Indian Federation of Green Energy

India's bioenergy opportunity: Pathways to energy security, decarbonization and rural prosperity

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Foreword

As India advances its ambition of becoming a global leader in clean energy and sustainable industrial growth, biofuels are emerging as a critical enabler of the nation's energy transition. The remarkable progress achieved in ethanol blending and the growing momentum around Sustainable Aviation Fuel (SAF) reflect India's ability to translate policy vision into scalable solutions that strengthen energy security, support rural livelihoods, reduce import dependence and contribute to climate objectives. Ethanol has evolved from a by-product of the sugar industry into a strategic pillar of India's transport decarbonization agenda, while SAF is rapidly gaining prominence as one of the most viable pathways to decarbonize aviation, a sector where alternatives remain limited.

The successful implementation of the Ethanol Blended Petrol (EBP) Programme, expansion of feedstock diversity, and development of production infrastructure have established ethanol as a cornerstone of the country's energy transition. Building on these achievements, SAF represents the next frontier, offering a scalable pathway to decarbonize aviation while leveraging India's strengths in biomass availability, refining capabilities and advanced biofuel technologies. At the same time, The growing adoption of biomass pellets in power generation and industrial applications is creating new opportunities to reduce fossil fuel dependence, address agricultural residue management challenges and support rural value chains, further strengthening India's bioenergy ecosystem.

Released at the India Bioenergy and Technology Expo (IBETE) 2026, this knowledge paper by EY-Parthenon and the Indian Federation of Green Energy provides a holistic perspective on India's evolving biofuel landscape.

It examines the market dynamics, policy frameworks, feedstock ecosystems, technology pathways and investment opportunities shaping the future of ethanol and SAF. More importantly, it highlights how these sectors can collectively accelerate India's aspirations for energy independence, rural prosperity, industrial competitiveness and environmental sustainability.

We hope this knowledge paper serves as a valuable resource for policymakers, industry leaders, investors, technology providers, researchers and the wider bioenergy community. By bringing together perspectives on market developments, policy evolution, technology pathways and emerging opportunities, it seeks to enhance understanding of India's evolving biofuel landscape and contribute to informed discussions on the future of ethanol and Sustainable Aviation Fuel.

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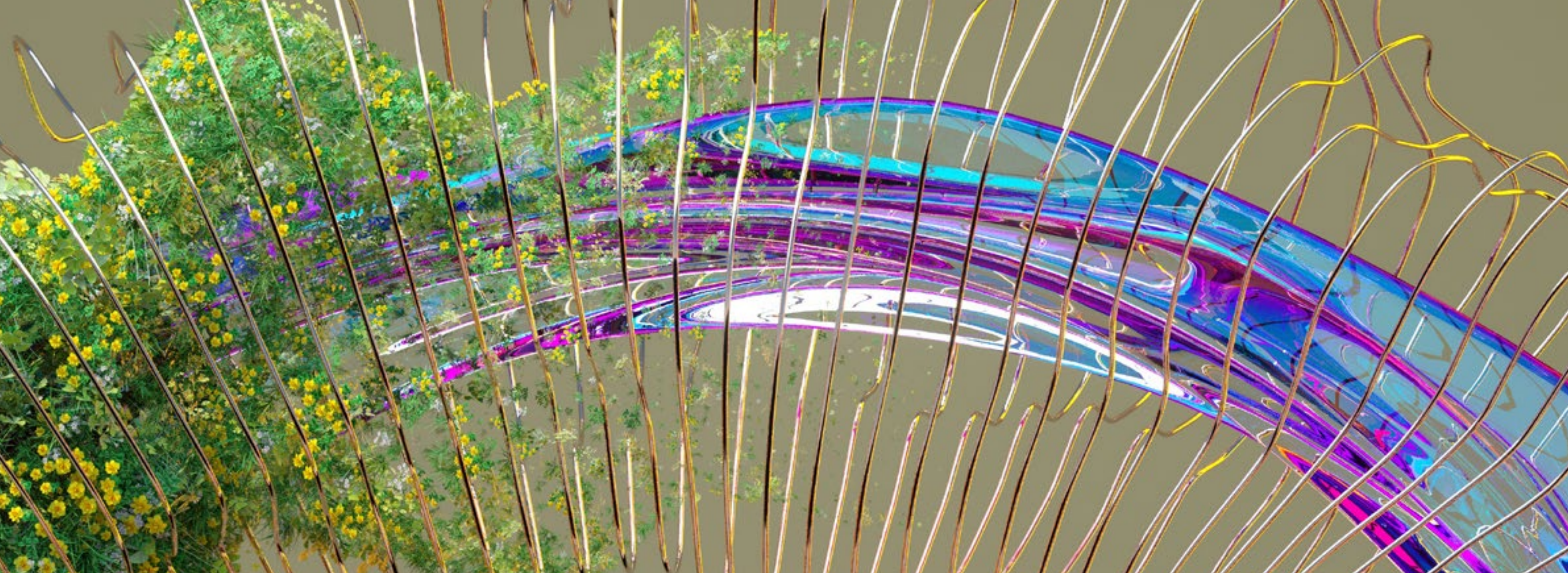


Executive overview

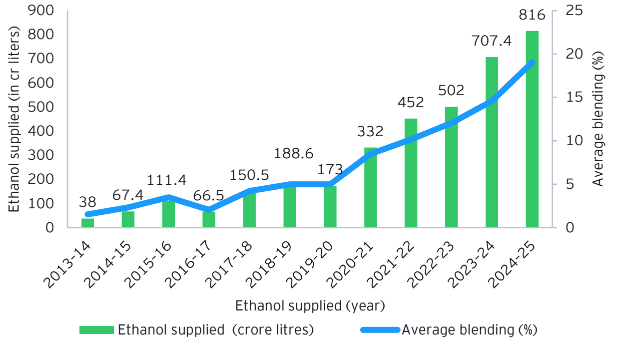
India's bioenergy transition is rapidly gaining momentum, driven by a combination of policy support, feedstock availability, energy security imperatives and decarbonization goals across the transport, aviation and industrial sectors. Ethanol, Sustainable Aviation Fuel (SAF) and biomass briquettes and pellets represent three complementary pathways through which agricultural residues, waste streams and biomass resources are being leveraged to reduce fossil fuel dependence, create rural income opportunities and support India's net-zero ambitions.

1 Ethanol: The foundation of India's biofuel ecosystem

The ethanol sector has evolved from a sugar-industry by-product market into a strategic pillar of India's energy transition. Demand growth has been primarily driven by the Ethanol Blended Petrol (EBP) Programme, which progressed from a 5% blending mandate in selected states in 2003 to a nationwide achievement of the E20 milestone in 2025-26. This transformation has been supported by a series of policy measures, such as feedstock diversification, administered pricing, reduction of GST on ethanol supplied under EBP and capacity-expansion incentives such as the Ethanol Interest Subvention Scheme (EISS) and DFPD's interest-subvention program for multi-feedstock ethanol facilities. As a result, ethanol procurement by PSU Oil Marketing Companies increased from 38 crore liters in ESY 2014 to 816 crore liters in ESY 2026, while blending levels rose from 12.06% in ESY 2023 to nearly 20% by 2025-26.

Beyond energy security, the program has delivered substantial economic and environmental benefits, including foreign-exchange savings exceeding INR1.9 lakh crore, reducing crude oil imports by over 310 lakh MT, reduction of ~ 930 lakh MT of CO emissions and additional farmer income exceeding INR1.6 lakh crore.

Growth in ethanol blending in India
(ESY 2013–14 to ESY 2024–25)



2 SAF: The next frontier in aviation decarbonization

Building on this progress, SAF is emerging as the next frontier of transport decarbonization. Globally recognized as the most practical near- to medium-term solution for reducing aviation emissions, SAF can be blended with conventional Aviation Turbine Fuel (ATF) and utilized within existing aircraft and fuel infrastructure. India's SAF opportunity is underpinned by robust aviation growth, with ATF consumption rising from approximately 6.3 MMT in FY2015-16 to 8.98 MMT in FY2024-25 and projected to reach ~13-14 MMTPA by 2035 and 20-21 MMTPA by 2050. The Government of India has already announced indicative SAF blending targets for international flights of 1% by 2027, 2% by 2028 and 5% by 2030, creating an initial demand of ~0.10-0.11 MMTPA at 1% blending and ~0.55-0.56 MMTPA at 5% blending. India's strong feedstock base, including surplus agricultural residues, biomass, used cooking oil (UCO), ethanol, municipal solid waste, industrial waste gases, supported by the green hydrogen and captured CO, provides a foundation for multiple SAF pathways including HEFA, Alcohol-to-Jet (AtJ), Fischer-Tropsch (FT) and e-SAF/Power-to-Liquid (PtL). Notably, the country's established ethanol ecosystem creates a natural pathway for scaling AtJ production, further strengthening the linkage between the ethanol and SAF industries. While HEFA and refinery co-processing are expected to drive initial deployment, AtJ may likely to emerge as India's strategic medium-term route because it builds on the country's Ethanol ecosystem, with FT and e-SAF supporting longer-term growth as technology and project economics mature.

3 Biomass briquettes and pellets: Decarbonizing industry and power generation

Complementing liquid biofuels, the biomass briquette and pellet industry has emerged as a critical pillar of India's industrial and power-sector decarbonization strategy. By 2025, approximately 1,100 pellet manufacturing plants had been established nationwide, each with an average production capacity of 80 MT/day and operating for around 250 days annually. At current utilization levels of 63%, the sector produces approximately 12.6 MMT of biomass pellets annually, consuming around 14.6 MMT of agricultural biomass feedstock. The industry has attracted investments of approximately INR11,165 crore, largely from MSMEs, first-generation entrepreneurs and farmer-linked enterprises. Beyond providing an avenue for the productive utilization of agricultural residues, the sector directly supports national priorities related to coal substitution, reduction of stubble burning, rural employment generation, and farmer income enhancement.

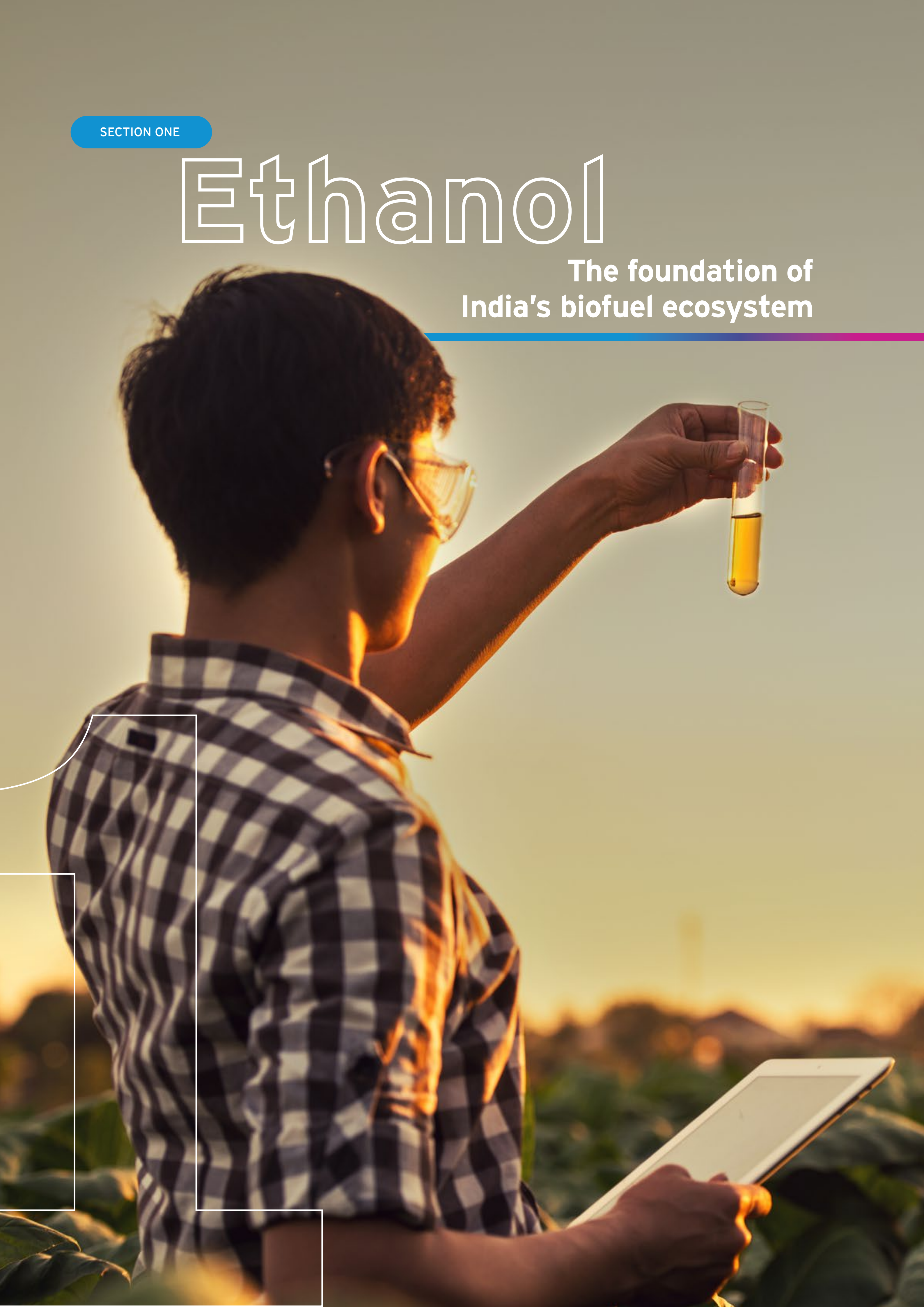
Looking ahead, achieving a 5% replacement of coal consumption with biomass could expand the industry to nearly 3,500 plants, requiring investments of approximately INR38,500 crore, producing 43.7 MMT of pellets annually, and creating an economic opportunity of INR50,000 to INR60,000 crore for rural India.

Collectively, ethanol, SAF and biomass briquettes and pellets demonstrate how India's abundant biomass resources can enable decarbonization across multiple end-use sectors while delivering broader socio-economic benefits. Together, these value chains strengthen energy security, reduce fossil fuel imports, create new markets for agricultural residues and waste streams, promote rural industrialization and offer scalable pathways toward achieving India's long-term climate and net-zero commitments.

SECTION ONE

Ethanol

The foundation of India's biofuel ecosystem



Strategic importance of ethanol in India

The rapid expansion of India's ethanol program is driven by objectives that extend beyond fuel blending. While the Ethanol Blended Petrol (EBP) Programme serves as the primary deployment mechanism, ethanol has emerged as a strategic tool for addressing multiple national priorities simultaneously. Unlike several alternative decarbonization pathways that require significant investments in new vehicle technologies or infrastructure, ethanol can be integrated into India's existing liquid-fuel ecosystem. Supported by a nationwide network of over 97,000 fuel retail outlets, ethanol blending can be scaled with minimal changes to consumer behavior or refueling infrastructure.

As a domestically produced renewable fuel, ethanol helps reduce dependence on imported fossil fuels while supporting rural livelihoods and industrial development. Consequently, the program has evolved into a broader policy instrument aligned with national priorities, including energy security, farmer welfare, climate action, agricultural diversification and the vision of Atmanirbhar Bharat. Beyond the achievement of E20, the long-term value of ethanol will increasingly be measured by its contribution to these economic, environmental and strategic objectives.

Strategic Priority	**Contribution of Ethanol**	**Evidence/ Rationale**
Farmer income	Creates additional market demand for sugarcane/sugar-rich, maize and surplus grains	Government estimates indicate that achieving E20 blending could generate ~INR40,000 crore annually for farmers and the agriculture sector through additional feedstock demand.
Sugar sector stability	Enable diversion of excess sugarcane/sugar rich feedstock towards ethanol production	Helps reduce sugar surpluses, improves mill liquidity and creates an additional revenue stream for sugar mills through ethanol production.
Environmental sustainability	Lowers lifecycle greenhouse gas emissions compared to petrol	Supports India's climate commitments. A NITI Aayog lifecycle emission assessment indicates that sugarcane-based ethanol and maize-based ethanol can reduce lifecycle GHG emissions by approximately 65% and 50%, respectively, compared to petrol[1].
Rural industrialization	Encourages investments in distilleries, logistics and bio refinery investments	Government-supported ethanol capacity expansion has attracted investments exceeding INR40,000 crore across rural and urban areas, supported through DFPD interest-subvention and capacity-expansion schemes[2].

India's ethanol program is best viewed as a multi-dimensional national initiative rather than solely a fuel-blending mandate. Its significance lies in its ability to simultaneously strengthen energy security, enhance farmer incomes, support agricultural diversification, reduce emissions and promote domestic industrial investment.

1 *REFINING - ETHANOL BLENDED PETROL | Ministry of Petroleum and Natural Gas | Government of India*
2 *Press Release:Press Information Bureau*

Demand drivers of India's ethanol market

Unlike many commodity markets where demand is driven primarily by consumer preferences, ethanol demand in India is largely shaped by policy mandates, transport fuel consumption and national energy-security objectives. While the achievement of E20 marks a significant milestone in India's biofuel journey, it does not represent the peak of ethanol demand. Rising petrol consumption is expected to support continued ethanol demand even at stable blending ratios, while emerging applications such as flex-fuel vehicles, Sustainable Aviation Fuel (SAF) and bio-based chemicals could expand ethanol's role beyond conventional fuel blending. Consequently, the next phase of market growth will be influenced by transport fuel demand, feedstock availability, application diversification and sustained policy support.

Accordingly, ethanol market expansion is expected to be supported by five key demand drivers:

1. Growth in petrol consumption
2. Policy stability and government support
3. Energy security and import substitution
4. Feedstock diversification and supply availability
5. Emerging industrial applications

Growth in petrol consumption

Following the achievement of E20, future ethanol demand will increasingly be linked to growth in petrol consumption rather than higher blending mandates. Rising urbanization, vehicle ownership, mobility demand and economic growth are expected to support sustained growth in petrol consumption, creating a structurally positive demand outlook for ethanol. Even at a constant 20% blending ratio, every incremental liter of petrol consumed translates into additional ethanol demand.

Policy stability and government support

Policy certainty remains one of the strongest foundations of India's ethanol market. Over the past decade, measures such as feedstock diversification, differentiated ethanol pricing, interest-subvention schemes and assured procurement by Oil Marketing Companies (OMCs) have significantly reduced investment risk and supported capacity expansion. Going forward, policy support is expected to focus on feedstock resilience, supply-chain efficiency, advanced biofuels and broader bioeconomy development.

Energy security and import substitution

With approximately 85% to 88% of crude oil requirements met through imports, reducing dependence on imported fuels remains a key priority. Ethanol supports energy security by partially substituting petrol imports with domestically produced renewable fuel. Unlike fuel imports, ethanol expenditure remains within the domestic economy, supporting farmers, distilleries and associated industries while reducing exposure to global oil price volatility.

Feedstock diversification and supply availability

Sustainable growth of the ethanol market depends on the availability of diverse and reliable feedstocks. While production was historically concentrated around molasses-based pathways, the approved feedstock basket has expanded to include B-heavy molasses, sugarcane juice, maize and selected food grains, improving supply flexibility and reducing dependence on a single crop. Over the longer term, second-generation (2G) ethanol derived from agricultural residues presents a significant opportunity to expand ethanol supply while addressing residue-management challenges.

