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Report Highlights:

FAS New Delhi expects India's ethanol production for 2024 to reach 6.35 billion liters (BL), a two percent drop from last year due to a projected decline in sugarcane production and a depleting rice grain supply. Total ethanol consumption is expected to rise to 7.1 BL out of which ethanol for fuel consumption is estimated at 6.2 BL. This estimate accounts for India's restrictions on sugar feedstocks and broken rice for fuel ethanol to avoid inflationary food prices, amidst a low sugar production year. India is expected to have a feedstock shortage and the ethanol blending rate for 2024 is expected to drop to 11.5 percent. In April 2023, India initially reached its current ethanol blending target of E-12 but will be hard pressed to reach E-20 by 2025. India also continues to aim for a 5 percent biodiesel blend for on-road use by 2030. Post projects Indian biodiesel production at 226 million liters due to government initiatives, under a 1 percent blend rate.

I. Executive Summary

In 2024, India is estimated to maintain an average ethanol blending rate of approximately 11.5 percent. Previously, India achieved its Ethanol Blending with Petrol Program (EBP) target of E-12 in April 2023 for the Ethanol Supply Year (ESY) (December-November) 2022/2023. As such, post revised its 2023 ethanol blending rate with petroleum estimate upward to 12 percent due to increased use of sugarcane syrup, B-heavy molasses, damaged food grains, and surplus rice available from the Food Corporation of India (FCI). Post forecasts ethanol supplies for the EBP to increase by the end of the current ESY 2023/2024 but expects the average blend rate will still be below the E-20 national target for 2025. This is owing to the ongoing shortage in major ethanol feedstocks due to adverse weather conditions. In 2024, imported ethanol will continue to backfill India's unmet demand within the industrial, alcoholic beverage, and medicinal grade industries.

For a decade, India has been one of the world's top producers of sugarcane, along with Brazil. This resulted in surplus stock which facilitated the EBP program by diverting the excess sugar production to fuel ethanol. India's EBP is unique with yearly targets to achieve its ethanol blending rate. India also operationalized a stable and more effective pricing system under the EBP program recently to ensure an appropriate flow of various feedstocks. This helped the country to reach its yearly target for 2023. However, since last year, sugarcane production started declining. For the current year, sugar production is estimated to decrease by 8 percent due to late rainfall and pest infestations in major sugarcane-producing regions.

India's priority on ethanol and achieving E-20 by 2025 has limited sugar exports. In response to two consecutively low sugarcane production years, India initially imposed a restriction on sugar exports from June 1 to October 31, 2022. Subsequently, India amended this restriction to be effective for an indefinite period (See: India Restricts Sugar Exports Beyond October 31 for Indefinite Period). For the current sugar Marketing Year (MY) (October - September) 2023/2024, to mitigate inflationary pressure on domestic consumption, the government has limited the use of sugarcane and its derivatives for ethanol production to 2.37 MMT. The one exception is for C-heavy molasses, which has a sugar recovery rate that is comparatively smaller than the other two derivatives, sugarcane juice and B-heavy molasses.

Similarly, rice production is also expected to be 2 percent lower than the previous year due to water stress. As such, India banned the use of broken rice for ethanol production due to the depleted food grain stock. The availability of these two major fuel ethanol feedstocks is expected to decrease by approximately 20 percent for the current year, compared to the previous year. Incidentally, the government is taking initiatives to increase the maize/corn production in India for fuel ethanol by offering a Minimum Support Price (MSP) for procurement. The approach is expected to increase maize/corn procurement for fuel ethanol and increase production in 2024/2025. India's policies have attempted to augment domestic production, by continuing the prohibition of imported ethanol for fuel blending along with the aforementioned actions.

