season and stored in inventory, to ensure continuous supply of raw material throughout the year, thus leading to a higher investment in inventory resulting in a longer working capital cycle.

Table 44: Receivable days FY18 to FY25

Receivable Days	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25
TruAlt Bioenergy	-	-	-	56.76*	43.01	26.54	57.50	61.61
Bajaj Hindusthan Sugar Ltd	11	10	10	10	14	10	9	8.62
Triveni Engineering & Indus	33	32	24	22	18	19	22	23.17
Dhampur Sugar Mills Ltd	26	39	36	50	39	23	25	21.44
Balrampur Chini Mills Ltd	15	27	27	18	14	10	8	9.05
Shree Renuka Sugars Ltd	44	43	16	9	13	10	13	18.39
Dalmia Bharat Sugar and Industries	12	25	32	19	16	17	17	12.28
Dwarikesh Sugar Indus Ltd	13	19	22	16	9	9	11	13.08
EID Parry India Ltd	43	43	45	29	11	7	16	N.A.

(*) For FY21, TruAlt's figure is derived from closing receivables, as opposed to average receivables

Source: Company regulatory filings

Table 45: Payable days FY18 to FY25

Payable Days	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25
TruAlt Bioenergy	-	-	-	76.07*	82.21	105.40	101.61	87.21
Bajaj Hindusthan Sugar Ltd	251	239	289	296	355	305	307	296.98
Triveni Engineering & Indus	89	104	78	73	62	34	40	40.72
Dhampur Sugar Mills Ltd	73	105	85	136	112	40	34	28.72
Balrampur Chini Mills Ltd	82	83	67	67	46	32	28	27.38
Shree Renuka Sugars Ltd	215	334	249	223	167	111	146	184.85
Dalmia Bharat Sugar and Industries	92	110	106	70	48	36	55	38.97
Dwarikesh Sugar Indus Ltd	68	91	69	50	35	17	14	13.34
EID Parry India Ltd	152	145	133	110	93	75	132	N.A.

(*) For FY21, TruAlt's figure is derived from closing account payables, as opposed to average account payables

Source: Company regulatory filings

11.4.2 Global Players

Table 46: Revenue

Global Players (\$ Mn)	CY 2017	CY 2018	CY 2019	CY 2020	CY 2021	CY 2022	CAGR (CY17-22)	% Of revenue from ethanol
Wilmar International	43,574	44,498	42,640	50,527	65,794	73,399	11.0%	NA
Petrobras	88,827	95,584	76,589	53,683	83,966	124,474	7.0%	NA
Valero	93,980	117,033	108,324	64,912	113,977	176,383	13.4%	3%
	FY18	FY19	FY20	FY21	FY22	FY23	CAGR (FY18-23)	
Raizen	16	17	21	24	18	38	19.3%	NA
Sao Martinho	522	685	672	739	861	1,144	17.0%	NA

Source: Company regulatory filings

Table 47: EBITDA

Global Players (\$ Mn)	CY 2017	CY 2018	CY 2019	CY 2020	CY 2021	CY 2022	CAGR (CY17-22)
Wilmar International	2,615.0	2,937.0	3,024.0	3,609.0	4,172.0	4,734.0	12.6%
Petrobras	30,125.0	34,460.0	34,251.0	20,510.0	48,626.0	68,510.0	17.9%
Valero	5,549.0	6,641.0	6,091.0	772.0	4,535.0	18,163.0	26.8%
	FY18	FY19	FY20	FY21	FY22	FY23	CAGR (FY18-23)
Raizen	1.34	1.26	1.20	1.81	1.67	2.51	13.7%
Sao Martinho	162.72	261.82	200.26	284.61	370.30	553.27	27.7%

Source: Company regulatory filing

Table 48: EBITDA Margin

Global Players	CY 2017	CY 2018	CY 2019	CY 2020	CY 2021	CY 2022
Wilmar International	6.0%	6.6%	7.1%	7.1%	6.3%	6.4%
Petrobras	33.9%	40.7%	44.7%	38.2%	57.9%	55.0%
Valero	5.9%	5.7%	5.6%	1.2%	4.0%	10.3%
	FY18	FY19	FY20	FY21	FY22	FY23
Raizen	8%	7%	6%	7%	9%	7%
Sao Martinho	31%	38%	30%	39%	43%	48%