Emerging industrial applications

Although petrol blending remains the dominant demand segment, emerging applications could create additional demand streams over the medium to long term. These include Sustainable Aviation Fuel (SAF) through the Alcohol-to-Jet (AtJ) pathway, bio-based chemicals, pharmaceuticals and industrial solvents. As these sectors mature, they have the potential to diversify demand, reduce reliance on a single end-use market and support the development of a broader bio-based economy.

Ethanol demand outlook: From E20 achievement to volume growth

India's ethanol demand has expanded rapidly over the past decade. The successful achievement of E20 blending marks an important milestone in India's biofuel journey. However, it does not signify the end of ethanol demand growth. India's petrol demand has remained strong despite the rollout of E20. Monthly petrol consumption remained in the range of 3.4–3.7 MMT during FY2025-26. These monthly levels imply an annualized petrol pool of roughly 41 MMT–43 MMT during FY2025-26[3].

3 *Consumption Of Petroleum Products | Petroleum Planning & Analysis Cell | Government of India*

For the demand model, a working FY2025-26 base of 42 MMT petrol consumption has been used. This translates into approximately 5,675 crore liters (1 million metric tons of petrol is equivalent to approximately 141.1 crore liters) of petrol and an estimated ethanol requirement of around 1,185 crore liters at E20.

The demand assessment therefore adopts a bottom-up approach, whereby ethanol demand is calculated as a function of petrol consumption and blending requirements. Transportation fuel ethanol demand remains the dominant component of the forecast and accounts for most of the total ethanol consumption across all scenarios. In addition to conventional petrol blending, the model incorporates:

1. Sensitivity cases evaluating higher ethanol blend levels (E25/E30) beyond the currently achieved E20 milestone
2. Emerging ethanol demand from Sustainable Aviation Fuel (SAF) production pathways
3. Additional ethanol demand by Flex Fuel Vehicle conversion kits around 415 crore liters per annum by 2030 and growing thereafter

Assumptions:

- FFV conversion kits adoption for old BS VI 2W at 5% in 2027 and increasing up to 30% by 2030
- FFV conversion kits adoption for old BS VI 4W at 2% in 2028 and increasing up to 20% by 2030

Vehicle segment	Vehicle population (BS VI) till date in India
Two-wheeler	~ 8.7-9 crore
Four-wheeler	~ 1.4-1.5 crore

Ethanol demand by conversion kits

ESY	2025-26	2026-27	2027-28	2028-29	2029-30
2W	0	52	104	209	313
4W	0	0	10	51	102
Total ethanol demand for conversion kits	0	52	114	260	415

Source: Vahan Portal https://vahan.parivahan.gov.in/vahan4dashboard/

The analysis does not explicitly quantify future demand from green chemicals and other bio-based applications due to the absence of mature market signals and long-term adoption trajectories. These sectors are therefore considered as potential upside opportunities beyond the forecast presented here. Given the uncertainties associated with future fuel demand, vehicle electrification, blending regulations and emerging biofuel applications, three demand scenarios were developed.

Conservative scenario

The conservative scenario assumes slower growth in motor spirit demand resulting from increasing fuel efficiency, vehicle electrification and gradual modal shifts in transportation.

Key assumptions include:

- Motor spirit demand growth of 2.0% during 2026-2030 and 1.5% thereafter
- Progression to E22 blending by 2030 and E25 maintained thereafter
- Limited SAF uptake reaching 100 crore liters by 2050

Base scenario

The base scenario reflects continued growth in personal mobility alongside the progressive expansion of India's biofuel program.

Key assumptions include:

- Motor spirit demand growth of 3.5% during 2026-2030 and 3.0% thereafter
- Scenario assumes progression to E25 blending by 2030 and E30 blending by 2035
- SAF demand increasing to 150 crore liters by 2050

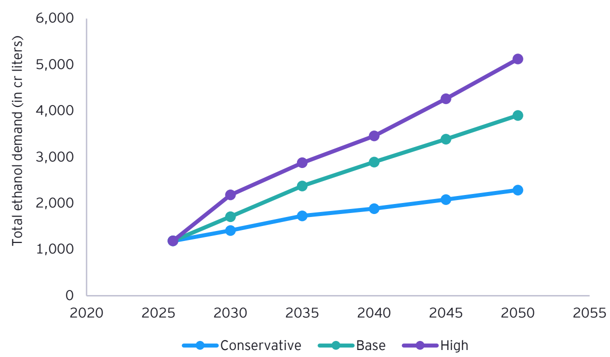
High-growth scenario

The high-growth scenario reflects accelerated economic growth, stronger transport fuel consumption and broader adoption of advanced biofuel pathways.

Key assumptions include:

- Motor spirit demand growth of 5.0% during 2026-2030 and 4.0% thereafter
- Scenario assumes progression to E30 blending by 2030 and maintained thereafter
- Strong SAF uptake reaching 300 crore liters by 2050

India ethanol demand outlook, 2026-2050



Note: E25/E30 pathways are sensitivity scenarios developed for demand forecasting purposes and should not be interpreted as announced government blending targets.

India's ethanol demand trajectory is expected to remain fundamentally linked to transport decarbonization. Even under conservative assumptions, ethanol demand is expected to nearly double by 2050. Under a more ambitious biofuel pathway incorporating E30 blending, flex-fuel deployment and SAF adoption, demand could exceed 5,100 crore liters annually by 2050.

Ethanol supply outlook: Can India meet its future demand?

While demand fundamentals remain strong, the long-term growth of India's ethanol market will depend on feedstock availability, production capacity, logistics infrastructure and supply chain resilience. As India moves beyond E20, supply-side readiness will become increasingly important in supporting future demand growth.

India's ethanol industry has undergone a major structural transformation over the past decade. Historically dependent on molasses-based production, the sector has evolved into a multi-feedstock ecosystem supported by policy measures that expanded approved feedstocks to include B-heavy molasses, sugarcane juice, maize, rice and other food grains.

Evolution of India's ethanol production capacity

Year	Total capacity (Cr liters)	Molasses-based	Grain-based
2022[4]	947	619 (65%)	328 (35%)
2023[5]	1,380	875 (63%)	505 (37%)
2026[6]	2000	Preliminary estimates; bifurcation not available	Preliminary estimates; bifurcation not available

By 2026, India's ethanol production capacity is estimated to have reached approximately 2,000 crore liters, supported by continued investments in both molasses-based and grain-based distilleries.

Feedstock Allocation Under EBP Programme (ESY 2025–26)

Feedstock	Share (%)
Maize	45.7%
FCI rice	22.3%
Sugarcane juice	15.8%
B-heavy molasses	10.5%
Damaged food grains	4.5%
C-heavy molasses	1.2%

Recent OMC allocation data for ESY 2025-26 indicates that maize has emerged as the largest feedstock (~46%), followed by FCI rice (~22%), sugarcane juice (~16%) and B-heavy molasses (~11%). The shift toward a diversified feedstock base has improved supply resilience, enabled higher year-round utilization of distillery assets and reduced dependence on sugar production cycles.

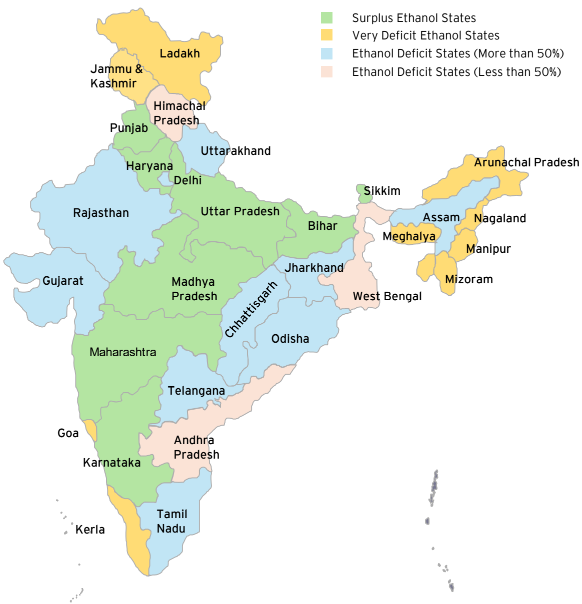
Ethanol production capacity and regional concentration

Ethanol production capacity remains concentrated in a limited number of states with strong feedstock availability and established agro-processing ecosystems. Maharashtra, Uttar Pradesh and Karnataka continue to form the backbone of India's ethanol industry, collectively accounting for over 900 crore liters of installed capacity. Feedstock diversification has also accelerated investments in grain-based distilleries across Punjab, Haryana, Bihar and Madhya Pradesh, expanding the geographic footprint of production and reducing reliance on the traditional sugar belt.

Several states including Maharashtra, Karnataka, Uttar Pradesh and Punjab possess installed capacities exceeding their estimated E20 requirements, enabling them to supply ethanol to deficit regions. As a result, inter-state ethanol movement has become a critical component of the blending ecosystem.

The emergence of production clusters across western, northern and central India has strengthened supply resilience, improved feedstock flexibility and supported year-round ethanol availability. As blending levels increase and new demand applications emerge, geographically diversified production centers will become increasingly important for ensuring long-term supply security.

Major ethanol production clusters in India as on 30 September 2024 (in cr liters)[7]



While Maharashtra, Uttar Pradesh and Karnataka remain the largest production hubs, emerging grain-based clusters in Punjab, Bihar, Haryana and Madhya Pradesh are playing an increasingly important role in strengthening feedstock diversification and national supply resilience.

4 *https://www.pib.gov.in/Pressreleaseshare.aspx?PRID=1885392&reg=48&lang=2*
5 *Press Release Page | Press Information Bureau*
6 *doc202675912001.pdf*
7 *Ethanol Policy | NSWS*

Ethanol logistics and supply chain infrastructure

As ethanol production and consumption are often geographically separated, logistics infrastructure is a critical enabler of India's ethanol program. While production remains concentrated in a few states, ethanol must be distributed across the country's fuel retail network to support blending requirements.

To facilitate E20 implementation, Oil Marketing Companies (OMCs) have expanded ethanol storage, handling and blending infrastructure across depots nationwide. However, unlike petrol and diesel, ethanol continues to rely primarily on road and rail transportation, increasing the importance of efficient logistics networks.

As production clusters expand and blending volumes increase, supply-chain efficiency will become a key factor influencing delivered ethanol costs, supply reliability and market scalability.

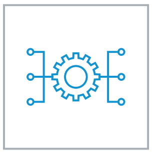
Key logistics considerations

Inter-state movement

The concentration of production capacity in a limited number of states means that ethanol must frequently be transported across state boundaries to meet blending requirements. The NITI Aayog roadmap specifically highlighted the need for movement of ethanol from surplus states to deficit regions in order to achieve uniform availability of ethanol-blended fuel across the country.

Cost competitiveness

Logistics costs can materially influence the delivered cost of ethanol. As blending volumes increase, improved rail connectivity, multimodal transport systems and strategically located storage facilities will be important for maintaining cost-efficient supply chains.



Supply reliability

The next phase of ethanol market growth will depend not only on production capacity but also on the efficiency of the supporting logistics ecosystem. As demand expands beyond E20, continued investments in storage, transportation and blending infrastructure will be essential to ensure cost-effective and reliable ethanol supply across the country.

Policy and regulations

India's ethanol market has been transformed over the past decade by one of the world's most aggressive biofuel policy frameworks, anchored in the National Policy on Biofuels, 2018 which replaced the earlier National Policy on Biofuels of 2009 and the Ethanol Blended Petrol (EBP) Programme. Ethanol blending in petrol rose from 1.53% in Ethanol Supply Year (ESY) 2013-14 to 20% by March 2025, a thirteen-fold increase achieved five years ahead of the original 2030 deadline. Ethanol supplied under the EBP Programme increased from about 38 crore liters in ESY 2013-14 to over 500 crore liters in ESY 2022-23 and procurement by public oil marketing companies (OMCs) reached 904 crore liters in 2024-25. India's ethanol production capacity has expanded from under 200 crore liters in 2014 to nearly 2000 crore liters, far exceeding the roughly 1,100 crore liters needed for the E20 mandate[8].

National Policy on Biofuels, 2018

The National Policy on Biofuels (NPB) 2018, notified by the Ministry of Petroleum and Natural Gas and approved by the Cabinet on 16 May 2018, replaced the 2009 policy. It set blending targets of 20% ethanol in petrol and 5% biodiesel in diesel by 2030. The policy sought to reduce crude oil import dependence, enhance energy security, mitigate climate change, increase farmers' incomes and generate sustainable employment. At the time, India met only about 17.9% of its crude oil demand through domestic production, making energy security a key concern[9].

NPB 2018 categorizes biofuels into 'Basic Biofuels' - First Generation (1G) bioethanol and biodiesel and 'Advanced Biofuels' - Second Generation (2G) ethanol, Municipal Solid Waste (MSW) to drop-in fuels, Third Generation (3G) biofuels and bio-CNG – to enable differentiated financial and fiscal incentives for each category, It expanded the feedstock base for ethanol production to include sugarcane juice, sugar beet, sweet sorghum, maize, cassava and damaged food grains.

In May 2022, the Cabinet amended NPB 2018, advancing the E20 (20% ethanol blending) target from 2030 to ESY 2025–26, expanding feedstock options, and supporting the goals of Atmanirbhar Bharat and the Prime Minister's vision of India becoming energy independent by 2047[10].

8 *Cabinet approves Amendment in "Pradhan Mantri JI-VAN Yojana" for providing financial support to Advanced Biofuel Projects using lignocellulosic biomass and other renewable feedstock | Prime Minister of India*
Rice, maize, or sugarcane? India's ethanol push triggers debate over agricultural concerns, subsidies
9 *National Policy on Biofuels - 2018 | ESCAP Policy Documents Managment*
10 *Amendments to the National Policy on Biofuels*

Ethanol Blending Programme (EBP): Structure and targets

Launched in 2003 and extended nationwide (excluding Andaman & Nicobar and Lakshadweep) from 1 April 2019, the EBP has public OMCs procure ethanol from distilleries through periodic tenders. In June 2021, the Cabinet Committee on Economic Affairs formally advanced the E20 target from 2030 to 2025.

India achieved 10% blending (E10) in June 2022, about five months ahead of schedule.[11] Blending then rose from 8.17% in ESY 2020-21 to 12.06% in ESY 2022-23 and 14.6% in ESY 2023-24, before the 20% target was hit by March 2025. As of April 2026, all petrol sold across India must contain 20% ethanol and meet a minimum Research Octane Number (RON) of 95.[12]

Fuel ethanol is bought at administered ex-mill prices fixed by the Cabinet Committee on Economic Affairs and differentiated by feedstock, supported by a Long-Term Ethanol Procurement Policy and Long-Term Offtake Agreements (LTOAs) with Dedicated Ethanol Plants. For 2024–25, the price of ethanol from B-heavy molasses was fixed at INR60.73 per liter, while ethanol from surplus rice was priced at INR60.32 per liter.[13]

Policy incentives and trade regulations for ethanol development

GST on fuel-grade ethanol was cut from 18% to 5%, the Industries (Development & Regulation) Act, 1951 was amended to free interstate movement of denatured ethanol, and ethanol was made into a priority-sector lending category[14]. For advanced biofuels, the PM JI-VAN Yojana (2019, outlay INR1,969.50 crore) gives viability-gap funding of up to 20% of project cost (capped at INR150 crore) to 2G plants; a 2024 modification extended it to 2028-29 and widened eligible feedstocks and project types[15].

Imported ethanol cannot be used for fuel blending – unchanged since 2018 – and undenatured ethanol attracts 150% basic customs duty, while DGFT has moved denatured-ethanol imports to the ‘restricted’ category. On exports, DGFT restricts ethanol exports to certified 2G ethanol from non-food biomass, subject to authorization and BIS 15464 compliance.[16].

State-level policies and union-state framework

In October 2024 a nine-judge Supreme Court bench (State of Uttar Pradesh vs. Lalta Prasad) held that Entry 8 of the State List covers industrial alcohol, restoring state power over production, pricing, and taxation of denatured spirit and adding regulatory variability. States administer denatured spirit through their own excise statutes and denatured-spirit rules, with inter-state movement requiring permits, and the union government has urged states such as Haryana, Punjab and Jharkhand to rationalize levies[17].

State	CAPEX incentives	OPEX / recurring incentives	Fiscal and duty exemptions
Bihar	15% of plant and machinery cost (max INR5 crore); 15.75% (max INR5.25 crore) for special-category investors	No state PLI; central EISS applicable	100% SGST reimbursement, 100% stamp-duty exemption, 100% electricity-duty exemption, land-conversion-fee waiver
Madhya Pradesh	50% subsidy on ZLD equipment (max INR1 crore); 50% infrastructure subsidy (max INR1 crore); 30% subsidy on biomass machinery (max INR20 lakh)	INR1.50 per liter PLI for up to 7 years; patent reimbursement up to INR5 lakh; quality certification supports up to INR1 lakh	100% stamp-duty rebate, 100% electricity-duty exemption, cess exemption for 10 years
Punjab	Capital subsidy for ethanol and 2G projects (varies by category)	Central EISS	SGST refund, stamp-duty reimbursement, electricity-duty exemption
Haryana	Subsidies via agriculture schemes	Waiver of grid-related charges	100% entry tax; P&M tax exemptions
Gujarat	Grain-ethanol subsidy scheme (linked to project size)	Central EISS	Electricity-duty concessions; industrial-policy benefits
Jharkhand	Capital subsidy + interest subsidy	Interest-subsidy support	Stamp duty; employment incentives
Odisha	Capital investment subsidy (industrial policy)	Central EISS	Stamp duty; electricity duty
Rajasthan	Investment-linked subsidy (state schemes)	Central EISS	Stamp duty; land conversion; electricity duty
Assam	Capital investment support + land support	Central EISS	Stamp duty; power-duty concessions
West Bengal	Capital subsidy under state ethanol policy	Central EISS	SGST reimbursement; stamp duty
Tamil Nadu	Support via industrial promotion schemes	Central EISS	Power-tariff concessions; land and infra support

11 *Press Note Details: Press Information Bureau*
12 *Government mandates 20% ethanol-blended petrol with RON 95 from April 1 - India Today*
13 *India Ethanol Market Size, Share & Industry Report by 2034*
14 *REFINING - ETHANOL BLENDED PETROL | Ministry of Petroleum and Natural Gas | Government of India*
15 *Press Note Details: Press Information BureauGovernment of India*
16 *Article on DGFT's Notification No. 32/2025-26 dated 24th September 2025 Export Policy of Second Generation (2G) Ethanol under HS Code 22072000 – A Regulatory Shift Toward Sustainable Trade*
17 *STATES TO REGULATE INDUSTRIAL ALCOHOL NOW*

Bihar became the first state to introduce a dedicated ethanol policy, while Bihar, Madhya Pradesh, Andhra Pradesh and the Punjab–Haryana grain belt emerged as major grain-ethanol hubs.

Regulatory challenges and future policy outlook

Food-versus-fuel concerns, high water consumption, fragmented state regulation, logistics and pollution-compliance hurdles, and surplus capacity causing reduced procurement, idle plants and legal disputes continue to challenge the sector. The government has responded by diversifying feedstocks (maize, damaged grains, surplus FCI rice, agri-residues), promoting 2G from non-food biomass, mandating Zero Liquid Discharge and creating demand through higher blends, flex-fuel vehicles, interstate movement reform and long-term offtake mechanisms

With E20 achieved early, focus has shifted beyond 20%: BIS notified IS 19850:2026 specifying E22, E25, E27 and E30 blends (effective May 2026), creating the regulatory groundwork for higher blends.[18] An E30 rollout is expected between 2028 and 2030, ARAI is studying E25 impacts on existing vehicles, draft rules recognize E85/E100 flex-fuel vehicles, and about 48 E85 outlets launched in June 2026. India also leads the Global Biofuels Alliance and views CORSIA-linked SAF as a structural demand outlet for surplus ethanol[19].