The Indian government has made commendable improvements by offering financial assistance and grants for setting up multi-feedstock and grain-based distillery units. In December 2023, The Ministry of Consumer Affairs, Food, and Public Distribution announced that India's ethanol

production capacity reached 13.8 billion liters per year in November 2023.[1] Despite this significant increase in distillation capacity, post ascertains that India may not be able to reach a 20 percent national blend rate by ESY 2025 with its current policies. Specifically, the government's ban on ethanol imports in gasoline blending and the lack of sufficient feedstocks may prevent India from achieving its goal. According to the government, in order to achieve the target of 20% blending by 2025, India needs about 10.2 billion liters of ethanol for fuel blending and a total of 13.5 billion for all uses. For this, India requires 17 billion liters in ethanol production capacity to be in place by 2025 considering most plants operate at 80% efficiency. This would require an additional 7 million hectares (MHa) of crop area.[2] As of April 2024, with only approximately 2.11 BL of ethanol contracted for the current ESY against the 8.25 BL required for blending by Oil Marketing Companies (OMCs), the shortfall remains significant, posing challenges to achieve E20 by 2025/2026. This decrease is nearly 58% compared to the corresponding period of the previous ESY.

At the same time, India's ban on sugar exports and its restrictions on sugar to ethanol could increase its sugar ending stock. According to FAS sources, India's sugar stocks has already reached 8 MMT in April for the current MY. Post estimated 10.5 MMT for India's ending sugar stock for the current MY (See: India: Sugar Annual). India's continued sugar export ban and a comparatively lower sugar price could increase the sugar to ethanol diversion after September 2024. This could lead to a rise in the procurement of sugarcane feedstocks and help India reach its 2024 E-15 target by the end of the current ESY.

On June 11, 2024, following the results of India's 2024 national election and the selection of the new cabinet, Minister Hardeep Puri of the Ministry of Petroleum and Natural Gas (MoPNG) announced that India achieved its ESY 2023/2024 target, a 15 percent ethanol blending rate in its nationwide gasoline pool for the month of May 2024. Additional reporting by India's Petroleum Planning & Analysis Cell (PPAC),[3] as well as prominent India news outlets further supported this update. Based on FAS analysis and industry sources, FAS New Delhi estimates India's current ethanol blending rate for the ESY 2023/2024 lower than the 15 percent target and PPAC's 12.6 percent cumulative ethanol blending rate for the November-May period. However, post estimates do not preclude the possibility of India achieving the 15 percent target by the end of the current ESY.

Turning to India's biodiesel program, its blending target of 5 percent for on-road use by 2030 has remained unchanged. The national average blend rate is forecasted at 0.16 percent for 2024, slightly higher than in 2023 but no different from the estimate for 2019. Post forecasts that India will produce approximately 226 million liters (ML) of biodiesel in the forecast year, up from 200 ML in 2023. Due to government incentives and interventions, Post estimates consumption slightly upward to 220 ML in 2024. Non-edible industrial oils, Used Cooking Oil (UCO), animal fats, and tallows are essential feedstocks for biodiesel production. However, their availability can be inconsistent, leading to intermittent production cycles. The Food Safety and Standards

[1] India's Press Information Bureau (PIB) on December 20, 2023: https://pib.gov.in/PressReleasePage.aspx?PRID=1988727#:~:text=2023%2C%20the%20ethanol%20production%20capacity,crore%20litres%20is%20grain%20based.
[2] NITI Aayog
[3] Snapshot of India's Oil and Gas Data- Monthly Ready Reckoner: https://ppac.gov.in/download.php?file=whatsnew/1718425099_Final-Sprial-Book.pdf

Authority of India (FSSAI) launched Repurpose Used Cooking Oil (RUCO) initiative in 2018 to prevent cooking oil reuse and convert it into biofuel but this initiative has yet to produce any meaningful results.

India has other programs underway that have longer-term potential to meaningfully change growth rates of fuel pools and thus longer-term market opportunity for biofuel use in land, marine and air transport. The Indian government is promoting domestic manufacturing of Flex-Fuel Vehicles (FFVs) and Electric Vehicles (EVs) through the "Make in India" initiative, aiming to enhance the automotive industry as well as address environmental and human health risk. India's policies and incentives contributed to a 6 percent surge in EV registration in India during the Indian Fiscal Year (IFY) 2023/2024, compared to the previous year.