Source: Company regulatory filings

Table 49: PAT

Global Players (\$ Mn)	CY 2017	CY 2018	CY 2019	CY 2020	CY 2021	CY 2022	CAGR (CY17-22)
Wilmar International	1,280	1,224	1,327	1,691	2,066	2,569	14.9%
Petrobras	169	7,414	10,363	948	19,986	36,755	193.4%
Valero	4,156	3,353	2,784	-1,107	1,288	11,879	23.4%
	FY18	FY19	FY20	FY21	FY22	FY23	CAGR (FY18-23)
Raizen	0.61	0.46	0.45	0.48	0.21	0.65	1.2%
Sao Martinho	56.8	98.3	62.8	127.8	185.4	296.2	39.1%

Source: Company regulatory filings

Table 50: PAT Margin

Global Players	CY 2017	CY 2018	CY 2019	CY 2020	CY 2021	CY 2022
Wilmar International	2.9%	2.8%	3.1%	3.3%	3.1%	3.5%
Petrobras	0.2%	8.8%	13.5%	1.8%	23.8%	29.5%
Valero	4.4%	2.9%	2.6%	-1.7%	1.1%	6.7%
	FY18	FY19	FY20	FY21	FY22	FY23
Raizen	3.9%	2.7%	2.1%	2.0%	1.2%	1.7%
Sao Martinho	10.9%	14.4%	9.3%	17.3%	21.5%	25.9%

Source: Company regulatory filings

Table 51: Net Worth

Global Players (\$ Mn)	CY 2017	CY 2018	CY 2019	CY 2020	CY 2021	CY 2022
Wilmar International	16,985	16,767	17,876	21,383	22,602	22,601
Petrobras	81,502	73,175	74,215	59,876	69,812	69,836
Valero	22,900	22,731	22,536	19,642	19,817	25,468
	FY18	FY19	FY20	FY21	FY22	FY23
Raizen	2	2	2	2.	1	4.
Sao Martinho	681	658	678	669	797	1,064

Source: Company regulatory filings

Table 52: Net Debt

Global Players (\$ Mn)	CY 2017	CY 2018	CY 2019	CY 2020	CY 2021	CY 2022
Wilmar International	18,372	21,694	21,594	20,443	26,422	27,430
Petrobras	86,527	70,276	55,888	42,177	25,233	21,958
Valero	3,022	6,127	7,089	11,364	9,748	6,773
	FY18	FY19	FY20	FY21	FY22	FY23
Raizen	2	2	2	3	1	3
Sao Martinho	715	757	851	944	752	1,155

Source: Company regulatory filings

Table 53: ROE

Global Players	CY 2017	CY 2018	CY 2019	CY 2020	CY 2021	CY 2022
Wilmar International	7.5%	7.3%	7.7%	8.6%	9.4%	11.4%
Petrobras	0.2%	9.6%	14.1%	1.4%	30.8%	52.6%
Valero	18.1%	14.7%	12.3%	-5.2%	6.5%	52.5%
	FY18	FY19	FY20	FY21	FY22	FY23
Raizen	24.8%	19.1%	19.2%	20.7%	12.0%	23.3%
Sao Martinho	8.3%	14.7%	9.4%	19.0%	25.3%	31.8%

Source: Company regulatory filings

Table 54: ROCE

Global Players	CY 2017	CY 2018	CY 2019	CY 2020	CY 2021	CY 2022
Wilmar International	5.0%	5.5%	5.3%	5.9%	6.3%	6.8%
Petrobras	8.9%	13.0%	13.2%	7.2%	33.7%	53.9%
Valero	11.2%	14.4%	12.0%	11.5%	14.2%	12.7%
	FY18	FY19	FY20	FY21	FY22	FY23
Raizen	18.4%	14.6%	13.2%	15.5%	29.3%	21.4%
Sao Martinho	8.2%	13.3%	7.6%	9.8%	14.6%	20.6%

Source: Company regulatory filings

Table 55: Net Debt to Equity

Global Players	CY 2017	CY 2018	CY 2019	CY 2020	CY 2021	CY 2022
Wilmar International	1.1	1.3	1.2	1.0	1.2	1.2
Petrobras	1.1	1.0	0.8	0.7	0.4	0.3
Valero	0.1	0.3	0.3	0.6	0.5	0.3
	FY18	FY19	FY20	FY21	FY22	FY23
Raizen	0.7	0.8	1.0	1.4	0.9	0.6
Sao Martinho	1.1	1.2	1.3	1.4	0.9	1.1