18 *India moves closer to higher Ethanol blends as BIS notifies E22 E30 fuel standards - BusinessToday*

19 *After E20: India's Ethanol Blending Programme Next Phase | CEEW*

Feedstock and technologies

India's ability to sustain and expand blending rests on the diversity of feedstocks it can draw on and the maturity of the conversion technologies that turn them into fuel-grade ethanol. The program has evolved from a narrow, molasses-based model into a dual-feedstock system spanning sugar, grain and, at an early stage, cellulosic and waste-based routes.

Ethanol feedstocks: Sugarcane, molasses and grains

Ethanol production in India was historically based on C-heavy molasses, a by-product of sugar manufacture with a sugar content of about 40%-45%, yielding roughly 220-235 liters of ethanol per ton. To raise yields, producers moved up the molasses ladder to B-heavy molasses and to direct use of sugarcane juice, sugar and syrup. The feedstock base was subsequently diversified to include rice, damaged grains, maize, jowar, bajra and millets[20].

During ESY 2025–26 (up to June 2026), total ethanol supplies reached 717 crore liters, of which grain-based feedstocks contributed 480 crore liters (67%) and sugarcane-based feedstocks contributed 238 crore liters (33%). Maize was the largest individual feedstock, accounting for 258 crore liters (36.0%)[21].

Ethanol yield by feedstock

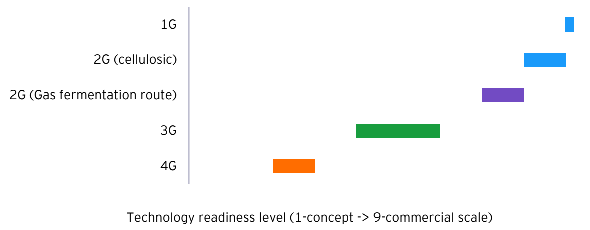
Feedstock	Approximate ethanol yield
C-heavy molasses	220–260 liters / ton
B-heavy molasses	300–370 liters / ton
Sugarcane juice / syrup	70–80 liters / ton cane
Rice / surplus rice	450–480 liters / ton
Maize	380–400 liters / ton

Residual biomass and waste-based ethanol

2G ethanol is produced from non-food lignocellulosic feedstocks – rice and wheat straw, bagasse, corn cobs, energy crops, forest biomass and municipal solid waste. The circular-economy rationale is strong: rice straw and bagasse are often burned in the field, so converting them to fuel simultaneously addresses stubble-burning and waste management. But India's pilot and demonstration plants have a combined capacity of only about 3.2 crore liters a year, confirming the segment is still at an early commercial stage. IOCL Panipat (India's first commercial-scale 2G plant), BPCL Bargarh, HPCL Bathinda and NRL Numaligarh are pioneering commercialization, supported by PM JI-VAN viability-gap funding of up to INR150 crore per commercial project.

Globally, proven technologies exist to accelerate India's 2G/3G ambitions: cellulosic pre-treatment and enzymatic-hydrolysis platforms (including Praj's Enfinity and, for forestry residues, Alcohol-to-Jet conversion (LanzaJet), gas-fermentation of industrial off-gases and CO2 (LanzaTech) and isobutanol pathways (Gevo) —all have Indian tie-ups or licenses. 2G addresses the food, water and land-use criticisms of 1G while valorizing crop residue and curbing stubble-burning and 3G/AtJ opens the high-value SAF market – but both need the differential pricing, VGF and biomass-aggregation infrastructure to close a cost gap.

Technologies readiness level



Source: Advancing bioethanol: exploring feedstock diversity, production pathways and environmental implications | RSC Sustainability | The Royal Society of Chemistry

Technology providers and the 3G frontier

The technology-provider landscape spans feedstock-agnostic integrators and pathway-specific specialists. Praj Industries is the dominant domestic integrator and is essentially feedstock-agnostic: its platforms process sugary, starchy and lignocellulosic feedstocks to produce multiple products (bioethanol, bio-CNG, SAF, renewable chemicals) and its Enfinity 2G pilot has run since 2009 processing over 450 tons of varied biomass . Praj is the technology licensor and EPCM partner for India's first three commercial 2G biorefineries (IOCL Panipat, BPCL Bargarh, HPCL Bathinda)[23] . For 1G, Praj and other EPC firms are largely feedstock-agnostic, whereas some pathway specialists are feedstock- or route-specific – LanzaJet (ethanol-to-jet AtJ), LanzaTech (carbon/off-gas gas-fermentation) and Gevo (isobutanol).

The 3G technology is being piloted in India primarily by IndianOil's R&D: with LanzaTech, IOCL demonstrated a pilot that integrates gas fermentation and renewable hydrogen to convert captured CO2 into acetate and then, via IOCL's patented aerobic fermentation, into algal lipids yielding biodiesel, high-value DHA (omega-3) and protein-rich animal feed[24].

20 *Grain vs Sugarcane Ethanol in India: Key Differences & Shift*
21 *Grain-based ethanol accounts for nearly 67% of supplies; maize remains the largest feedstock - The Economic Times*

22 *2G Ethanol - Praj Industries*
23 *Advanced Bioethanol - Praj Industries*
24 *https://bioenergyinternational.com/indianoil-and-lanzatech-poised-to-scale-up-co2-to-food-feed-and-fuel/*

Technology providers

Provider	Feedstock stance	Role / India footprint
Praj Industries	Agnostic (sugary/ starchy/cellulosic)	1G+2G licensor/EPCM; Panipat, Bargarh, Bathinda; SAF
LanzaJet	Route-specific (ethanol-to-jet)	AtJ SAF with IOCL, Panipat
LanzaTech	Feedstock-specific (CO2 / off-gas)	3G gas-fermentation pilot with IOCL
Gevo	Route-specific (isobutanol)	Isobutanol tie-up with Praj
IndianOil R&D	Multi-pathway	2G, 3G algae, off-gas ethanol, SAF
IndianOil R&D	Multi-pathway	2G, 3G algae, off-gas ethanol, SAF

Cost comparison of feedstocks

Because imported ethanol cannot be used for blending, fuel-grade ethanol is procured at administered ex-mill prices set by the Cabinet Committee on Economic Affairs (CCEA) and differentiated by feedstock.[25]

Administered ex-mill ethanol prices by feedstock (ESY 2025-26)

Feedstock	Price (INR/liter)
C-heavy molasses	57.97
B-heavy molasses	60.73
Sugarcane juice / sugar / syrup	65.61
Damaged food grains	64.00
Maize	71.86
Surplus FCI rice	60.32

India has no separate administered pricing for 2G ethanol (pricing is delegated to Oil PSUs, with support provided mainly through PM JI-VAN viability gap funding), while no pricing mechanism or blending mandate exists for 3G/4G ethanol due to their early-stage technological maturity.

Supply chain constraints

Ethanol's affinity for water requires specialized, anti-corrosive storage and transport, and inadequate tankage at depots and limited rail tank-car availability hamper smooth movement from plants to OMC blending points. [26]

Feedstock competition is intensifying, maize faces competing demand from the poultry and livestock sectors, tightening availability for ethanol, while rice and sugarcane diversion is capped to protect food and sugar security. Downstream, the mismatch between roughly 1,900 crore liters–2,000 crore liters of installed capacity and about 1,100 crore liters of E20 demand have produced a structural surplus, causing procurement-quota cuts and temporary plant shutdowns in states such as Bihar.[27]

Innovation and R&D trends

R&D is concentrated on making 2G viable and widening the feedstock envelope: the modified PM JI-VAN Yojana (2024) broadened eligible feedstocks to agricultural and forestry residues, industrial waste, synthesis gas and algae and prioritized proposals introducing new technologies. The next frontier is the Alcohol-to-Jet (AtJ) pathway, which converts surplus ethanol into sustainable aviation fuel and offers a high-value demand outlet as CORSIA obligations take effect from 2027.

Contribution to the rural economy and farm incomes

The Ethanol Blended Petrol (EBP) Programme has emerged as a significant new income stream for India's agricultural sector, generating over INR1.60 lakh crore in additional earnings for farmers[28] since 2014–15 through increased demand for feedstocks such as sugarcane, maize and surplus rice, while also providing more than INR1.29 lakh crore in revenue to sugar mills, helping to stabilize an industry historically affected by cyclical fluctuations[29]. In FY2024–25 alone, nearly INR50,000 crore flowed directly into the rural economy due to ethanol blending activities[30].

The pivot to maize has created a new remunerative market for grain farmers, backed by an MSP of INR2,400/quintal for KMS 2025-26[31]. By-products deepen the value chain further: DDGS becomes cattle feed, bagasse is combusted for power and process steam and potash-rich ash returns as fertilizer.

Employment generation

The industry has generated significant rural employment across the agriculture value chain, alongside indirect roles across construction, transport, maintenance and logistics around dedicated ethanol plants, which are typically located in rural areas. Ethanol production creates 290 direct jobs and 1280 indirect jobs for each crore liter of ethanol produced[32]. Because ethanol distilleries are decentralized and located close to agricultural hinterlands, the employment they create is dispersed across rural India rather than concentrated in a few coastal industrial hubs.

25 *Govt raises FCI rice ethanol price for ESY 2025-26; sugar industry faces margin pressure - The HinduBusinessLine*

26 *India Ethanol Market Revenue Analysis & Data Report 2034*

27 *Why India's plan to sell rice for ethanol undermines food and water security*

28 *PIB-202675912001.pdf*

29 *Rice, maize, or sugarcane? India's ethanol push triggers debate over agricultural concerns, subsidies*

30 *https://energy.economictimes.indiatimes.com/news/oil-and-gas/indias-2-lakh-crore-ethanol-blending-revolution-unlocking-foreign-exchange-savings-and-strengthening-rural-economy/126028915*

31 *Press Release:Press Information Bureau*

32 *https://government.economictimes.indiatimes.com/blog/maize-based-ethanol-driving-the-rural-economy-while-sustaining-the-environment/117971921*

The government's push for 2G (second-generation) ethanol plants utilizing agricultural waste has fostered additional employment in the biomass supply chain.

Reducing the Import Oil Bill

India imports close to 88.5% of the crude oil it consumes, which is the central reason ethanol blending sits at the top of the national energy-security agenda. The program has saved more than INR1.9 lakh crore in foreign exchange since 2014-15 by substituting over 310 lakh metric tons of crude oil, directly easing pressure on the balance of payments. Looking ahead, scaling up blending targets is projected to unlock additional forex savings of up to INR2 lakh crore annually. Even a mere 1% adoption of flex-fuel petrol vehicles in 2026-27 is estimated to save INR195 crore in foreign exchange by reducing crude oil imports[33].

Carbon emission reduction and the lifecycle perspective

The transition towards blended fuels has resulted in a net reduction of 909 lakh metric tons in CO emissions since the inception of the current EBP framework. Shifting to an E20 fuel blend substantially lowers lifecycle carbon emissions by approximately 40% compared to pure petrol[34]. Widespread adoption of bioethanol remains a cornerstone of India's international commitment to achieving a 45% reduction in emissions intensity by 2030. Just a 1% transition of new petrol vehicles to flex-fuel capabilities in ESY 2026-27 will yield an additional net CO reduction of nearly 0.86 lakh metric tons[35].

Environmental performance depends heavily on feedstock cultivation: resilient crops such as sorghum and millets deliver superior life-cycle metrics due to lower agricultural inputs, and the shift toward 2G cellulosic ethanol from agricultural residues drastically minimizes the carbon footprint relative to 1G.

Water use, land use and the food-versus-fuel question

Water use remains one of the most significant environmental concerns associated with ethanol production because many feedstocks require substantial irrigation.

The water footprint of millet- and grain-based ethanol systems varies considerably across India, ranging from approximately 1,906 cubic meters/ton in Andhra Pradesh to 6,596 cubic meters/ton in Rajasthan, reflecting the strong influence of local agro-climatic conditions and feedstock choice. However, water requirements differ markedly among feedstocks[36].

In India, paddy crop is applied with 4,076 cu.m (102 cm ha-1) of water per acre for cultivation, which includes both blue (irrigated) and green (rainfall) water. With average 1.144 t/acre of national rice productivity being considered in India, 3,562 liters of water (both blue and green) would be required to produce 1 kg of milled rice in India.

Similarly, sugarcane in India requires 6,304 cu.m (158 cm ha-1) water per acre for cultivation. That means 184 liters of water required to produce 1 kg of cane when average cane productivity of 34.196 t/acre is considered.

Maize requires 2,705 cu.m. (68 cm ha-1) water per acre for its cultivation. The water required to produce 1 kg of maize grains is 1,881 liters when 1.438 t/acre average productivity of the crop is considered.

Substantial amount of water applied to a crop goes back to the soil through percolation and seepage below root zone (30%). The water evaporated from the soil (50%) and transpirated through the crop (20%) into the atmosphere is retained through rainfall. Therefore, hardly any actual water is utilized (0.01%) by the crop for its metabolic activities and tissue formation.

Beyond water concerns, expanding ethanol demand may encourage land-use change, increase nitrogen emissions and intensify competition with food crops such as pulses and oilseeds.

Air quality and the green premium

Ethanol blends enable cleaner combustion, reducing particulate emissions and their high-octane rating (RON ~108) suits modern high-compression engines[37]. Scaling 2G ethanol from crop residues also offers a direct route to curb seasonal stubble burning by giving farmers a paid alternative to setting fields alight. Despite high initial capital costs for distillery infrastructure, bioethanol blends attract environmentally conscious consumers and corporations committed to sustainability goals. The Indian government significantly reduced the Goods and Services Tax (GST) on ethanol from 18% to 5%, thereby minimizing the green premium passed on to the end consume[38]. The government also eliminated central excise duty on higher blends up to E30 to incentivize market adoption and neutralize price barriers against conventional fuels.[39]

Collectively, these environmental benefits and supportive policy measures position bioethanol blends as a commercially viable and scalable pathway for reducing transport-sector emissions while advancing India's energy security and circular bioeconomy objectives.

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33 *https://www.business-standard.com/markets/capital-market-news/ethanol-blending-program-has-saved-india-rs1-84-lakh-crore-in-foreign-exchange-126060400399_1.html*

34 *Press Release Page | Press Information Bureau*

35 *https://www.business-standard.com/markets/capital-market-news/ethanol-blending-program-has-saved-india-rs1-84-lakh-crore-in-foreign-exchange-126060400399_1.html*

36 *https://link.springer.com/article/10.1007/s43832-024-00117-6*

37 *https://www.pib.gov.in/PressReleasePage.aspx?PRID=2155558&reg=48&lang=2*

38 *Press Release Page | Press Information Bureau*

39 *https://www.flame.edu.in/in-the-media/ethanol-beyond-e20-why-indias-clean-fuel-plan-needs-a-water-audit*

The investment landscape

India's ethanol story has shifted from a policy-driven blending push into a fully-fledged investment theme, spanning fuel ethanol, industrial and potable alcohol, and increasingly, sustainable aviation fuel (SAF).

Demand and supply outlook

Ethanol procurement is projected to exceed 1,200 crore liters in the 2025-26 supply year, up from about 38 crore liters in 2013-14, reflecting a structural, mandate-driven demand base backed by guaranteed OMC offtake. On the supply side, installed capacity of roughly 2,000 crore liters now materially exceeds requirements; E20 blending needs about 1,100 crore liters and industrial and other uses another 300 crore liters, leaving close to 700 crore liters of capacity without an assured market. The feedstock mix has shifted structurally toward grains: in ESY 2025-26 grain-based distilleries supplied about 67% of ethanol and sugarcane-based feedstocks 33%, with maize alone the single largest feedstock at roughly a third of supply[41].

Looking forward, if flex-fuel vehicles reach 20% of new registrations by 2028, ethanol demand could rise from around 1,016 crore liters in 2025 to about 1,600 crore liters by 2028, an increase of more than 50%, which is the main pathway to absorbing today's surplus. Beyond flex-fuel vehicles, three further demand channels are being actively developed to absorb over-capacity: a proposed 5% ethanol-diesel blend (ED-5), growing non-fuel industrial demand for ethanol as a solvent and chemical intermediate and potential exports to neighboring markets.

Market size outlook

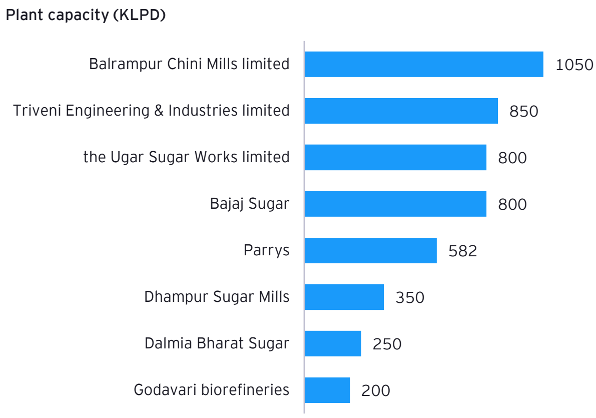
The Indian ethanol market is set for strong double-digit value growth through the early-to-mid 2030s, driven overwhelmingly by fuel blending. The market stands at roughly INR32,300 crores (US$3.4 billion) in 2025 and is on track to reach INR1,12,100 crore (US$11.8 billion) by 2034 at a compound growth rate close to 14%, with bio-ethanol holding about 87.6% share and growing faster than the overall market[42] .

Layered on top is SAF, which is nascent today but structurally large: India has committed to 1% SAF blending on international flights by 2027, 2% by 2028 and 5% by 2030, translating to roughly 53 million liters of SAF by 2027 and about 290 million liters by 2030, or around 720 million liters if the broader ATF pool is targeted, a multi-decade opportunity in which surplus ethanol is a primary feedstock via the Alcohol-to-Jet (AtJ) route.

Capital formation, investors and recent investments

Investment has so far been led by policy-enabled debt and a mix of public and private capital. Government-backed interest-subvention loans unlocked over INR41,000 crore of distillery capacity by 2024, and the broader ethanol build-out has drawn roughly INR40,000 crore of investment, de-risked by assured administered pricing and Long-Term Offtake Agreements (LTOAs) with OMCs[43]. State industrial policies compete actively for projects – Bihar attracted over INR30,000 crore in distillery commitments, while states such as Madhya Pradesh and Andhra Pradesh offer 25% to 35% of capital subsidies on grain-distillery investments[44]. Recent deal flow shows continued momentum: Andhra Pradesh's investment board cleared proposals worth INR9,076 crore with ethanol as a stated priority, and Uttar Pradesh allocated funds for a new 120 KLPD distillery at the Pipraich sugar mill. India's largest sugar refiner and ethanol producer has a distillery plant capacity of 1250 KLPD.