Simultaneously, the Indian government has allocated $72.2 million for the National Green Hydrogen Mission in the Union Budget 2024/2025, a 100 percent increase from the previous year's budget of $30 million. Furthermore, the National Biofuel Coordination Committee (NBCC) has set targets for blended Sustainable Aviation Fuel (SAF) in India, with a target of 1 percent by 2025 and 5 percent by 2030 for domestic flights. SAF output is expected to be 1.87 BL in 2024, accounting for 3 percent of all renewable fuels.

The EBP helped reduce gasoline use during ESY 2022/2023, with Oil Marketing Companies (OMCs) saving about 5.09 billion liters. This program lowered India's reliance on foreign exchange and reportedly reduced carbon emissions by 10.8 million metric tons. These accomplishments highlight that India's biofuel programs are encouraging sustainable energy practices and moving the country toward a greener, more resilient energy landscape. Finally, of note, in September 2023, India and the U.S. launched the Global Biofuels Alliance, which aims to support the global adoption of cleaner, greener fuels globally to support decarbonization goals.

II. Policy and Programs

India's 2018 National Policy on Biofuels was a significant step towards promoting the production and use of biofuels in the country.[4] The policy aimed to reduce India's dependency on fossil fuels, promote sustainable development, and address environmental concerns. It established the framework that is still relevant today, leading to an upward trajectory for the fuel ethanol industry and market after a long history of policies that failed to advance the sector. Under the current framework, the Ethanol Blending with Petrol Program (EBP) in India has been instrumental in boosting ethanol production from various feedstocks like sugarcane juice, B-heavy molasses, C-heavy molasses, broken rice, damaged grains, and maize. In contrast, India's biodiesel policies have failed to advance its goals.

In the 2018 National Biofuels Policy, the Indian government lays out its targets for ethanol blend rates in gasoline. The aim is to significantly increase the use of ethanol as a renewable fuel source. In 2023, India reached its highest level with a national 12 percent blending rate. Previously it reached E-10 in June 2022 for the 2022/2023 year. Looking ahead, India aims to reach 15 percent in 2023/2024, and is targeting 20 percent (E-20) by 2024/2025. To achieve these targets, the government is focusing on the following four areas:

[4] Ministry of Petroleum and Natural Gas

1. Increasing Domestic Production: The emphasis is on boosting domestic production of ethanol from diverse feedstocks. This includes first-generation (1G), second-generation (2G), and third-generation (3G) biofuels, which utilize different raw materials and conversion processes to produce ethanol. The Cabinet Committee of Economic Affairs (CCEA) approved the Indian government's initiative Pradhan Mantri JI-VAkN Yojana which aims at accelerating the development of 2G ethanol capacity in India, and provide viability gap funding to support the establishment of 2G ethanol projects. Excluding union territories, OMCs are responsible for nationwide blending ethanol into gasoline.

Relatedly, India's amendment to the Sugarcane Control Order in May 2021, marked a significant shift in policy that helped to boost domestic production.[5] It allows for the development of independent ethanol manufacturing plants. The amendment restricts procurement from informal sources to ensure quality control and standardization in the ethanol production processes.[6] It also regulates the sugar and ethanol industries to ensure fair practices, consumer protection, and compliance with government policies. Additionally, India's financial assistance program to sugar mills for ethanol production increased by 12 percent in the Indian Fiscal Year (IFY) 2024/2025, compared to IFY 2023/2024 (Table 1).

Table 1. Indian Government Budget Allocation-Sugar Industry (USD million/INR billion)

Allocation	**IFY 2022/2023**	**IFY 2023/2024**		**2024/2025**	**% Change**
	Realized Outlays	**Initial Budget**	**Revised Budget**	**Budget**	
Scheme for extending financial assistance to sugar mills to enhance and augment ethanol production capacity	$21 million (INR 1.75 billion)	$48 million (INR 4 billion)	$48 million (INR 4 billion)	$54 million (INR 4.5 billion)	12.5

Note: Percent change depicted for IFY 2024/2025 with initial budget estimate over the IFY 2023/2024 revised budget estimate.
Source: Notes on Demands for Grants, 2024-2025, Department of Food and Public Distribution.