Source: Company regulatory filings

Table 56: Fixed Asset Turnover

Global Players	CY 2017	CY 2018	CY 2019	CY 2020	CY 2021	CY 2022
Wilmar International	5.0	4.9	4.1	4.2	4.9	5.1
Petrobras	0.5	0.5	0.5	0.4	0.7	1.0

Valero	3.4	4.2	3.7	2.2	3.7	5.7
	FY18	FY19	FY20	FY21	FY22	FY23
Raizen	7.4	7.8	7.8	7.4	7.5	13.2
Sao Martinho	0.5	0.6	0.6	0.6	0.7	0.9

Source: Company regulatory filings

Table 57: Working Capital Days

Global Players	CY 2017	CY 2018	CY 2019	CY 2020	CY 2021	CY 2022
Wilmar International	100	97	98	92	88	90
Petrobras	37	42	44	38	27	32
Valero	18	15	18	32	15	8
	FY18	FY19	FY20	FY21	FY22	FY23
Raizen	10	8	1	-5	-4	-3
Sao Martinho	46	42	30	6	0	-7

Source: Company regulatory filings

Table 58: Inventory Days

Global Players	CY 2017	CY 2018	CY 2019	CY 2020	CY 2021	CY 2022
Wilmar International	75	73	76	71	66	69
Petrobras	52	61	69	87	55	49
Valero	28	23	26	40	22	16
	FY18	FY19	FY20	FY21	FY22	FY23
Raizen	11	11	12	15	21	15
Sao Martinho	49	46	34	13	10	14

Source: Company regulatory filings

Table 59: Receivable Days

Global Players	CY 2017	CY 2018	CY 2019	CY 2020	CY 2021	CY 2022
Wilmar International	34	35	37	34	34	33
Petrobras	20	23	23	29	24	17
Valero	27	22	28	42	26	23
	FY18	FY19	FY20	FY21	FY22	FY23
Raizen	9	10	11	10	11	8
Sao Martinho	24	18	19	16	16	14

Source: Company regulatory filings

Table 60: Payable Days

Global Players	CY 2017	CY 2018	CY 2019	CY 2020	CY 2021	CY 2022
Wilmar International	10	12	15	13	11	12
Petrobras	35	42	48	78	52	34
Valero	37	30	36	50	33	31
	FY18	FY19	FY20	FY21	FY22	FY23
Raizen	10	13	22	29	36	26
Sao Martinho	26	23	23	24	26	35

Source: Company regulatory filings

Formulas used:

$\text{EBITDA} = \text{PBT} + \text{D\&A} + \text{Finance costs} - \text{Other Income}$

$\text{Net debt} = \text{Long-term borrowing} + \text{short-term borrowing} - \text{Cash and cash equivalents}$

$\text{EBITDA margin (\%)} = \text{EBITDA} / \text{Revenue from operations}$

$\text{PAT margin (\%)} = \text{PAT} / \text{Revenue from Operations}$

$\text{Fixed Asset turnover} = \text{Revenue from operations} / \text{Average Property Plant Equipment}$

$\text{RoE} = \text{PAT} / \text{Average Shareholders' equity (Net worth)}$ [Return on Equity for TruAlt Bioenergy Ltd is calculated as profit after tax less preference dividend divided by average total equity. (Note: Closing total equity is used for year ended 2021).]

$\text{RoCE} = \text{EBIT} / \text{Average Capital employed}$ [Return on Capital Employed for TruAlt Bioenergy Ltd is calculated as EBIT divided by average capital employed. Capital employed is calculated as Net Worth (Shareholders Equity) plus total debt plus Deferred Tax Liability (Net of Deferred Tax Assets); while EBIT is calculated as profit after tax plus total income tax expense plus finance costs minus other income. (Note: Closing capital employed is used for year ended 2021).]

$\text{Capital Employed} = \text{Shareholder's Equity} + \text{Total Bank Debt}$

$\text{Working capital days} = \text{Inventory days} + \text{receivable days} - \text{payable days}$

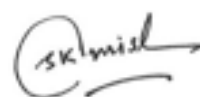
$\text{Inventory days} = \text{Average inventory} * 365 / \text{COGS}$

$\text{Receivable days} = \text{Average trade receivable} * 365 / \text{revenue from operations}$

$\text{Payable days} = \text{Average trade payables} * 365 / \text{COGS}$

$\text{Net debt-equity ratio} = \text{Net debt} / \text{Shareholders equity}$

Exchange rate: 1 Reals = \$0.2



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