Other players anchoring the sector include:



Source: Top 10 Ethanol Manufacturing Companies in India 2026 - Businesses Estate

On the public side, OMCs (IndianOil, BPCL, HPCL) anchor demand through procurement. On the advanced-fuel frontier, IOCL's first commercial 2G plant at Panipat was dedicated in 2022, with further 2G projects by BPCL (Bargarh), HPCL (Bathinda) and NRL (Numaligarh) advancing under PM JI-VAN. The modified scheme now extends eligibility to 'bolt-on' and brownfield projects, lowering the entry barrier for existing distillers to add advanced-biofuel capacity[45].

40 *https://www.business-standard.com/markets/capital-market-news/ethanol-blending-program-has-saved-india-rs1-84-lakh-crore-in-foreign-exchange-126060400399_1.html*
41 *Rice, maize, or sugarcane? India's ethanol push triggers debate over agricultural concerns, subsidies*
42 *Conversion factor (USD-INR): 95*
43 *https://www.fortuneindia.com/business-news/40000-crore-ethanol-push-nears-oversupply-aida-urges-use-in-kitchens/132355*
44 *India Ethanol Market Revenue Analysis & Data Report 2034*
45 *Cabinet approves Amendment in "Pradhan Mantri JI-VAN Yojana" for providing financial support to Advanced Biofuel Projects using lignocellulosic biomass and other renewable feedstock | Prime Minister of India*

Bankability considerations

The core bankability strength is demand certainty: blending is legally mandated and offtake is guaranteed through long-term OMC procurement, substantially reducing market risk for a well-structured project. The principal vulnerability is feedstock cost, typically 60% to 70% of manufacturing expense, exposing producers to grain and cane price cycles that administered prices may not always track. Foreign capital is explicitly welcomed: 100% Foreign Direct Investment (FDI) in biofuel technologies is permitted through the automatic route, provided the biofuels produced are for domestic use.

Distillery economics: Capex and the molasses ladder

A 1G distillery, whether sugar-based (B-heavy molasses or syrup) or grain-based, costs about INR1.3 crore–INR1.6 crore per KLPD to build, of which 71% to 76% is plant and machinery[46]. Within sugarcane feedstocks, ethanol economics improve with high-value feedstocks, with procurement prices increasing from INR57.97/liter for C-heavy molasses to INR60.73/liter for B-heavy molasses and INR65.61/liter for cane juice/syrup. The economic logic behind the ladder is yield: C-heavy molasses retain very little fermentable sugar, so B-heavy and direct-juice routes produce substantially more ethanol per ton of cane, which is why most sugarcane ethanol has shifted away from C-heavy despite its lower headline price[47].

The incremental capex required to shift from C-heavy to B-heavy molasses is generally justified by superior ethanol economics, driven by higher yields, premium pricing and lower working-capital requirements[43]. A multi-feedstock (dual-feed) distillery carries a modest cost premium over a single-feed plant but earns it back through year-round operation, since grain lets the plant run through the sugarcane off-season and lift utilization above 90%[48]. By contrast, a few OMCs are investing in 2G cellulosic plants costing roughly INR9 crore per KLPD, about six times a 1G plant, thus restricting investments.

Why build an ethanol distillery today?

The case rests on a legally mandated market, guaranteed government offtake, layered fiscal support, and a demand curve still climbing toward higher blends. A well-structured plant faces input and execution risks rather than market risk. On unit economics, a 100 KLPD grain-based distillery can generate revenue of about INR200 crore–INR210 crore a year at current administered prices with operating margins of 16% to 19%, against a build cost near INR130 crore–INR160 crore[49]; by-products deepen returns, as distillers' grains (DDGS) become animal feed, bagasse and biogas provide process energy, and captive ethanol can feed higher-margin bio-chemicals such as ethyl acetate and butanol.

TAM/ SAM framing for a new ethanol distillery

Layer	Definition	Indicative size
Total Addressable Market (TAM)	All Indian ethanol (fuel + industrial + potable) + SAF layer	~ INR32,300 crores-INR1,12,100 crores
Serviceable Addressable Market (SAM)	Fuel-ethanol blending demand served by EBP	>1,200-1,600 crore liter/yr by 2028; ~INR62,566 crore

A new entrant's obtainable share depends on feedstock cost position, location near OMC depots and utilization – a single 100KLPD–200 KLPD plant produces roughly three to six crore liters a year, favoring flexible, well-sited, high-utilization plants over undifferentiated greenfield capacity.

Key risks and challenges and the role of government support

For all its momentum, the ethanol program now carries a distinct set of risks concentrated on the supply side, in resource use, and in fiscal exposure, and for each, the government has deployed, or is preparing, specific mitigation.

Overcapacity and stranded-investment risk

The most immediate risk is structural surplus: capacity heading past 2,000 crore liters by 2026 against E20 demand of ~1,100 crore liters, threatening stranded investment across a sector that has drawn over INR40,000 crore. The government's mitigation is to manufacture new demand faster than capacity idles – clearing standards for E22-E30, E85 and E100, removing central excise duty on higher blends, allocating more FCI rice to lift utilization at multi-feed plants, and opening additional channels including isobutanol-diesel blends, ethanol cookstoves to displace imported LPG, SAF and possible exports.

Food-versus-fuel and feedstock risk

Diverting rice and maize to fuel raises a genuine food-security tension: the rice-allocation target for ethanol rose to about 90 lakh tons for 2025-26 (from 52 lakh the year before), and the government proposed cutting the broken-rice share in the public distribution system from 25% to 10% to free up grain . India ranked 102 out of 123 on the 2025 Global Hunger Index and was warned that the surplus calculus can flip quickly after two poor monsoons.

46 *Ethanol blending enthuses large sugar mills to step up distillery capacities - The-Print - ANIFeed*

47 *Govt raises procurement price of C-heavy molasses ethanol by Rs 1.69/liter | Agriculture - Business Standard*

48 *How Dual-Feed Ethanol Plants Are Transforming India's Biofuel | Ethanol Distillery Plant Manufacturers in Pune*

49 *Ethanol blending enthuses large sugar mills to step up distillery capacities - The-Print - ANIFeed*

The government's mitigations are the National Biofuel Coordination Committee's dynamic feedstock allocation and surplus-declaration mechanism, caps on grain diversion during shortages (a 24 lakh-ton rice cap), a deliberate tilt toward maize, the feedstock most experts prefer for its lower water footprint, and, structurally, a push toward non-food 2G/3G feedstocks.

Current and probable future feedstock scenario

To get the required amount of feedstock to meet the future demand for ethanol of 3,000-3,200 crore liter equivalent, the following steps/majors would be required:

- Initiative to declare corn an energy crop and enhancement in corn production
- Intercropping of sweet sorghum in sugarcane, extended sugar season by sugar beet cultivation
- Utilization of excess bagasse for low carbon ethanol production
- Encouraging and implementation of AI model in present sugarcane, corn and rice fields
- Promotion of alternate feedstock as cassava/tapioca in costal and North-east states
- Development of high-yield cane verities with agriculture research centers

Water, environment and sustainability

Ethanol's water footprint is large and geographically concentrated: producing one liter needs roughly 10,790 liters of water from rice, 4,670 from maize and 3,630 from sugarcane, while NITI Aayog warns groundwater in 21 major cities could approach zero around 2030. Distilleries are also 'red-category' polluters, and assured procurement is nudging farmers from pulses and oilseeds toward water-hungry cane and maize. Mitigations combine mandatory zero-liquid-discharge compliance for subsidized plants, a policy tilt to lower-water maize and to residue-based 2G, drip-irrigation incentives in cane states and lifecycle-emissions accounting.

Vehicle compatibility, fiscal cost and import-dependence shift

Higher blends raise engine-compatibility and mileage concerns, which the government addresses through E20-material mandates on new vehicles, separately marked pumps for each blend, BIS standards for E22-E30 and flex-fuel-vehicle incentives. Fiscally, the true cost of the program – about INR87,390 crore in ESY 2024-25 once feedstock, power and fertilizer subsidies are counted – exceeds the OMC procurement cost of INR62,566 crore, exposing policy to future rationalization. Here the government leans on demonstrated returns: cumulative forex savings above INR1.9 lakh crore, roughly 310 lakh tons of crude substituted and faster farmer payments.

Future outlook and strategic roadmap

With E20 achieved ahead of schedule in December 2025, the focus of India's ethanol program must shift from expanding supply to addressing demand growth, resource sustainability and fiscal efficiency.

Recommended roadmap

Phase 1

Foundation (2026–2027): New demand channels

With E20 now implemented nationwide, the focus should shift to expanding ethanol demand through E85/E100 policy finalization, wider ethanol retail infrastructure and greater adoption of flex-fuel vehicles. Future policy support should prioritize advanced biofuels by promoting 2G ethanol, encouraging maize-based production over rice, developing a national SAF strategy, advancing isobutanol-diesel pilots, and improving transparency around the program's fiscal costs.

Phase 2

Scale-up (2028–2030): Expand demand and transition feedstocks

During the scale-up phase, the focus should be on expanding ethanol demand through flex-fuel vehicle incentives and gradual adoption of higher ethanol blends, while accelerating feedstock diversification toward 2G biofuels and reducing dependence on food grains. Surplus ethanol can support SAF production, and future investments in new pathways and capacity expansion should be guided by commercial viability, fuel demand trends and EV adoption.

Phase 3

Maturity (2031–2035): Build a diversified and competitive sector

By the early 2030s, the focus should be on establishing a mature, competitive ethanol industry driven by diversified non-food demand streams. Flex-fuel vehicles and higher ethanol blends should become mainstream, while new capacity increasingly relies on advanced 2G and 3G technologies. SAF could emerge as a major growth avenue, positioning India as a global production hub, with the sector gradually transitioning from policy-driven support to market-based competitiveness.

50 *India's Ethanol Push at a Crossroads Between Energy Security, Water Stress and Food Risks*

Strategic recommendations

Diversify the molecule, not just the blend: The single greatest strategic risk is stranded distillery assets tied exclusively to petrol blending. India should reposition surplus ethanol capacity toward alcohol-to-jet Sustainable Aviation Fuel (SAF), bio-ethylene and green chemicals and export markets. A national "flex-refinery" retrofit scheme, concessional finance conditional on plants adding at least one non-petrol offtake stream, would convert the overcapacity problem into a first-mover advantage in aviation decarbonization, where CORSIA-driven demand is structurally rising even as road-fuel demand declines.

Introduce water-indexed differential pricing for feedstock: Rather than a flat procurement price, oil marketing companies should pay a premium graded by the water and carbon intensity of the feedstock: highest for agricultural-residue (2G) and rain-fed maize ethanol, lowest for groundwater-irrigated sugarcane in stressed districts. This uses the procurement lever India already controls to steer the feedstock mix without banning anything, and it creates the long-term price certainty 2G projects currently lack.

Build residue aggregation hubs to make 2G bankable: The binding constraint on second-generation ethanol is not technology, but a broken biomass supply chain. District-level "biomass banks"- mechanized collection, baling, storage and quality grading of paddy straw and other residues, operated as farmer-producer-company franchises, would simultaneously feed 2G plants, monetize stubble that is otherwise burned, and give lenders the feedstock-security assurance needed to finance pre-treatment capex.

Shift consumer pricing from per-liter to energy-equivalent terms: Consumer concerns over E20 fuel efficiency are the program's biggest reputational liability. Pricing higher blends (E27, E85) at a discount reflecting their lower energy content keeps the cost per kilometer neutral. Retailers should also offer a choice of blends rather than relying solely on a single mandated blend.

Create dedicated ethanol logistics corridors: Hydrous ethanol cannot share petroleum pipelines; blending economics deteriorate with distance. Therefore, India should designate rail-based corridors linking surplus clusters (UP, Maharashtra, Karnataka) to deficit coastal and north-eastern markets, with hub-and-spoke depot blending and pilot dedicated pipelines on the high-volume routes.

Monetize carbon intensity through certification: India should adopt a lifecycle carbon-intensity (CI) scoring system for every liter of ethanol. Low-CI ethanol could then earn tradable credits domestically and command premiums in SAF and export markets and giving Indian producers a certified product rather than a commodity.

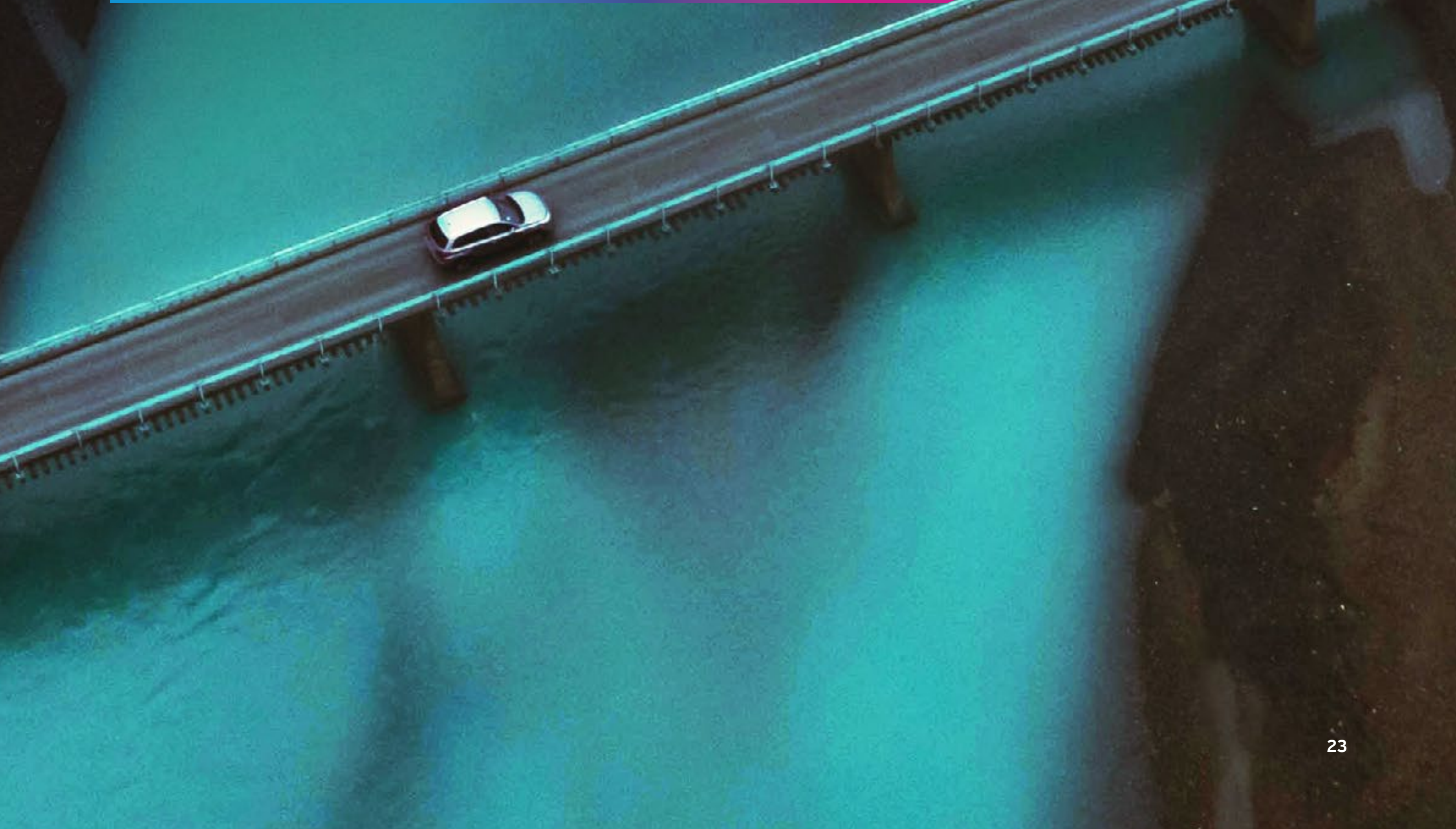
Conclusion

India's bioethanol program stands out as one of the country's most notable industrial policy achievements in recent years. Ethanol blending increased from just 1.5% in 2014 to 20% by December 2025, helping reduce crude oil imports, generate substantial foreign exchange savings, and attract significant investments that expanded production capacity beyond 2000 crore liters. However, this success has also shifted the sector's primary challenge. The key issue is no longer increasing supply, but rather ensuring adequate demand, managing resource sustainability and containing fiscal costs. As a result, the next phase of the program focuses on efficiently utilizing existing and emerging capacity rather than pursuing unchecked expansion.

To address these challenges, the government has adopted a multifaceted strategy. Demand is being stimulated through initiatives such as higher ethanol blending targets, the promotion of flex-fuel vehicles, exploration of isobutanol-diesel blends, development of sustainable aviation fuel (SAF) and the potential use of ethanol as a cooking fuel.

At the same time, sustainability measures include dynamic feedstock allocation, a greater emphasis on maize and second-generation (2G) biofuels, and stricter environmental requirements such as zero-liquid-discharge systems. Investor confidence is supported through mechanisms including administered pricing and assured procurement arrangements.

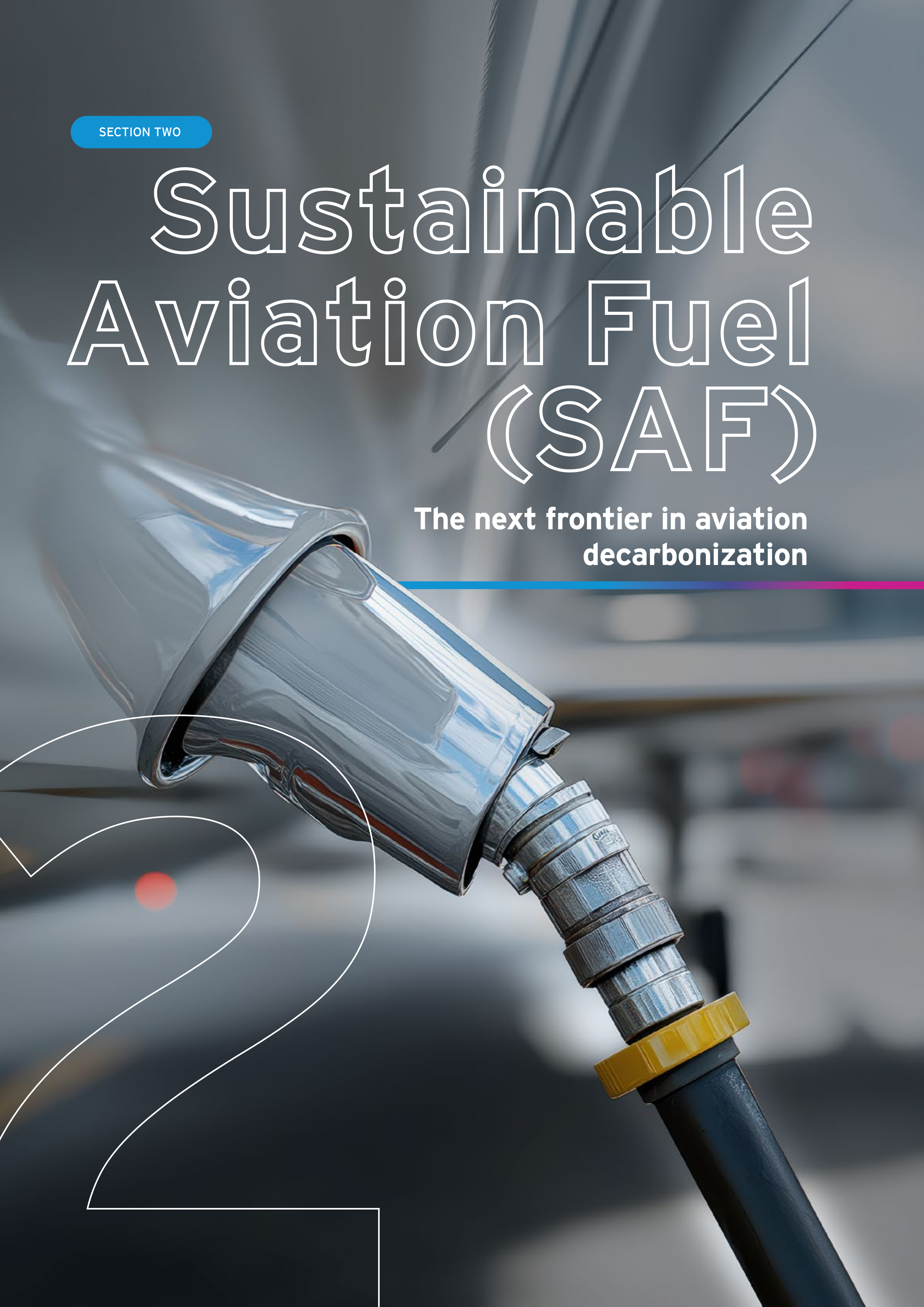
For both investors and policymakers, the most prudent approach is to focus on efficient, feedstock-flexible first-generation (1G) plants and carefully selected 2G, third-generation (3G), and SAF projects that enjoy clear policy support. The long-term success of India's ethanol economy will depend on factors such as the adoption rate of flex-fuel vehicles, the rollout of higher blending mandates, and the evolution of subsidy policies. These developments will ultimately determine whether bioethanol becomes a sustainable pillar of India's energy security framework or faces constraints arising from resource limitations and fiscal pressures.