2. **Diverse Application of Feedstocks:** Under the 2018 National Biofuel Policy, EBP encourages using different feedstocks like molasses, broken rice, damaged food grains, and corn/maize for ethanol production. To meet E-20 by ESY 2024/2025, the Indian government actively persuaded sugar-mills and distilleries to divert excess sugar to ethanol. This worked when India had an ample sugarcane production during the past six years.

In February 2024, the Cabinet Committee on Economic Affairs updated its Fair and Remunerative Price (FRP) for sugarcane for MY 2024/2025 from $3.79/quintal (INR 315/quintal)[7] to $4.09/quintal (INR 340/quintal), based on a recovery rate of 10.25 percent. The

[5] Ministry of Consumer Affairs
[6] *Khandsari* is a local type of low-recovery sugar prepared by open-pan evaporation.
[7] For the purpose of this report, 1 United States Dollar (USD/$) is equal to INR 83.

revised FRP is to be implemented on October 1, 2024, Marketing Year (MY) 2024/2025, which is 8 percent higher than the current year 2023/2024.[8]

However, due to a low sugar production this year, the Indian government has put 2.37 MMT limit on the use of sugarcane and its derivatives for ethanol production and continued the sugar export ban to correct the domestic sugar market. Initially the restriction was set at 1.7MMT, but in April, due to an excess production of B-heavy molasses, the Indian government allowed an additional diversion of 0.67 MMT of B-heavy molasses for ethanol production. Furthermore, FCI stopped supplying broken rice for ethanol in response to higher market prices due to the lower rice production for the current MY. As a result, OMCs increased procurement prices of damaged food grains and maize to attract more use for ethanol production.

3. Regulated Supply Chains with Effective Tender Pricing: One of the key objectives of this initiative is to prevent the diversion of ethanol produced by mills for localized purchasing. Through long-term agreements with OMCs, these entities can secure fixed rates for their ethanol, providing them with financial stability and predictability. Additionally, the program aims to address logistical challenges by providing secure transportation options for ethanol and ensuring timely payments to ethanol suppliers. This helps to streamline the supply chain and facilitate the smooth flow of ethanol from producers to OMCs. As per the policy and key to its success, procurement prices have increased over time, reflecting the government's commitment to more effectively incentivize ethanol production (**Table 2**).

Table 2: India: Ethanol Price by Feedstock for ESY 2021/22 and ESY 2022/23 (INR/Liter)

Feedstock	ESY 2021/22	ESY 2022/23	ESY 2023/24
Sugarcane Juice/Sugar Syrup/Sugar	63.45	65.61	65.61
B-Heavy Molasses	59.08	60.73	60.73
C-Heavy Molasses	46.66	49.41	56.28
Damaged Food Grains/Maize	51.55	55.54	71.86
Surplus Rice (from Food Corporation of India)	56.87	58.50	58.50

Source: Ministry of Petroleum and Natural Gas Note: B-heavy molasses, sugarcane juice and damaged food grains were allowed only from ESY 2018-2019 onward. Surplus rice by FCI and maize as feedstocks were allowed beginning ESY 2020-2021.

4. Expansion into Various Sectors: The utilization of ethanol blends extends beyond just automotive use. The government intends to promote its use in machinery, stationary power applications, and portable power applications, thereby diversifying the market for ethanol and creating new opportunities for its production and consumption.

International Collaboration

India's efforts are seen in international collaboration as well. In April 2022, the collaborative efforts between the governments of India and Brazil regarding ethanol production and bioenergy cooperation resulted in a joint project "Center of Excellence on Ethanol". The program was launched in January 2023 to promote efficient ethanol production from sugarcane and molasses in association with the Society of Indian Automobile Manufacturers and the Brazilian Sugarcane

[8] Ebit. The sugar industry has routinely requested that the Indian government raise the minimum support price for sugar, which was last changed in 2019.

Industry Association. By focusing on Flex Vehicle (FV) technology, Sustainable Aviation Fuel (SAF), 2G ethanol production, and other activities, the two countries developed a "Joint Working Group on Bioenergy Cooperation" to exchange knowledge, share technological advancements, and explore joint research and development initiatives.