SECTION TWO

Sustainable Aviation Fuel (SAF)

The next frontier in aviation decarbonization



Introduction and context

Aviation decarbonization challenge

The global aviation sector is at a critical inflection point, facing the dual challenge of sustaining rapid traffic growth while aligning with increasingly stringent climate commitments. Aviation contributed approximately 2.5% of global energy-related CO emissions[51] in 2023, a share concentrated in a sector with few near-term fuel alternatives.

Passenger demand worldwide continues to expand strongly, with global passenger traffic predicted to reach 10.2 billion passengers in 2026 and 18.8 billion by 2045[52]. Without intervention, aviation emissions could rise significantly in absolute terms, even as other sectors decarbonize. Estimates suggest that aviation's share of global emissions could increase substantially by mid-century if mitigation measures are not deployed at scale[53]. In response, the International Civil Aviation Organization (ICAO) has committed to achieving net-zero carbon emissions by 2050[54] through a combination of technological innovation, operational efficiency and market-based measures.

Among all available levers, fuel substitution remains the most immediate and scalable solution, placing Sustainable Aviation Fuels (SAF) at the center of global aviation decarbonization strategies. Feedstock and production assessments suggest that the industry can realistically supply around 80% of aviation's projected fuel requirements, around 500 Mt annually, to achieve net-zero emissions by 2050[55].

Role of SAF globally and in India

Global context

Sustainable Aviation Fuel (SAF) refers to non-fossil-derived aviation fuels produced from renewable or waste-based feedstocks, including used cooking oil, agricultural residues, municipal solid waste and synthetic pathways using renewable energy.

SAF presents a drop-in solution, meaning it can be blended with conventional jet fuel and used in existing aircraft and infrastructure without modification, an advantage unmatched by other decarbonization technologies. Lifecycle emissions reductions from SAF can reach up to 80% or more, depending on feedstock and production pathway[56].

SAF is widely recognized as the primary decarbonization lever for aviation in the near- to medium-term. Industry estimates suggest that SAF could contribute up to 65% of the total emissions reductions required for the sector to achieve net-zero emissions by 2050[57]. SAF adoption is being advanced through the following instruments.

Instrument category	Mechanism	Description	Geography	Unit of measure	Trajectory
Blending mandates	ReFuelEU Aviation Regulation[58]	EU-wide mandatory SAF blending requirements for all flights departing EU airports	European Union	% SAF blend of total jet fuel	2% (2025) >> 70% (2050)
	UK SAF Mandate[59] (Renewable Transport Fuel Obligation Order, 2024)	Legal blending obligation on UK fuel suppliers, enforced through tradable certificates	UK	% SAF blend of total jet fuel	2% (2025) >> 10% (2030) >> 22% (2040)
	National SAF blending target[60]	Target share of SAF in fuel used in international flights	Japan	% SAF blend (International flights)	10% by 2030
	Indicative National SAF blending target[61]	Target share of SAF in fuel used initially in international flights	India	% SAF blend (international flights)	1% (2027) >> 2% (2028) >> 5% (2030)

51 *European Aviation Environmental Report, 2025; European Union Aviation Safety Agency*

52 *World Air Traffic Forecast 2025-2054; 2025; Airports Council International (ACI)*

53 *Decarbonizing Aviation: Enabling Technologies for a Net-Zero Future, 2024; Clean Air Task Force*

54 *Long term global aspirational goal (LTAG) for international aviation, 2022; The International Civil Aviation Organization (ICAO)*

55 *Global Feedstock Assessment for SAF Production, 2025; The International Air Transport Association (IATA)*

56 *Sustainable Aviation Fuels; International Air Transport Association (IATA)*

57 *Developing Sustainable Aviation Fuels, International Air Transport Association (IATA)*

58 *SAF Policy Actions, 2025; European Union Aviation Safety Agency*

59 *SAF Mandate, 2024; Government of UK*

60 *Clean the Earth with Aviation SAF Report, 2024; Ministry of Land, Infrastructure, Transport and Tourism*

61 *Feasibility Study On The Use Of Sustainable Aviation Fuels, 2025; Ministry of Civil Aviation, in partnership with the International Civil Aviation Organization (ICAO)*

Instrument category	Mechanism	Description	Geography	Unit of measure	Trajectory
Fiscal incentives	Clean Fuel Production Tax Credit[62]	Per-gallon tax credit for producers of qualifying low-carbon SAF	USA	US$ per gallon	0.35 US$ per gallon (base) >> 1 US$ per gallon (For compliant SAF facilities based on the One, Big, Beautiful Bill Act[63])
	SAF Mandate Buy-Out Price[64]	Penalty rate paid by suppliers per liter of shortfall against their blending obligations	UK	GBP per liter	GBP 4.70 per liter
International frameworks	CORSIA[65] (Carbon Offsetting and Reduction Scheme for International Aviation)	Global scheme requiring airlines to offset emission growth above a fixed baseline	193 ICAO Members; 130 committed as of 2026	% of 2019 baseline emissions	Baseline: 85% of 2019 levels; mandatory phase: 2027-2035

Table 1. Global policy instruments for SAF adoption

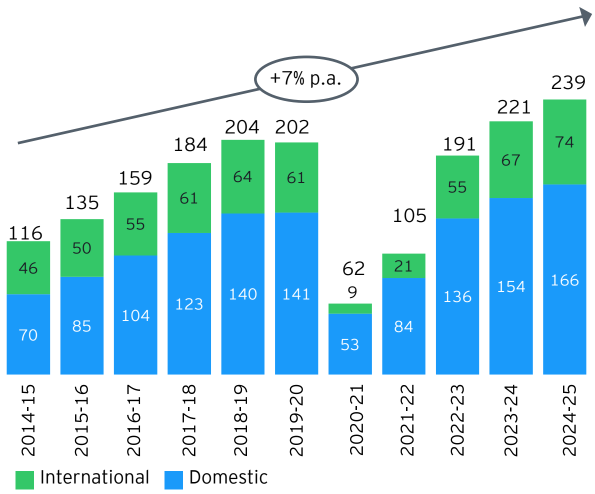
These policy interventions are critical to bridging the cost gap, as SAF currently remains significantly more expensive than conventional aviation turbine fuel.

India context

India represents one of the most compelling emerging markets for SAF deployment, with annual aviation turbine fuel (ATF) consumption of 8.98 MT in 2024, driven by both rapid aviation growth and strong bioenergy fundamentals.

The country is already among the world's fastest-growing aviation markets. Domestic air passenger traffic reached 165 million passengers in FY2024-25, growing by 7.6% year-on-year[66]. This growth is translating into rising ATF demand, which has increased from approximately 6.3 million tons in FY2015-16 to 8.98 million tons in FY2024-25 and is expected to more than triple by 2040.

India's air passenger traffic growth[67]



62 *Clean Fuel Production Credit, 2022; US Department of Energy*
63 *One Big Beautiful Bill Public Law, 2025; United States Congress*
64 *Sustainable Aviation Fuel Mandate, 2024; Department of Transport*
65 *CORSIA, 2021; The International Civil Aviation Organization (ICAO)*
66 *Indian Aviation Industry Report, 2025; ICRA Limited*
67 *Handbook on Civil Aviation Statistics, 2025, Directorate General of Civil Aviation (DGCA)*

Growing aviation demand increases both crude oil dependence and aviation emissions. At the same time, India possesses several structural advantages for SAF development:

- Availability of 230 million tons of surplus agricultural residue[68]
- A mature refining ecosystem through co-processing, existing fuel logistics infrastructure and integration with established refining and distribution networks
- Strong policy experience in biofuels (e.g., ethanol blending)
- Expanding airport and fuel infrastructure

Recognizing this opportunity, the Government of India is actively developing a SAF roadmap, with indicative blending targets of:

- 1% by 2027
- 2% by 2028
- 5% by 2030

SAF is increasingly positioned not only as an environmental solution but also as a strategic economic lever. It offers the potential to:

- Reduce crude oil import dependence
- Create rural income streams through biomass utilization
- Enable India to emerge as a global SAF production and export hub
- Reduce exposure to exchange rate volatility through domestic feedstock availability and localized SAF production

68 *Sustainable Aviation Fuel (SAF) Feasibility Study for India, 2025; Ministry of Civil Aviation, GoI*

Recent milestones, such as the certification of IndianOil's Panipat Refinery as India's first ISCC CORSIA-compliant SAF production site[69] in 2025, signal early but meaningful progress toward building a domestic SAF ecosystem. However, scaling SAF will require coordinated action across:

- Policy frameworks
- Feedstock aggregation systems
- Financing mechanisms
- Airline and refinery participation

The subsequent sections of this report examine these dimensions in detail, with a focus on translating India's structural advantages into a viable and scalable SAF ecosystem.

Key facts at a glance

Global SAF market snapshot

Metric	India / global signal
Aviation emission contribution	2.5% of global energy-related CO emissions
Global air travel	4.99 billion passengers in 2025; forecast to exceed 5.2 billion in 2026
SAF contribution to net-zero pathway	Expected to deliver ~65% of aviation emissions reductions required for net zero by 2050
Global SAF production potential	400 Mt SAF production potential by 2050 versus 500 Mt required for net zero
Cost premium	2–5x conventional ATF

Indian SAF market snapshot

Metric	India / global signal
India ATF consumption	8.98 MMTPA in FY2024-25
SAF blending targets	1% by 2027, 2% by 2028, 5% by 2030 for international flights
First certified producer	IndianOil Panipat refinery
Panipat capacity	35,000 t/year
India feedstock base	230 MMT surplus agricultural residue
2030 SAF demand estimate	720 million liters at 5% blend

69 *IndianOil's Panipat Refinery Secures Nation's First ISCC CORSIA Certification for Sustainable Aviation Fuel Production, 2025; Ministry of Petroleum & Natural Gas*

Current market landscape

India's SAF market is transitioning from concept to early commercialization, driven by rapid aviation growth, CORSIA-linked requirements and the GoI's ambition to build domestic SAF production capacity. The Ministry of Civil Aviation's 2025 SAF Feasibility Study20, prepared with ICAO and EU, explicitly assessed India's feedstock availability, production pathways, infrastructure readiness and policy requirements for a domestic SAF ecosystem.

Global SAF market: High strategic importance, low current penetration

Globally, SAF remains a very small share of aviation fuel use despite its central role in aviation decarbonization. IATA estimates that SAF production is expected to reach 1.9 million tons in 2025, representing only 0.6% of global jet fuel consumption. Production is projected to increase to 2.4 million tons in 2026, equivalent to approximately 0.8% of global jet fuel consumption[70], highlighting the significant supply gap relative to the aviation industry's net-zero requirements.

India's SAF market: Nascent but strategically attractive

India's SAF market is entering a formal market-formation phase. In 2025, the GoI released the SAF Feasibility Study in partnership with ICAO and the EU under the ACT-SAF program, indicating a whole-of-government approach involving MoCA, DGCA, EASA, oil companies, aircraft manufacturers and industry stakeholders. The government has announced indicative SAF blending targets for international flights of 1% by 2027, 2% by 2028, and 5% by 2030[71], creating the first structured demand signal for the Indian SAF market.

In April 2026, the Government amended the Aviation Turbine Fuel Control Order to bring SAF-blended aviation fuel under the regulatory ambit of ATF marketing[72]. The amendment expanded the ATF definition to include SAF co-processed with ATF in refineries and SAF blended with ATF, provided the final fuel meets relevant BIS specifications. This reduces regulatory ambiguity around marketing, blending and distribution of SAF in India and aligns domestic fuel regulation with CORSIA-linked requirements for international aviation.

70 *Growth in SAF Production, 2024; The International Air Transport Association (IATA)*

71 *Feasibility Study On The Use Of Sustainable Aviation Fuels, 2025; Ministry of Civil Aviation, in partnership with the International Civil Aviation Organization (ICAO)*

72 *Government Brings SAF-Blended Aviation Fuel Under ATF Control Order, 2026; Ministry of Petroleum & Natural Gas (MoPNG)*

Demand drivers in India

The first major demand driver is aviation growth. India's ATF consumption reached a record level in FY2024–25 at approximately 8.98 million tons, growing by nearly 3.9% year-on-year, with April 2025 monthly consumption touching 0.77 MMT[73]. India's passenger traffic base is also expanding, supported by rising incomes, regional connectivity, tourism and fleet expansion by major carriers. Domestic airlines carried 72.94 million passengers in Jan to May 2026 as against 71.57 million during the corresponding period of the previous year, thereby registering an annual growth of 1.91% and monthly growth of 9.49%[74].

The second demand driver is international compliance. CORSIA's mandatory phase begins in 2027, and India's SAF targets currently apply to international flights departing from India22. SAF use can reduce airlines' carbon-offsetting obligations under CORSIA, making it economically relevant not only as fuel but also as a compliance instrument.

The third demand driver is energy security. India's crude oil import dependence rose to around 88.7% in FY2025–26, with May 2026 crude import dependence reaching about 90%[75]. SAF produced from domestic biomass, UCO, agricultural residues and other waste streams can reduce marginal dependence on imported crude-derived jet fuel over time, while also creating domestic value chains in agriculture, waste management and refining.

Demand potential under blending scenarios

India's near-term SAF demand will be determined by blending mandates and the fuel base to which they apply. For international aviation alone, the government's announced trajectory of blending creates a predictable early market. If domestic aviation is included later, the demand pool could expand materially as domestic aviation accounts for the majority of India's ATF consumption; industry reporting indicates domestic aviation contributes around 74% of India's ATF demand, international traffic around 25%, and military use about 1%[76].

Based on estimates cited by India's Petroleum Minister, a 1% SAF blend in India could require roughly 0.10 million tons–0.11 million tons per year, while a 5% blend could require around 0.55 million tons–0.56 million tons per year[77], depending on the ATF demand base and whether domestic aviation is included. These volumes are sufficient to support multiple commercial projects while enabling phased market development through anchor production facilities and long-term offtake agreements.

Supply landscape and early commercial activity in India

The Indian supply ecosystem is beginning to take shape around public-sector oil marketing companies, especially IndianOil. In August 2025, IndianOil's Panipat Refinery became the first Indian facility to receive CORSIA certification for SAF production. The certification validates India's ability to produce, certify and distribute SAF within globally recognized frameworks. IndianOil has also signed an MoU with Air India for SAF supply[78], linking India's first certified SAF production pathway with one of the country's largest international aviation demand centers. The Panipat SAF facility is expected to use used cooking oil as feedstock, indicating that India's first commercial phase will likely be based on waste-lipid and co-processing pathways before broader scale-up through ATJ, FT and residue-based routes.

Supply-demand gap and investment implication

Current domestic SAF production remains well below projected demand for India's planned 5% blending target. While the Panipat refinery marks an important milestone, significantly larger production capacity will be required to meet future demand.

For investors, this supply gap represents the primary opportunity. India combines rising aviation fuel demand, high crude import dependence, announced blending targets, abundant biomass resources, and an established refining ecosystem. However, scaling the market will depend on clear policy support, bankable offtake agreements, sustainability certification, feedstock traceability and mechanisms to address SAF's green premium. Overall, India's SAF market remains nascent but is steadily transitioning toward commercialization.

Production ecosystem and supply chain

India has strong feedstock potential, a mature refining base, proven biofuel policy experience, and early certification milestones, but commercial-scale production remains limited. The near-term production landscape is expected to be led by bio-based SAF, particularly used cooking oil (UCO), agricultural residues, ethanol and other biomass,

73 *Industry Consumption Report-POL & NG, 2025; Petroleum Planning and Analysis Cell (PPAC)*

74 *Performance of domestic airlines for the year 2026, 2026; Directorate General of Civil Aviation*

75 *Snapshot of India's Oil & Gas Data Monthly Ready Reckoner, 2026; Petroleum Planning and Analysis Cell (PPAC)*

76 *Industry Consumption Report-POL & NG, 2025; Petroleum Planning and Analysis Cell (PPAC)*

77 *Feasibility Study On The Use Of Sustainable Aviation Fuels, 2025; Ministry of Civil Aviation, in partnership with the International Civil Aviation Organization (ICAO)*

78 *Air India Press Release, 2025; Air India*

while e-SAF / power-to-liquid (PtL) pathways are to remain longer-term options because of their dependence on low-cost renewable power, green hydrogen and CO supply.