Additionally, under India's 2023 G20 presidency, a "Global Biofuel Alliance" was launched between 19 countries including the governments of India, Brazil, and the United States, among others.[9] The strategic collaboration aims to increase the use of sustainable biofuels, especially in the transportation industry, involving various aspects such as technical knowledge transfer and assessment of the international biofuel market.[10]

Biodiesel Policy

Turning to biodiesel, India has an aspirational target of blending 5 percent of biodiesel (for on-road use) by 2030, which would require 4.5 BL of biodiesel per year.[11] The national average blend rate in India grew slightly from 0.06 percent from 2022/2023 to 0.16 percent in 2023/2024 (**Table 9**). Following a failed policy dependent on the jatropha plant, India's biodiesel production now relies on animal fats, non-edible oils, used cooking oil (UCO), and imported palm oil and palm stearin. However, there is little progress to date due to feedstock import restrictions and failure to develop a domestic large-scale, low-cost UCO collection system. India's UCO market is one of the world's largest and expanding rapidly from 3 MMT in 2022 to 3.2 MMT in 2023 and is expected to reach 4.5 MMT by 2030.

Based on experiences elsewhere in the world where UCO is a major biofuel feedstock, India's chances of successfully exploiting this resource remain limited given there are no incentives favoring UCO and other 'waste' feedstock that lead to lower carbon intensity biofuels. This is a factor that explains why no supply chain has yet developed (only an estimated 125,000 MT is used today). Also, the biodiesel plants that do exist are very small and thus cost inefficient which only intensifies the problem that biodiesel prices typically exceed diesel prices. Biodiesel markets mostly do not exist without use mandates and/or tax credits or other types of subsidy support.

Import Policies

Fuel ethanol and biodiesel imports are restricted by the Indian government's requirement for a license under the Harmonized System (HS) codes 220710, 220720, 271020, and 382600. The import license covers the following products: undenatured ethyl alcohol (220710) strength by volume of 80 percent or higher, denatured ethyl alcohol (220720) of all strengths, petroleum oils containing up to 30 percent biodiesel (271020), pure biodiesel, and blends of biodiesel with petroleum oil that contain more than 30 percent biodiesel (both under 382600).[12] The ethanol import duty (denatured/undenatured) has not changed since April 2023 (**Table 3**). India is still not permitted to import biofuels for fuel blending. The import duties for biodiesel also remain unchanged from 2022 (**Table 4**).

Table 3. India: Ethanol Import Duty (Percent ad valorem on Customs Insurance, and Freight [CIF] Value)

[9] "Global Biofuel Alliance: One of the priorities under India's G20 Presidency." Published on February 11, 2023.
[10] Ministry of Petroleum and Natural Gas
[11] Ministry of Petroleum and Natural Gas
[12] See: USDA GAIN, India: Biofuels Annual 2022, IN2022-0056.

ITC HS Tariff Number	Total Import duty
Ethyl alcohol and other spirits, denatured, of any strength; denatured ethanol; and denatured spirits [2207 2000]	Basic customs duty on denatured ethanol for manufacture of excisable goods is zero percent. However, denatured spirits assessed five percent duty for all goods except above. *
Undenatured Ethanol [2207 1000] of an alcoholic strength by volume of 80 percent or higher	150 percent (SWS of 10 percent on basic customs duty exempted; State excise/value added tax as applicable).

Source: Central Board of Indirect Taxes and Customs (Updated as of May 1, 2024).
Note: If the importer follows the procedure set out in the Customs Rules, 2017 (import of goods at concessional rate of duty), the central excise duty is a fixed amount and not a percentage on price.
*Ethyl alcohol supplied to OMCs for blending with gasoline will be assessed a five percent Integrated Goods and Service Tax.