SAF production pathways relevant for India

Globally, SAF can be produced through multiple pathways, including (i) HEFA, (ii) Alcohol-to-Jet (AtJ), (iii) Fischer-Tropsch (FT), and (iv) power-to-liquid / e-SAF routes. Currently SAF can be used as a drop-in fuel when blended with conventional aviation turbine fuel, with most approved routes permitting blends of up to 50%, while co-processing has lower regulated limits.[79]

Pathway	Feedstock	Production potential	MSP[80]
HEFA / HVO-based SAF	Used cooking oil, animal fats, waste oils	India generates around 2.4 MMT/year of used cooking oil, with significant leakage back into the food chain.[81] The potential volume of SAF is 0.8 MMT/year-1.6 MMT/year through UCO/waste-oil routes, depending on collection efficiency.[82]	US$0.8 /L - US$1.1 /L
Alcohol-to-Jet (AtJ)	Ethanol, isobutanol, other alcohols	India produces over 5 billion liters of ethanol annually, and the ethanol ecosystem is already supported by OMC procurement and blending infrastructure.[83] ~2.9 MMT/year-5.8 MMT/year based on the 1G ethanol production in India. Longer-term potential is higher if 2G ethanol from residues scales.[84]	US$0.8 /L - US$2.4 /L
Fischer-Tropsch SAF	Agricultural residues, forestry waste, municipal solid waste, syngas	India has about 400 MMT/year surplus biomass including agricultural residues, forestry waste and MSW.[85] ~4MMT/year-8 MMT/year from 230 MMT agricultural residue alone, using ICAO's FT agricultural-residue yield of 0.14 ton distillate per ton feedstock, ~50% SAF share and assuming only 25%-50% aggregation.	US$0.9 /L - US$2.0 /L
e-SAF / PtL SAF	Green hydrogen and captured CO	India's National Green Hydrogen Mission targets 5 MMT/year of green hydrogen by 2030. Additionally, around 4.5MMT of biogenic CO2 can be available as an ethanol production by-product.[86]	US$2.7 /L - US$3.6 /L

Feedstock landscape: India's core competitive advantage

India's strongest SAF advantage lies in its biomass and agricultural residue base. India has over 680 million metric tons of available biomass and nearly 230 million metric tons of surplus agricultural residue, creating the potential to meet domestic SAF demand and eventually develop export-oriented production.[87] Key feedstock categories include:

Feedstock category	Examples	Key consideration
Used cooking oil (UCO)	Waste cooking oils, used edible oils	Limited by collection efficiency and competing demand from the biodiesel sector
Agricultural residues	Rice straw, wheat straw, sugarcane trash, cotton stalks	Requires aggregation, storage, logistics and farmer participation systems
Municipal solid waste (MSW) and industrial waste gases	Urban waste streams, syngas sources, industrial off-gases	Higher technology complexity and lower commercial maturity compared to HEFA and AtJ
CO and green hydrogen	Captured CO, renewable hydrogen	Economic viability depends on declining green hydrogen costs and scaling carbon capture infrastructure after 2030

79 *SAF Handbook, 2024, IATA*

80 *Minimum Selling Price (MSP) based on 0 NPV - compared to $0.5/L for jet fuel in May 2025, Feasibility study on the use of sustainable aviation fuels, 2025; ICAO,*

81 *India generates ~2.4MMT of UCO annually, 2025; EnergyWatch*

82 *Feasibility study on the use of sustainable aviation fuels, 2025; ICAO*

83 *India produces over 500 crore liters of ethanol annually, 2025; EnergyWatch*

84 *Feasibility study on the use of sustainable aviation fuels, 2025; ICAO*

85 *India generates more than 400MT of surplus biomass every year, 2025; Energy-Watch*

86 *Feasibility study on the use of sustainable aviation fuels, 2025; ICAO*

87 *Feasibility study on the use of sustainable aviation fuels, 2025; ICAO*

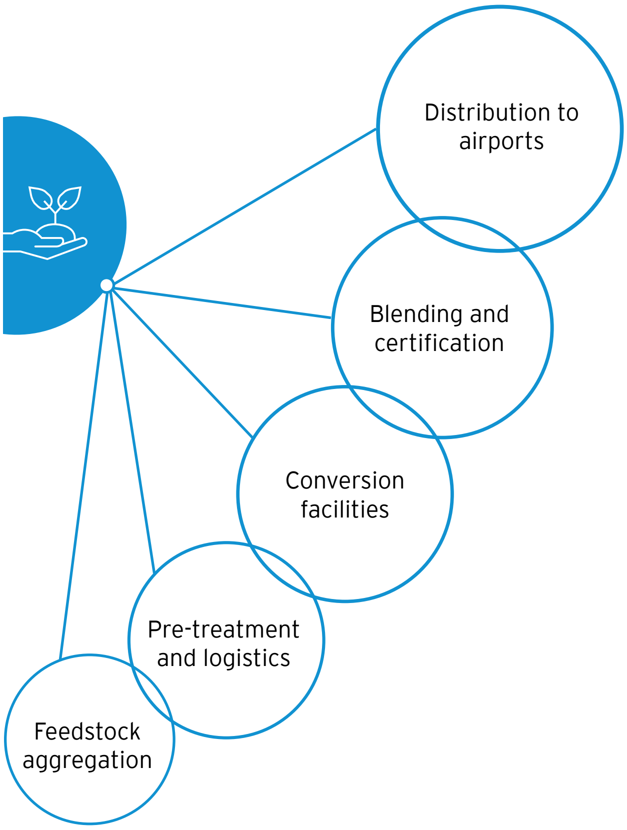
Refinery integration and co-processing

Co-processing is likely to be one of India's most attractive near-term scale-up routes because it allows renewable feedstocks or intermediates to be processed in existing refinery units alongside petroleum streams. Co-processing can serve as a bridge technology for SAF ramp-up, though it requires feedstock pretreatment, quality controls, and refinery modifications when oxygen-rich bio-oils or lipid feedstocks are introduced. For India, this route is particularly relevant because the country has large integrated refining assets and established OMC-led fuel networks.

However, co-processing alone will not be sufficient for long-term demand if blending targets expand beyond international aviation. This is because the upper limit of SAF blending through the co-processing route is limited to 5% to 10%.[88]

Logistics, storage and distribution infrastructure

SAF has a major advantage over other aviation decarbonization options because it is a drop-in fuel that can use much of the existing jet fuel infrastructure after certification and blending. The production-side logistics, however, are much more complex than conventional ATF because SAF feedstocks are dispersed, heterogeneous and often seasonal. A scalable Indian SAF supply chain will require five infrastructure layers:



88 SAF Handbook, 2024, IATA

Role of UCO and the RUCO ecosystem

Used cooking oil is the most immediate SAF feedstock in India, but building a reliable UCO supply chain will require stronger traceability and aggregation. FSSAI's RUCO initiative was designed to divert used cooking oil away from the food chain and toward non-food uses such as biodiesel, thereby supporting food safety, energy security and environmental objectives.[89] For SAF producers, this ecosystem can become a foundation for HEFA and co-processing supply. However, UCO-based SAF will face limits because UCO is already used in biodiesel and other industrial applications, and collection is easier from large food businesses than from fragmented small eateries. Therefore, UCO should be seen as a first-wave feedstock, not the sole basis for India's SAF industry.

Ethanol and AtJ: India's strategic mid-term pathway

India's ethanol program provides one of the strongest foundations for scaling Alcohol-to-Jet (AtJ) SAF because of the following factors:

1 Ethanol Blending Programme

The Ethanol Blending Programme (EBP) has already demonstrated India's ability to create a large-scale liquid biofuel market: ethanol blending in petrol increased from ~1.5% in 2014 to 20% by March 2025, while ethanol production capacity expanded nearly eight-fold from 1.7 billion liters in 2014 to 13.8 billion liters in 2023.[90]

2 Multiple feedstocks

AtJ can use both 1G ethanol from sugarcane and 2G ethanol from lignocellulosic residues. This feedstock flexibility is a strategic advantage: 1G ethanol can support early commercial AtJ deployment, while 2G ethanol can progressively shift the pathway toward lower-carbon, residue-based SAF without creating long-term food-versus-fuel concerns.

3 Availability of feedstock

India also has a large AtJ-compatible biomass base, of which nearly 230 MT is surplus after accounting for competing uses.

Around 70% of this agricultural residue pool comes from eight major crops. Beyond agricultural residues, the report identifies additional surplus biomass streams, including forestry residues, animal waste and urban biomass.

89 RUCO Initiative, FSSAI
90 The opportunity for AtJ SAF in India, 2025, ICF

4 Existing and emerging infrastructure
AtJ pathway can also build on India's emerging 2G ethanol infrastructure. Several public-sector OMC-backed 2G ethanol plants can become backward-integration points for future AtJ production. In parallel, Indian private-sector capability is beginning to emerge: Praj Industries has commissioned a 1 KLPD AtJ demonstration plant in Pune, while TruAlt Bioenergy is planning a 15 KTPD–20 KTPD AtJ facility in Belagavi, using sugarcane ethanol.[91]

However, AtJ SAF will require targeted policy and financial support to become commercially viable. AtJ SAF production is currently three to five times more expensive than conventional jet fuel, with ethanol feedstock alone accounting for 50% to 70% of total production cost.

Production clusters and state-level opportunity

India's SAF clusters are likely to emerge where feedstock availability, refinery infrastructure, airport demand and logistics converge. Early opportunities include:

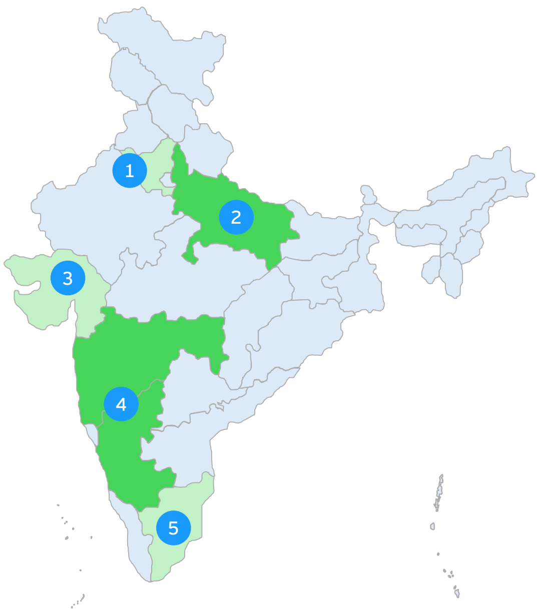


Figure: States with favorable SAF policy/production clusters

1. **Haryana/North India:** Housing the IOCL Panipat refinery, UCO aggregation from urban areas and proximity to Delhi aviation demand.
2. **Uttar Pradesh:** High agricultural residue availability, relevant for 2G ethanol, AtJ and residue-to-FT routes. In 2025, UP announced India's first SAF Manufacturing Promotion Policy 2025 (currently in draft stage), targeting the conversion of sugarcane bagasse, rice husk and wheat straw into bio-jet fuel.[92]
3. **Karnataka and Maharashtra:** Emerging relevance due to UCO collection systems, aviation demand centers and bioenergy ecosystems. Both states have dedicated ethanol blending policies that can support ethanol-linked AtJ SAF.
4. **Gujarat and coastal refinery hubs:** Potential for refinery integration, export logistics and future hydrogen/e-SAF development.
5. **Tamil Nadu:** Strong food-processing, hospitality and industrial bases that can support UCO aggregation and ethanol-linked pathways. Tamil Nadu Ethanol Blending Policy 2023 aims to promote fuel-grade ethanol production, attract INR5,000 crore investment, and meet around 130 crore liters ethanol blending requirement during the policy period.[93]

For investors, the most attractive clusters will be those with secure feedstock catchments, refinery or conversion infrastructure, airport demand, and state-level facilitation for biomass logistics and land acquisition.

Key production challenges

India's SAF production opportunity is significant, but will depend on solving:

1. Feedstock aggregation
2. Technology selection
3. Certification and traceability
4. Cost competitiveness
5. Infrastructure readiness

91 *The opportunity for AtJ SAF in India, 2025, ICF*
92 *First-of-its-kind SAF production policy on the anvil in U.P., 2025; Hindustan Times*
93 *Ethanol blending policy, 2023; TN State Planning Commission*

Policy, regulations and certification

Policy and certification will determine whether India's SAF market becomes a bankable, scalable industry or remains limited to pilot volumes. For investors, the most important policy signals are now visible: India has announced phased SAF blending targets for international flights, amended aviation fuel marketing rules to recognize SAF-blended ATF, built on a strong national biofuel policy base and achieved its first ISCC CORSIA-certified SAF production milestone.

Policy layer	What exists today?	Key impact	What is needed next?	Outcome sought
Demand creation	Indicative SAF blending targets for international flights: 1% (2027), 2% (2028), 5% (2030) aligned with CORSIA obligations.	Creates initial demand visibility and investment signals for SAF producers.	Clear roadmap for domestic aviation, blending mandates and long-term demand trajectory.	Larger, more bankable domestic SAF market.
Fuel regulation	SAF-blended ATF recognized under the ATF Control Order (2026 amendment), enabling marketing, blending and distribution of SAF.	Reduces regulatory uncertainty and provides a legal foundation for SAF deployment.	Detailed operational blending protocols, quality standards and implementation guidelines.	Smooth commercialization and nationwide SAF distribution.
Biofuel policy base	National Policy on Biofuels, Ethanol Blending Programme, National Biofuel Coordination Committee and PM JI-VAN support for advanced biofuels and 2G ethanol projects.	Provides institutional, feedstock and financing foundation for early SAF pathways such as HEFA, co-processing and AtJ.	SAF-specific production incentives, feedstock support mechanisms and dedicated SAF policy framework.	Accelerated deployment of AtJ, FT and future e-SAF pathways.
Certification and compliance	India's first ISCC CORSIA-certified SAF production facility at IOCL Panipat; the CORSIA framework provides an international compliance architecture.	Enables CORSIA eligibility and establishes India's first benchmark for certified SAF production.	Scaled MRV, LCA, traceability and certification ecosystem (ISCC, RSB, CORSIA-ready).	Export-ready, globally compliant SAF supply chains.
Market support and bankability	Ethanol procurement mechanisms, GST concessions, interest subvention schemes, infrastructure support and long-term offtake structures.	Demonstrates how policy support can establish a large-scale biofuel market.	VGF, Contracts for Difference (CfD), concessional finance, capital subsidies, feedstock aggregation incentives and green premium-sharing mechanisms.	Improved project economics and reduced first-mover risk for investors.

Key takeaway

India's SAF policy framework has moved from broad biofuel support to early SAF-specific regulation. The National Policy on Biofuels and the ethanol program provide the institutional base; CORSIA creates the international compliance driver; the ATF Control Order amendment enables SAF blending and marketing, and ISCC CORSIA certification at IndianOil Panipat establishes India's first SAF production benchmark.

Market outlook and investment landscape

India's SAF market is moving from a compliance-led niche to a potential strategic industry. The investment case rests on four factors: fast-growing aviation fuel demand, announced blending targets, abundant domestic feedstock, and a refining/biofuel ecosystem that can be adapted for SAF production.

Demand outlook: From mandated volumes to scalable market

Near-term demand will be driven by India's blending targets for international flights under CORSIA:1% by 2027, 2% by 2028 and 5% by 2030. Based on estimates cited by India's Petroleum Minister, a 1% SAF blend in India could require roughly 0.10 million tons–0.11 million tons per year, while a 5% blend could require around 0.55 million tons–0.56 million tons per year[94], depending on the ATF demand base and whether domestic aviation is included.

Demand could increase substantially if blending requirements are extended to domestic aviation. However, as no domestic mandate has been announced, these projections remain scenario-based rather than policy committed.

Supply outlook: Early capacity, large gap

India's SAF production capacity remains at an early stage and is expected to remain below projected demand in the near term. However, India's estimated 230 million tons of surplus agricultural residues provide a strong feedstock base for future capacity expansion as collection and certification systems mature. Globally, the supply constraint is even more pronounced. IATA's 2025 expected SAF production of less than two million tons remains below 1% of jet fuel demand[95], while long-term SAF demand forecasts run into 10 million tons by 2030 and beyond.

Market size and scenario outlook

India's SAF market can be viewed through three scenarios:

1. **Compliance-led scenario:** SAF adoption remains limited to international flights under CORSIA-linked blending targets. Demand reaches approximately 0.55 million tons–0.56 million tons per year under the 5% international-flight blending target, as outlined in the above sections. This scenario is anchored to India's formally notified blending mandate.
2. **Domestic expansion scenario:** India extends SAF blending to domestic aviation in addition to the existing international mandate. This would expand the demand base significantly beyond the compliance-led scenario. However, no domestic blending mandate has been formally notified, so the scale of this demand will depend on the blending percentage and timeline eventually adopted.
3. **Export-oriented hub scenario:** Beyond meeting domestic and international demand, India's feedstock base and refining capacity could support exports of certified SAF to regulated markets such as the EU, the UK, Japan, Singapore and the Middle East, where blending mandates are tightening and local supply may remain constrained

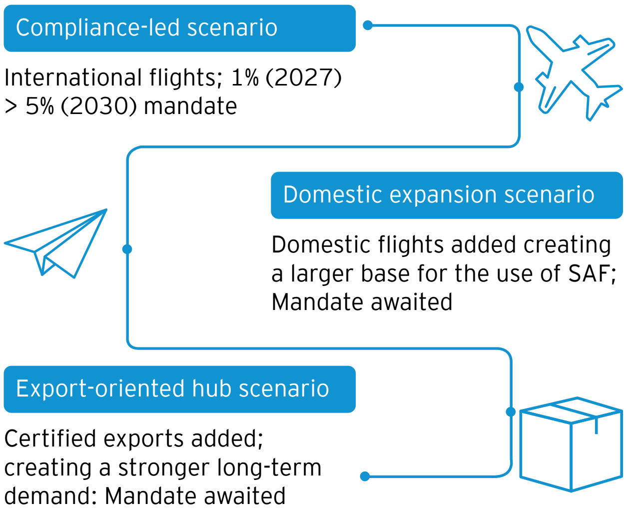


Figure: India's SAF demand scenarios

** Scenarios build cumulatively: each adds a demand layer to the previous. Only Scenario 1 rests on confirmed policy; Scenarios 2 and 3 are directional.*

Investment requirement and capital formation

Scaling SAF will require investment across feedstock supply chains, fuel production facilities, refinery integration, certification systems, logistics networks and airport fueling infrastructure. IATA estimates that achieving aviation's net-zero pathway by 2050 will require between 3,000 and more than 6,500 new renewable fuel plants worldwide[96]. This highlights that SAF is a long-term infrastructure investment theme spanning production assets, feedstock logistics and associated energy infrastructure.

Near-term deployment in India is expected to focus on commercially mature HEFA pathways using UCO and refinery co-processing. Over the medium term, Alcohol-to-Jet (AtJ) is expected to play an important role, while Fischer-Tropsch (FT) and Power-to-Liquid (PtL) pathways are expected to expand in the longer term as technology, feedstock availability and economics improve[97].

94 *Feasibility Study On The Use Of Sustainable Aviation Fuels, 2025; Ministry of Civil Aviation, in partnership with the International Civil Aviation Organization (ICAO)*

95 *Policy Shortcomings Puts SAF Production at Risk, 2025; The International Air Transport Association (IATA)*

96 *IATA Press Release, 2024; The International Air Transport Association (IATA)*

97 *Feasibility Study On The Use Of Sustainable Aviation Fuels, 2025; Ministry of Civil Aviation, in partnership with the International Civil Aviation Organization (ICAO)*

Investor landscape: Who will fund India's SAF scale-up?

Early SAF investments in India are currently being driven by refinery-based initiatives led by oil marketing companies such as IndianOil with its Panipat refinery and its subsequent SAF supply MoU with Air India. In parallel, BPCL and other refiners are pursuing SAF production pathways, including co-processing and alcohol-to-jet technologies.

The first wave of Indian SAF investment is expected to be led by public-sector oil marketing companies, given their refinery assets, ATF distribution networks, and ability to manage regulated fuel markets. Among private-sector participants, Praj Industries has emerged as an early mover in the SAF ecosystem through its Bio-Mobility® platform and indigenous AtJ technology for converting renewable feedstocks into aviation-grade fuel. The company has pioneered SAF production at its R&D center in Pune and is collaborating with industry stakeholders to support the development of the SAF value chain in India[98], including through its partnership with IATA and ISMA to advance carbon assessment and certification frameworks for SAF produced from Indian feedstock[99]. Other participants are also exploring opportunities in sustainable fuels, indicating the potential for broader private-sector participation in the emerging SAF market.

Airlines will play a critical role by providing long-term offtake agreements, supporting green premium mechanisms and driving CORSIA compliance. Globally, Virgin Atlantic's transatlantic SAF flight demonstrated commercial viability[100], while in India, Air India and IndiGo have initiated SAF partnerships and demonstration flights, signaling growing airline commitments.