Table 4. India: Biodiesel Import Duty (percent ad valorem on CIF value)

ITC HS Tariff Number	Total Import duty
Biodiesel and mixtures thereof, not containing or containing less than 70 percent by weight of petroleum oils and oils obtained from Bituminous minerals (greater than B30 to B100) [3826 0000]	10 percent BCD per KG
Petroleum oil and oils obtained from Bituminous minerals (other than crude), containing by weight more than 70 percent or more of petroleum oils, contain biodiesel, other than waste oils (B1-B30), [2710 2000] *	5 percent BCD per KG
Automotive diesel fuel, containing biodiesel, Conforming to standard IS 1460 (2710 2010)	2.5 percent BCD per KG

Data source: CBIC (Updated as of May 1, 2023).
*For the purposes of the sub-headings of 2710, the term “biodiesel” means mono-alkyl esters of fatty acids of a kind used as a fuel, derived from animal, vegetable or microbial fats and oils, whether or not used.

Export Policies

On January 17, 2024, the Indian government levied a 50 percent export duty on two key biofuel feedstocks, B and C-heavy molasses. The purpose of the increase from zero to 50 percent is to ensure the availability of feedstock for domestically supplied ethanol.[13] Around 11 percent of molasses production was exported in the previous year, making India the largest exporter of molasses in the world.

Flex Fuel Vehicles (FFVs)and Electric Vehicles (EVS)

The Indian government's active promotion of domestic manufacturing of Flex Fuel Vehicles (FFVs) and Electric Vehicles (EVs) through the "Make in India" initiative is a strategic step towards enhancing the country's automotive industry while also addressing environmental and health concerns. The introduction of FFVs and E-20 fuel-compliant vehicles into the Indian market in late 2022 were designed to run on a blend of gasoline and ethanol, offering consumers greater flexibility and promoting the use of biofuels in transportation. The move aligns with global trends towards reducing reliance on fossil fuels and mitigating climate change impacts.

[13] “Govt imposes 50% export duty on molasses; extends lower duty on edible oils”. Business Standard, Published on January 16, 2024.

While there are potential benefits like reducing oil import costs, boosting energy security, and lowering carbon emissions, there are also concerns about the impact on vehicle efficiency and maintenance costs. Ethanol has a lower energy content compared to pure petrol, which can result in decreased mileage. Additionally, certain engine components may be more susceptible to corrosion when exposed to higher ethanol concentrations, potentially leading to the need for premature replacements and increasing the total cost of ownership for vehicles. Furthermore, vehicles designed to run on E10 fuel may not be optimized for E20 blends, which could result in accelerated engine wear and tear over time.

On August 29, 2023, the Ministry of Petroleum and Natural Gas launched the world's first BS-6 (Stage II) Electrified FV developed by Toyota Kirloskar Motor.[14] By encouraging domestic production, the government aims to boost economic growth, create job opportunities, and reduce dependence on imported vehicles and fossil fuels. India's trade department has supported the reduction of taxes on hybrid vehicles to facilitate the shift towards cleaner energy sources, aligning with requests from Japanese automakers.[15]

According to FAS sources, around 12,000 retail outlets in India have capability to offer E20 fuel by 2025. However, storage availability and distribution networks can be barriers to adoption expansion. Public awareness campaigns, incentives for consumers, and government policies that support the expansion of ethanol blending infrastructure, can contribute to overcoming barriers and foster a more sustainable energy landscape in India. In a parallel development, Hindustan Petroleum Corporation Limited (HPCL) has initiated a pilot study involving vehicles running on E27 fuel and ethanol-blended diesel. [16]

Under the National Mission for Electric Mobility 2020, the Indian government launched the "Faster Adoption and Manufacturing of Hybrid and Electric Vehicles" (FAME) program. By promoting the adoption of EVs and supporting the domestic manufacturing of electric and hybrid vehicles, the FAME program aligns with India's broader goals of enhancing energy security. EV sales increased by 49 percent in March 2024, compared to the corresponding period of the previous year.[17] This is attributed to the consumer rush before India stopped the FAME-II subsidy scheme in March 2024.

Financial Supports

India has implemented new financial programs to encourage more environmentally friendly vehicles. On March 14, 2024, the Ministry of Heavy Industries notified lower import taxes for EVs if the carmakers invest $500 million or more in India. This could help to increase domestic manufacturing within the next three years.[18] While boosting the domestic automotive industry, this move is also a win for foreign automakers and promotes sustainable mobility solutions.