In India, airlines have also begun supporting SAF adoption. Air India's MoU with IndianOil for the supply of SAF reflects the carrier's commitment to SAF as part of its broader strategy to achieve the IATA Net Zero 2050 target and comply with CORSIA requirements[101]. Similarly, IndiGo has joined the World Economic Forum (WEF)'s Clean Skies for Tomorrow coalition to support the scale-up of SAF and previously operated a flight delivered with a 10% SAF blend[102], signaling broader airline support for the development of a domestic SAF market. Airports also have the potential to become important aggregation points for SAF distribution.

Private equity, infrastructure funds, climate investors, DFIs, MDBs, green-bond investors are likely to participate where projects have long-term offtake, certified technology, feedstock security and policy-backed demand. Interest from private capital is already evident in global SAF markets. For example, Brookfield Asset Management has committed up to US$1.1 billion to Infinium's eSAF platform through its Brookfield Global Transition Fund[103], while Breakthrough Energy Catalyst has also invested in SAF-related projects[104] to accelerate the scale-up of low-carbon aviation fuels. These investments highlight the growing appetite among climate-focused investors for SAF opportunities backed by credible technology, secure feedstock supply and long-term offtake.

However, early projects may still require public support through viability gap funding, concessional debt, tax incentives, production-linked support, or contracts for-difference to bridge the SAF–ATF price gap.

Bankability considerations

The bankability of Indian SAF projects will depend on five factors:

1. **Feedstock security:** Projects must lock in long-term access to UCO, agricultural residues, ethanol, MSW or other certified feedstocks.
2. **Certified technology:** Investors will prefer ASTM-approved pathways such as HEFA, ATI and FT, or technologies with a clear certification pathway.
3. **Offtake certainty:** Long-term contracts with airlines, OMCS or fuel suppliers are essential to reduce revenue risk.
4. **Policy support:** Blending mandates, fiscal incentives, certification support and carbon-credit mechanisms will determine project returns.
5. **Sustainability certification:** CORSIA eligibility, ISCC/RSB certification and chain-of-custody systems will be critical for both domestic compliance and export markets.

The cost gap remains the biggest investment challenge. IATA notes that SAF is still two to five times more expensive than conventional aviation fuel[105]. Without mechanisms to allocate or reduce the green premium, producers may struggle to finance capacity, and airlines may resist voluntary uptake beyond mandated levels.

98 *Annual Report, 2025; Praj Industries*

99 *Praj, IATA, and ISMA Join Forces to Advance SAF Carbon Assessment and Certification in India, 2025; Praj Industries*

100 *Virgin Atlantic flies world's first 100% Sustainable Aviation Fuel flight from London Heathrow to New York JFK, 2023; Virgin Atlantic*

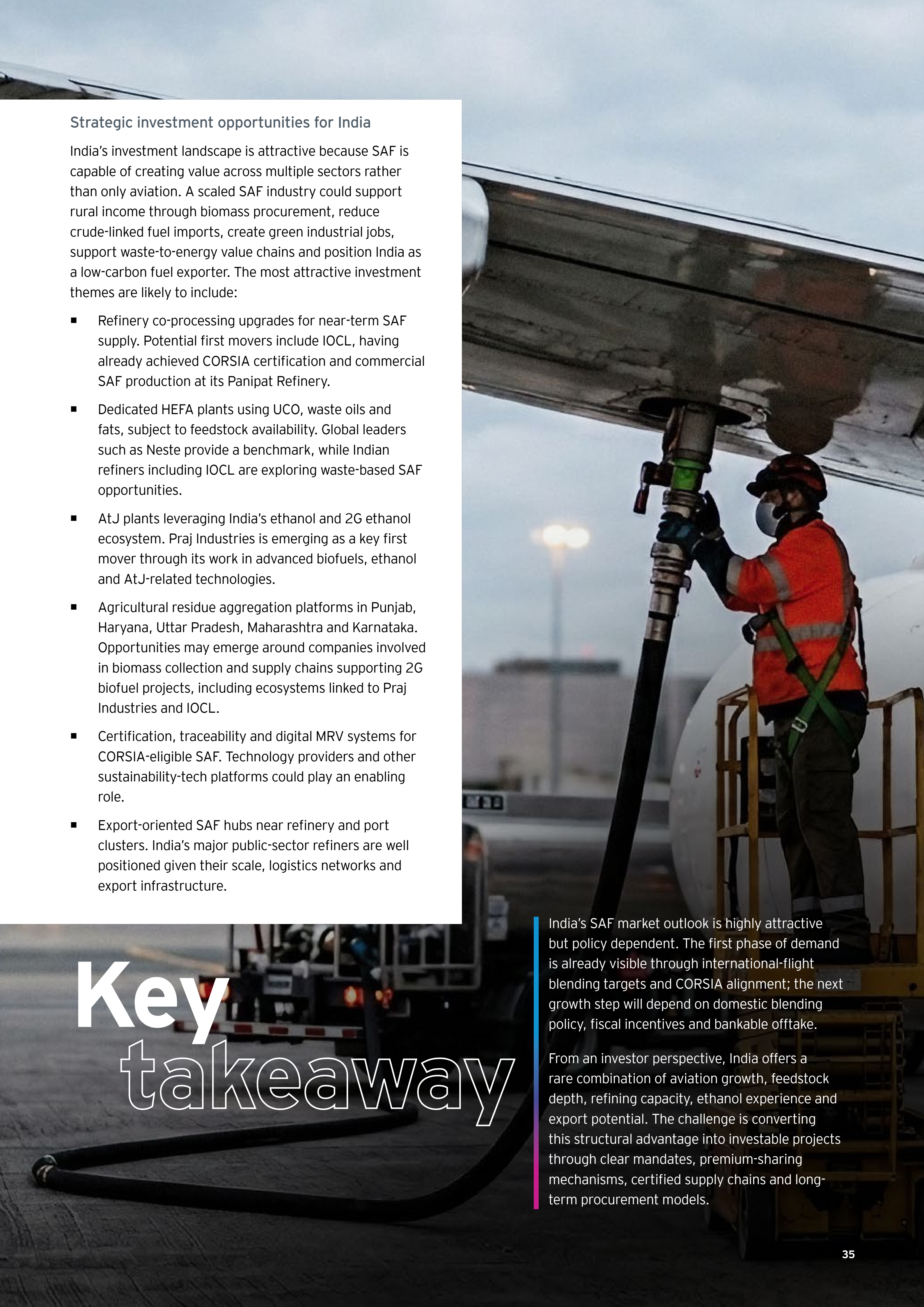
101 *Air India Press Release, 2025; Air India*

102 *IndiGo joins WEF Sustainability Campaign 'Clear Skies for Tomorrow', 2022; Indigo Airlines*

103 *Brookfield to Invest Up to $1.1 Billion in Infinium to Scale Ultra-Low Carbon eFuels, 2024; PR Newswire*

104 *eFuels Leader Infinium Receives $75M Equity Commitment from Breakthrough Energy Catalyst for Investment in Project Roadrunner, 2023; Citigroup*

105 *Why and how to bring down the cost of SAF, 2025; The International Council on Clean Transportation (ICCT)*



Strategic investment opportunities for India

India's investment landscape is attractive because SAF is capable of creating value across multiple sectors rather than only aviation. A scaled SAF industry could support rural income through biomass procurement, reduce crude-linked fuel imports, create green industrial jobs, support waste-to-energy value chains and position India as a low-carbon fuel exporter. The most attractive investment themes are likely to include:

- Refinery co-processing upgrades for near-term SAF supply. Potential first movers include IOCL, having already achieved CORSIA certification and commercial SAF production at its Panipat Refinery.
- Dedicated HEFA plants using UCO, waste oils and fats, subject to feedstock availability. Global leaders such as Neste provide a benchmark, while Indian refiners including IOCL are exploring waste-based SAF opportunities.
- AtJ plants leveraging India's ethanol and 2G ethanol ecosystem. Praj Industries is emerging as a key first mover through its work in advanced biofuels, ethanol and AtJ-related technologies.
- Agricultural residue aggregation platforms in Punjab, Haryana, Uttar Pradesh, Maharashtra and Karnataka. Opportunities may emerge around companies involved in biomass collection and supply chains supporting 2G biofuel projects, including ecosystems linked to Praj Industries and IOCL.
- Certification, traceability and digital MRV systems for CORSIA-eligible SAF. Technology providers and other sustainability-tech platforms could play an enabling role.
- Export-oriented SAF hubs near refinery and port clusters. India's major public-sector refiners are well positioned given their scale, logistics networks and export infrastructure.

Key takeaway

India's SAF market outlook is highly attractive but policy dependent. The first phase of demand is already visible through international-flight blending targets and CORSIA alignment; the next growth step will depend on domestic blending policy, fiscal incentives and bankable offtake.

From an investor perspective, India offers a rare combination of aviation growth, feedstock depth, refining capacity, ethanol experience and export potential. The challenge is converting this structural advantage into investable projects through clear mandates, premium-sharing mechanisms, certified supply chains and long-term procurement models.

Economic and environmental impact

SAF's value proposition for India extends beyond aviation-sector decarbonization. If scaled effectively, it can reduce lifecycle emissions, strengthen energy security, create rural value chains and position India as a supplier to global low-carbon aviation markets. Realizing these benefits will depend on feedstock selection, certification and supportive policy.

Emissions reduction potential

SAF is the aviation sector's primary near-term decarbonization solution as it can be used in existing aircraft and infrastructure as a drop-in fuel. IATA estimates that SAF could contribute up to 65% of the emissions reductions required for aviation to reach net-zero CO emissions by 2050, while lifecycle emissions reductions from SAF are typically around 80% compared with conventional jet fuel[106], depending on feedstock and production pathway.

Beyond reducing lifecycle CO emissions, SAF can also help mitigate certain non-CO climate impacts associated with aviation. Many SAF pathways contain lower concentrations of aromatic and sulphur compounds than conventional jet fuel and generate fewer soot particles during combustion. Studies report that HEFA- and Fischer–Tropsch-based SAF blends reduced soot emission indices by approximately 45% to 53% relative to conventional Jet A 1 fuel. These reductions translated into 45% to 74% lower contrail ice crystal number concentrations, with fuels containing higher hydrogen content and lower naphthalene concentrations delivering the greatest benefits[107]. Fewer ice crystals are associated with larger crystal sizes that sediment and dissipate more rapidly, shortening contrail persistence and reducing their warming effect.

SAF offers a meaningful opportunity to reduce aviation's non-CO climate footprint in addition to its carbon benefits. However, these reductions do not eliminate aviation's total climate impact, and complementary measures such as contrail avoidance strategies, optimized flight routing, and altitude management will remain necessary to achieve deeper climate mitigation.

Lifecycle assessment and sustainability integrity

The environmental value of SAF must be assessed on a life-cycle basis. ICAO's CORSIA methodology calculates SAF emissions in grams of CO-equivalent per megajoule and includes emissions from feedstock cultivation, harvesting, collection, processing, transport, fuel conversion, distribution and combustion. It also accounts for induced land-use change and may include credits for municipal solid waste pathways where landfill avoidance benefits are demonstrable.

This is crucial for India because different SAF feedstocks can produce very different lifecycle outcomes. Waste-based feedstocks such as used cooking oil, agricultural residues and municipal solid waste generally offer stronger sustainability credentials than food-crop-based feedstocks, provided collection, traceability and processing emissions are well managed.

India's strongest lifecycle advantage lies in the use of surplus agricultural residues, used cooking oil and waste streams. These feedstocks can avoid direct food-versus-fuel concerns, reduce crop-residue burning, improve waste management and create monetizable rural supply chains. Studies estimate that India's 230 million tons of surplus agricultural residue[108] can serve as a crucial input for SAF production, particularly through 2G ethanol and AtJ pathways.

However, lifecycle benefits are not automatic. If SAF production relies heavily on irrigated crops, high-carbon electricity, long-distance feedstock transport, or poorly governed land conversion, lifecycle benefits can decline materially. Therefore, India's SAF scale-up must be anchored in robust certification, sustainable feedstock prioritization, digital traceability and CORSIA-compatible lifecycle accounting.

Cost competitiveness and the green premium

The principal challenge for SAF adoption remains its cost premium relative to conventional Aviation Turbine Fuel (ATF). SAF production costs remain higher because of expensive feedstocks, limited production scale, immature conversion pathways, certification requirements and underdeveloped supply-chain infrastructure. Industry estimates indicate that SAF currently costs approximately two to five times more than conventional jet fuel[109], depending on feedstock, production pathway and geography.

From 2027, however, airlines will increasingly face carbon-compliance obligations under Phase II of ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). CORSIA-eligible carbon credit prices are projected to range from approximately US$27 per tCOe – US$91 per tCOe during 2027–2035[110].

In this context, the economic assessment of SAF should not be based solely on its premium over ATF, but also on

106 *Sustainable Aviation Fuel (SAF), 2025; International Air Transport Association*
107 *The non-CO2 climate co-benefit of SAF and other fuels with low aromatic and sulfur content, 2025; International Air Transport Association*

108 *Sustainable Aviation Fuel (SAF) Feasibility Study for India, 2025; Ministry of Civil Aviation, GoI*
109 *Why and how to bring down the cost of SAF, 2025; The International Council on Clean Transportation (ICCT)*
110 *CORSIA: Costs and Implications for the Airline Industry, 2024; MSCI*

its potential to reduce future carbon-compliance costs and exposure to tightening emissions regulations. While low SAF blending rates, such as 1% to 5% still increase fuel costs in the near term, they may partially offset future CORSIA liabilities and position airlines for compliance with emerging sustainable aviation fuel mandates. For Indian airlines, cost competitiveness is particularly sensitive because ATF is a major operating-cost component and the domestic market is price elastic.

From an investor perspective, the cost challenge is not only the per-liter production premium but also the upfront capital cost of building production capacity, which varies significantly by pathway and by plant scale. Applying average per-ton capital cost estimates by pathway, an illustrative 50,000-ton-per annum (500 KTPA) facility indicates the following, noting that smaller facilities typically carry a higher per-ton cost than these averages imply:

Production pathway	CapEx in dollars per metric ton of installed capacity	Average cost for a 50 KTPA SAF facility (US$)
HEFA	US$1,500	US$75 million
AtJ	US$4,300	US$215 million
G-TF	US$7,200	US$360 million
PtL	US$12,700	US$635 million

Table 4: Overview of CapEx requirements for greenfield SAF refinery, by pathway (US$/ton)111

As the table indicates, capital intensity rises steadily from HEFA through Alcohol-to-Jet to the gasification-Fischer-Tropsch and Power-to-Liquid pathways, while HEFA and AtJ represent the most investable near-term options, the higher-CapEx routes will become increasingly relevant as feedstock and technology constraints ease over time.

The near-term policy objective should therefore not be to force cost parity immediately, but to reduce first-mover risk and create a predictable market. Instruments such as viability gap funding, concessional finance, production-linked incentives, carbon markets, GST rationalization, green procurement and long-term offtake agreements can help bridge the gap while production scales.

Socio-economic impact

A domestic SAF industry can create significant socio-economic value for India. Scaling SAF production at the levels envisioned under India's blending roadmap will require substantial capital investment across feedstock aggregation, conversion capacity and supporting infrastructure, and is expected to generate meaningful employment across the value chain. The Ministry of Civil Aviation has stated that scaling SAF production is expected to reduce crude oil imports, cut aviation emissions by 20 million tons–25 million tons annually[112] and boost farmers' incomes by creating a strong value chain for agricultural residue and biomass.

The employment impact would span feedstock collection, aggregation, logistics, storage, pre-treatment, biorefining, certification, testing, distribution and airport fuel operations. Unlike conventional ATF, where value creation is concentrated in crude sourcing and refining, SAF can create distributed economic activity across rural and semi-urban regions, especially in states with high residue availability.

Agriculture-linked SAF can also create a new income stream for farmers. This is particularly relevant for residue-rich regions such as Punjab, Haryana and UP, where biomass aggregation for 2G ethanol and ATJ pathways could support both climate and rural-income objectives.

There are also broader industrial benefits. SAF can strengthen India's bioeconomy, create demand for advanced biofuel technologies, accelerate refinery modernization, support green hydrogen and carbon capture ecosystems over time, and position India as an exporter to markets with binding SAF requirements.

Environmental co-benefits and trade-offs

SAF can support waste management by creating high-value demand for UCO, municipal solid waste and agricultural residues. This can reduce the unsafe reuse of cooking oil, lower the landfill burden and create formal collection networks. Agricultural-residue-based SAF can also help address crop burning over time. However, this requires strong aggregation infrastructure, appropriate residue-removal limits to protect soil health and regional biomass management plans.

Key takeaway

For India, SAF offers a rare combination of climate, economic, rural-development and energy-security benefits. It can reduce lifecycle aviation emissions by up to 80%, cut annual aviation emissions by 20 million tons–25 million tons at scale, reduce crude import dependence, generate new income streams and raise farmer incomes through agricultural residue monetization.

However, these benefits will materialize only if India builds a certified, traceable and cost-competitive SAF ecosystem. The policy priority should be to scale waste- and residue-based pathways first, bridge the green premium through market-support mechanisms and ensure that lifecycle emissions accounting remains rigorous and internationally accepted.

111 *Financing Sustainable Aviation Fuels: Case Studies and Implications for Investment, 2025; World Economic Forum (WEF)*

112 *Sustainable Aviation Fuel (SAF) a practical and immediate solution to decarbonize the aviation sector, 2025; Ministry of Civil Aviation*

Risks, challenges and constraints

India's SAF opportunity is substantial, but the transition from pilot-scale production to a bankable commercial industry will be constrained by feedstock aggregation, production economics, certification complexity, technology maturity and policy certainty. Globally, SAF remains below 1% of aviation fuel use, with IATA noting that production growth is still slow and costs remain 3 to 10 times higher than conventional jet fuel[113].

Pathway	TRL	Status	Rationale[114]
HEFA / HVO SAF	TRL 9	Fully commercial	HEFA is the most mature SAF pathway and dominates current global SAF production.
Alcohol-to-Jet (AtJ)	TRL 8-9	Early commercial / first commercial deployment	AtJ is ASTM-approved and commercially available, but large-scale deployment is still emerging.
Fischer-Tropsch SAF	TRL 7-8 for biomass/ MSW-to-SAF TRL 9 for core FT chemistry	Demonstration to early commercial for SAF from biomass/waste	Fischer-Tropsch synthesis itself is mature, but integrated biomass/ MSW gasification-to-SAF remains less widely commercialized and capital intensive. Some sources classify biomass FT SAF as commercially available, while others place gasification-FT around TRL 6-7. For India-focused residue/MSW FT SAF, TRL 7-8 is a balanced estimate.
e-SAF / PtL SAF	TRL 5-7	Pilot / demonstration, pre-commercial	PtL/e-SAF uses renewable electricity, green hydrogen and captured CO. It is technically proven at pilot/demo scale but not yet commercially mature.

Feedstock availability versus feedstock aggregation

India has strong theoretical feedstock potential, including large volumes of biomass and surplus agricultural residue. The challenge is not availability, but aggregation, quality control, moisture management, transport costs, and competing uses for biomass, ethanol, used cooking oil and municipal waste.

Used cooking oil can support the first wave of HEFA/co-processing projects, but its collection remains fragmented beyond large hotels, restaurants and food businesses. Agricultural residues offer greater long-term potential, but require baling, storage, farmer participation, logistics networks and safeguards to avoid excessive residue removal.

High cost and green premium

SAF remains significantly more expensive than conventional ATF. Industry reports suggest that SAF is currently around 3 to 10 times costlier than standard ATF, while IATA has warned that SAF costs globally can be several times higher than jet fuel.

The green premium is especially important because ATF is one of the largest airline operating costs, accounting for ~40% to 45% of total operating expenses.[115]

Certification and traceability complexity

SAF must satisfy both technical fuel standards and sustainability certification requirements. ASTM standards govern technical approval and blending limits, while CORSIA eligibility requires lifecycle carbon accounting and certification through approved sustainability schemes. India's first ISCC CORSIA certification at IndianOil's Panipat refinery is a major milestone, but scaling this across multiple producers and feedstock chains will be complex.

Infrastructure and logistics constraints

SAF is a drop-in fuel once certified and blended, but the upstream supply chain differs significantly from that of conventional ATF. India will need infrastructure for feedstock collection, pre-treatment, storage, blending, certification, airport supply and sustainability-claim tracking.

Key risks

Risk	Key constraint	Investor impact
Technology	HEFA mature; AtJ/FT/e-SAF need scale-up	Technology choice affects capex, certification and financing.
Feedstock	Fragmented UCO and residue supply chains	Need long-term feedstock contracts and aggregation platforms.
Cost	SAF remains 2x-5x ATF	Requires incentives, mandates and premium-sharing.
Certification	CORSIA eligibility requires robust LCA and traceability	Certification capability becomes a bankability requirement.
Infrastructure	Need blending, storage, MRV and book-and-claim systems	Requires coordinated investment across OMCs, airports and airlines.

113 IATA Fact Sheet, 2026
114 Feasibility study on the use of sustainable aviation fuels, 2025; ICAO
115 Ministry of Civil Aviation, 2025; Rajya Sabha

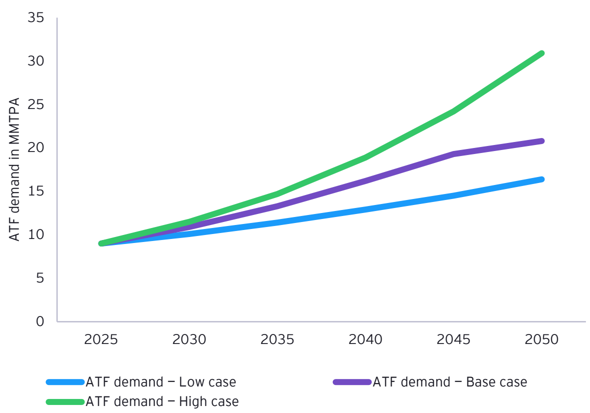
Future outlook and strategic roadmap

India's SAF opportunity is entering a decisive execution phase. The country has already established the basic demand signal through SAF blending targets for international flights—1% by 2027, 2% by 2028 and 5% by 2030—and has taken an enabling regulatory step by bringing SAF-blended aviation fuel under the ATF Control Order. The next phase must shift from feasibility and pilot production to a coordinated national scale-up program that aligns feedstock, technology, finance, certification, airline offtake and refinery integration.

Strategic outlook: India as a regional SAF hub

India is well placed to become a regional SAF production hub because it combines fast-growing aviation demand, significant biomass availability, an expanding ethanol ecosystem, substantial refinery capacity and proximity to high-demand aviation markets in the Middle East, Europe and Asia-Pacific.

Estimated ATF demand in India (2025-50)



In the near term, demand will be compliance-led, focused on international flights under CORSIA-linked obligations. Over the medium term, the market could expand significantly if domestic aviation is included in SAF mandates and if India develops export-grade, CORSIA-eligible SAF for regulated markets such as the EU, the UK, Japan and Singapore.

Recommended roadmap for 2026–2035

India should adopt a phased SAF roadmap that balances near-term feasibility with long-term technology diversification.

2026-2028	2028-2030	2030-2035
Phase 1	Phase 2	Phase 3
Market activation and compliance readiness	Domestic scale-up and pathway diversification	Export-oriented growth and advanced SAF

Strategic recommendations

1. Create a National SAF Mission
2. Prioritize waste and residue-based feedstocks
3. Bankable demand through offtake contracts
4. Bridge the green premium
5. Develop certification and MRV infrastructure
6. Develop certification and MRV infrastructure

Conclusion

India's SAF opportunity is no longer speculative. The country has announced blending targets, completed a national SAF feasibility study, certified its first SAF producer, and attracted growing industry attention around ethanol-, residue- and refinery-led pathways.

The next decade will determine whether India becomes merely a SAF consumer or a competitive SAF producer and exporter. A coordinated roadmap—anchored in mandates, incentives, certification, feedstock aggregation and long-term offtake agreements—can convert India's biomass and refining strengths into a scalable green aviation fuel industry. If executed well, SAF can become a strategic pillar of India's aviation decarbonization, rural bioeconomy, fuel security and clean energy export ambitions.

SECTION THREE

Biomass briquettes and pellets

Decarbonizing industry and power generation

3

Executive Summary

India's biomass pellet industry has emerged as a substantial clean energy ecosystem in a remarkably short span of time. Pellet manufacturing plants have been established across the country, each with an average production capacity of 80 MT/day and operating for approximately 250 days per year. At current utilisation rates of 63%, these plants collectively produce 12.6 MMT of pellets annually, requiring the aggregation of 14.6 MMT of biomass feedstock from the surrounding rural landscape.

The capital mobilised to build this sector is substantial. Each plant carries a term loan of 4 crore and a working capital requirement of 7 crore, translating to a total sectoral investment of 11,165 crore, financed predominantly by MSMEs, first-generation entrepreneurs, and farmer-linked enterprises. If India were to achieve a 5% replacement of coal consumption with biomass, this industry could scale to 3,500 plants, requiring a total investment of 38,500 crore, producing 43.7 MMT of pellets annually

The sector sits at the convergence of three national priorities: energy security (substituting coal with domestic biomass), agricultural sustainability (eliminating stubble burning and creating a market for crop residue), and rural livelihoods (employment for plant workers and aggregators). Yet the industry is at a critical inflection point. Policy uncertainty around the Minimum Benchmark Pricing (MBP) mechanism and inconsistent offtake by Thermal Power Plants (TPPs) threaten to convert this green capital base into stressed assets.

Industry Snapshot: Installed Base & Investment

Particulars	Per Plant	National Total (1,015 Plants)
Particulars	Per Plant	National Total (1,015 Plants)
Average Installed Capacity	80 MT/day	–
Operating Days per Year	250 days	–
Installed Annual Capacity	20,000 MT	2.20 crore MT (22.0 MMT)
Current Capacity Utilisation	~63%	~63%
Biomass Aggregation (installed basis)	23,000 MT	2.53 crore MT (25.3 MMT)
Biomass Feedstock Aggregated (actual)	–	15.94 MMT
Capital Investment (Term Loan)	4 crore	4,400 crore
Working Capital	7 crore	7,700 crore
Total Investment	11 crore	12100 crore

Farmer Impact & Rural Income Generation

Farmer Coverage & Biomass Collection

Particular	Assumption / Basis	Value
Average Land Holding	Rural India average	2 acres
Biomass Generated	Crop residue availability	2 MT/acre (4 MT/farmer)
Surplus Biomass Available	Collectable biomass share	50% (2 MT/farmer)
Farmers Connected per Plant	23,000 MT ÷ 2 MT/farmer	11,500 farmers

Additional Income for an Average Farmer (2 Acres)

Particular	Formula	Amount
Field Cleaning Cost Saving	700 per labour × 2 acres × 2 seasons	2,800
Biomass Generated	2 MT × 2 acres	4 MT
Biomass Sale Income	4 MT × 1,000/MT	4,000

National Level Farmer Benefit

Particular	Formula	Value
Farmers Benefitted (installed-capacity basis)	11,500 × 1,100 plants	1.27 crore (12,650,000)
Benefit per Farmer	Fixed	6,800/year
Total Farmer Income Generated	1.27 crore × 6,800	8,602 crore/year

Rural Employment & Entrepreneurship

Category	Per Plant	Number of Plants	National Total
Plant Workers (direct)	20	1,100	22,000
Aggregators & Transport (indirect)	50-85	1,100	55,000 - 93,500
Total Rural Livelihoods	70-105	1,100	77,000 (current) - 1,15,500 (installed-capacity basis)
Family Members Impacted	4 per family	–	4,62,000 (installed-capacity basis)

Energy Security & Coal Replacement Potential

Energy Generation Potential (Installed-Capacity Basis)

Particular	Formula / Basis	National Impact
Pellet Production	Industry output (installed capacity)	2.20 crore MT (22.0 MMT)
Electricity Generation Potential	1.25 kg pellet = 1 unit	17.60 billion units (17.60 BU)
Continuous Power Equivalent	Electricity conversion	2.01 GW
Green Steam Generation Potential	1 kg pellet = 4 kg steam	88.0 MMT/year

Co-firing Programme Status (as of 31 March 2026)

Particular	Formula
Indicator	Status
TPPs with co-firing commenced	75 plants nationwide
Cumulative biomass co-fired (national)	51.83 lakh MT (5.183 MMT)
Electricity generated from co-fired biomass	6,533 million units (MU)
CO Emission Avoided through co-firing (national)	62.2 lakh MT CO2 (6.22 MMT)
NCR-region biomass co-fired	37.45 lakh MT (3.745 MMT)
NCR-region electricity generated	4,721 million units (MU)
NCR-region CO saved	44.94 lakh MT CO2 (4.494 MMT)
Ministry of Power co-firing mandate	5% mandatory biomass co-firing for eligible thermal power plants (TPPs) (implementation ongoing)

Scale-Up Potential: 5% Coal Replacement Scenario

The industry submission frames its growth potential against a single, clearly defined national scenario. If India were to achieve a 5% replacement of coal consumption with biomass pellets, the sector could scale roughly 3.4x from its current installed base.

Particular	Current (1,015 Plants)	5% Coal-Replacement Scenario
Number of Plants	1,100	3,500
Total Investment	12,100 crore	38,500 crore
Annual Pellet Production (installed)	2.20 crore MT (22.0 MMT)	43.7 MMT
Cumulative Inflow to Rural Economy	–	Over 1.25 lakh crore

Consolidated National Impact: Master Numbers

Key Indicator	Value
Biomass Pellet Plants Installed	1,100
Total Sector Investment	12,100 crore
Installed Pellet Production Capacity	2.20 crore MT/year (20.3 MMT)
Actual Pellet Production (~63% utilisation)	13.86 MMT/year
Biomass Aggregation Capacity (installed)	2.53 crore MT (25.3 MMT)
Biomass Feedstock Aggregated (actual)	15.94 MMT
Farmers Benefitted (installed-capacity basis)	1.27 crore (12.65 million)
Farmer Benefit Generated (installed-capacity basis)	8,602 crore/year (12,650,000 farmers × 6,800)
Rural Livelihoods Supported	77,000 (current) - 1.16 lakh (installed-capacity basis)
Area Protected from Stubble Burning	15.94 million acres (current) / 2.53 crore acres (installed-capacity basis)
Electricity Generation Potential	17.6 billion units/year
Green Steam Generation Potential	88.0 MMT/year
Co-firing TPPs Active (as of 31 Mar 2026)	75 plants; 51.83 lakh MT cumulative co-fired; 6,533 MU generated; 62.2 lakh MT CO saved
5% Coal-Replacement Scale-Up Scenario	3,500 plants; 38,500 crore investment; 43.7 MMT pellets/year; over 1.25 lakh crore to rural economy

Conclusion

1. India's biomass pellet industry has shown, in barely a decade, that a decentralized farmer-linked clean energy model can be built at a national scale without relying on large corporate capital.
2. With over 1,100 plants operational, roughly INR12,100 [SS1.1][DJ1.2]crore already invested and close to 80 lakh farmers currently benefiting from a new market for crop residue, the sector has become one of India's more effective vehicles for delivering energy security, agricultural sustainability and rural income generation simultaneously.
3. The industry converts an environmental liability (stubble burning) into a revenue stream for smallholder farmers, while also displacing coal in thermal power generation. This is a rare instance of policy intent translating into measurable ground-level impact.
4. The current trajectory should not be mistaken for stability. The sector operates at roughly 63% capacity utilization, and the gap between installed potential and actual output stems from demand-side uncertainty, particularly inconsistent offtake commitments from Thermal Power Plants (TPP) and the unresolved status of the Minimum Benchmark Pricing (MBP) mechanism.
5. Because the industry is capitalized predominantly by MSMEs and first-generation entrepreneurs operating on thin margins, this uncertainty does not merely suppress growth. It actively risks converting productive green assets into stressed ones, with wider consequences for rural lenders, aggregators and the farmers who now depend on this income stream.
6. The 5% coal replacement scenario illustrates the scale of opportunity being left on the table: roughly a 3.4-fold expansion of the plant base, over INR38,500 crore of fresh investment, and more than INR1.25 lakh crore in cumulative inflow to the rural economy.
7. Realizing this potential is less a question of technology or feedstock availability, both of which are largely proven and more a question of policy certainty. A stable, predictable MBP framework and enforceable co-firing offtake obligations for TPPs would do more to unlock this scale-up than any new incentive scheme.
8. In summary, the biomass pellet sector sits at an inflection point where the cost of inaction is not stagnation but reversal, the erosion of green capital already deployed. Consistent policy signaling on pricing and offtake is the single most important lever available to convert an early-stage success story into a durable pillar of India's clean energy and rural development agenda.

Abbreviations

Ethanol

Abbreviation	Full form
AtJ	Alcohol-to-Jet
BIS	Bureau of Indian Standards
BPCL	Bharat Petroleum Corporation Limited
CCEA	Cabinet Committee on Economic Affairs
CEEW	Council on Energy, Environment and Water
CI	Carbon Intensity
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
DDGS	Distillers Dried Grains with Solubles
DFPD	Department of Food and Public Distribution
DGFT	Directorate General of Foreign Trade
DHA	Docosahexaenoic Acid
E10	10% Ethanol Blended Petrol
E20	20% Ethanol Blended Petrol
E22	22% Ethanol Blended Petrol
E25	25% Ethanol Blended Petrol
E27	27% Ethanol Blended Petrol
E30	30% Ethanol Blended Petrol
E85	85% Ethanol Fuel Blend
E100	100% Ethanol Fuel Blend
EBP	Ethanol Blended Petrol Programme
EISS	Ethanol Interest Subvention Scheme
EPCM	Engineering, Procurement and Construction Management
ESY	Ethanol Supply Year
EV	Electric Vehicle
FCI	Food Corporation of India
FDI	Foreign Direct Investment
FY	Financial Year
GHG	Greenhouse Gas
GST	Goods and Services Tax
HPCL	Hindustan Petroleum Corporation Limited
IOCL	Indian Oil Corporation Limited
KLPD	Kilo Liters Per Day
KMS	Kharif Marketing Season
LTOA	Long-Term Offtake Agreement
MMT	Million Metric Tons
MoPNG	Ministry of Petroleum and Natural Gas
MSP	Minimum Support Price
MSW	Municipal Solid Waste
NITI	National Institution for Transforming India
NPB	National Policy on Biofuels
NRL	Numaligarh Refinery Limited
OMC	Oil Marketing Company
PPAC	Petroleum Planning and Analysis Cell
PM-JI-VAN	Pradhan Mantri JI-VAN Yojana
PSU	Public Sector Undertaking
RON	Research Octane Number
SAF	Sustainable Aviation Fuel
SAM	Serviceable Addressable Market
SGST	State Goods and Services Tax
TAM	Total Addressable Market
VGF	Viability Gap Funding
1G	First-generation biofuel/ethanol
2G	Second-generation biofuel/ethanol
3G	Third-generation biofuel
4G	Fourth-generation biofuel

Sustainable Aviation Fuel (SAF)

Abbreviation	Full form
AAI	Airports Authority of India
ACI	Airports Council International
ACT-SAF	Assistance, Capacity-building and Training for Sustainable Aviation Fuels
ATF	Aviation Turbine Fuel
AtJ	Alcohol-to-Jet
BIS	Bureau of Indian Standards
BPCL	Bharat Petroleum Corporation Limited
CAPEX	Capital Expenditure
CBG	Compressed Biogas
CEF	CORSIA Eligible Fuel
CHT	Centre for High Technology
CO	Carbon Dioxide
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
DGCA	Directorate General of Civil Aviation
EASA	European Union Aviation Safety Agency
EBP	Ethanol Blended Petrol
EPA	Ethanol Purchase Agreement
ESY	Ethanol Supply Year
ETS	Emissions Trading System
EU	European Union
FICCI	Federation of Indian Chambers of Commerce and Industry

Abbreviation	Full form
FOGs	Fats, Oils and Greases
FSSAI	Food Safety and Standards Authority of India
FT	Fischer-Tropsch
GH	Green Hydrogen
GoI	Government of India
GST	Goods and Services Tax
HEFA	Hydroprocessed Esters and Fatty Acids
HPCL	Hindustan Petroleum Corporation Limited
HVO	Hydrotreated Vegetable Oil
IATA	International Air Transport Association
IBETE	India Bioenergy and Technology Expo
ICAO	International Civil Aviation Organization
IOCL	Indian Oil Corporation Limited
IS	Indian Standard
ISCC	International Sustainability and Carbon Certification
JI-VAN	Jaiv Indhan–Vatavaran Anukool Fasal Awashesh Nivaran
KLPD	Kiloliters per Day
KTPA	Thousand Tons Per Annum
LCA	Life-Cycle Analysis
LCOE	Levelized Cost of Energy
LCOH	Levelized Cost of Hydrogen
LTAG	Long-Term Aspirational Goal
ML	Million Liters
MMT	Million Metric Tons
MMTPA	Million Metric Tons Per Annum
MNRE	Ministry of New and Renewable Energy
MoCA	Ministry of Civil Aviation
MoPNG	Ministry of Petroleum and Natural Gas
MRV	Monitoring, Reporting and Verification
MSW	Municipal Solid Waste
MT	Million Tons / Metric Tons, depending on context
MTPA	Million Tons Per Annum
NBCC	National Biofuel Coordination Committee
NDC	Nationally Determined Contribution
NFP	Non-Food Production
OMC	Oil Marketing Company
PE	Private Equity
PIB	Press Information Bureau
PM JI-VAN	Pradhan Mantri Jaiv Indhan–Vatavaran Anukool Fasal Awashesh Nivaran Yojana

Abbreviation	Full form
PPAC	Petroleum Planning and Analysis Cell
PtL	Power-to-Liquid
R&D	Research and Development
RSB	Roundtable on Sustainable Biomaterials
RUCO	Repurpose Used Cooking Oil
SAC	Scientific Advisory Committee
SAF	Sustainable Aviation Fuel
SAFc	Sustainable Aviation Fuel Certificate
SAF-SPK	Sustainable Aviation Fuel–Synthesized Paraffinic Kerosene
SIP	Synthesized Iso-Paraffins
SPK	Synthesized Paraffinic Kerosene
TAM	Total Addressable Market
TRL	Technology Readiness Level
UCO	Used Cooking Oil
UK	United Kingdom
US / USA	United States / United States of America
USD	United States Dollar
VAT	Value Added Tax
VC	Venture Capital
VGF	Viability Gap Funding

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India's biomass pellet industry

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