Further, during the Indian Fiscal Year (IFY) 2023/2024, there was a growth of approximately 45 percent in EV sales, accounting for 1.6 million units. Sales of two-wheelers in the EV category are the highest, followed by three-wheelers and four-wheelers. Additionally, an extension of the Electric Mobility Promotion Scheme until July 2024 with a budget of $60 million (INR 5 billion)

[14] Press Information Bureau. Release ID: 1953249
[15] "Indian Oil to open 300 ethanol fuel stations: Transport minister Nitin Gadkari". Economic times, Published on January 13, 2024
[16] "E20 fuel currently sold at over 1,900 pumps: Govt in Rajya Sabha". Economic Times, Published on August 7, 2023.
[17] Vahan
[18] Ministry of Heavy Industries

will further promote electric mobility in India. All these factors together – government incentives, infrastructure development, and increasing consumer interest, contributed to the growth of EVs in India.

Renewable Energy and Greenhouse Gas (GHG) Emissions

While moving toward its E20 target, India is also investing in other forms of renewable energy. It has increased its installed capacity of renewable electricity by nearly 53% in 2024 to 191 gigawatts (GW) compared to 2023 (**Table 5 and 6)**. Solar power is the highest at 67 GW, followed by wind with nearly 43 GW, biomass with nearly 11GW and small hydropower with 5GW.

Table 5. India: Installed Generation Capacity (GW) as on April 30, 2024

Category	Wind Power	Solar Power	BM Power/ Bagasse Cogeneration	Waste to Energy	Small Hydro Power	Total
Installed Generation Capacity	46.16	82.63	10.94	0.6	5	145
% Share of Total	24.08	43.11	5.71	0.31	2.61	32.41

Data source: MNRE, Government of India.

Table 6. India: Installed Capacity of Renewables (In Gigawatts) by State[19]

State/Union Territory	Small Hydro Power	Wind Power	Bio-Power					Solar Power	Large Hydro Power	Total Capacity
			Biomass Power/ Bagasse Cogeneration	Biomass Cogen. Non Bagasse	Waste to Energy	Waste to Energy (Off-grid)	Total Bio-Power			
Andhra Pradesh	163.31	4096.65	378.1	113.57	53.16	29.21	574.39	4590.06	1610	11034.41
Gujarat	91.64	11783.62	65.3	12	7.5	25.93	112.48	13797.24	1990.00	27774.98
Karnataka	1280.73	6224.99	1867.1	20.2	1	19.42	1907.72	8718.02	3689.20	21820.66
Maharashtra	384.28	5212.18	2568	16.4	12.59	46.2	2643.19	6308.41	3047.00	17595.06
Rajasthan	23.85	5195.82	119.25	2	0	4.39	125.64	21469.62	411.00	27225.93
Tamil Nadu	123.05	10608.34	969.1	43.55	6.4	24.65	1043.7	8332.46	2178.20	22287.50
Others	2938.39	3040.19	3466.71	714.07	169.09	191.76	4539.53	19422.05	34002.77	63941.18
Total (in MW)	**5005.25**	**46161.79**	**9433.56**	**921.79**	**249.74**	**341.56**	**10946**	**82637.86**	**46928.17**	**191679.72**
Total (in GW)	**5.00**	**46.16**	**9.43**	**0.92**	**0.24**	**0.34**	**10.94**	**82.63**	**46.92**	**191.67**

Note: All figures as on April 30, 2024.
Data source: Ministry of Power, New, and Renewable Energy (MNRE), Government of India

Related to this, the Prime Minister has an initiative, the Farmer Energy Security and Upliftment Campaign Scheme (PM Kusum), which reflects the government's commitment to promoting renewable energy adoption in the agricultural sector.[20] This scheme provides transparency and standardization in the selection of vendors and cost estimates for the implementation of solar-

[19] State-wise installed capacity of Renewable Power as on 30.04.2024
[20] PM KUSUM

powered water pump projects. By expanding access to solar pumps and incentivizing their deployment, the scheme aims to improve energy access, increase agricultural productivity, and contribute to rural development and sustainability.

Greenhouse Gas Emissions

The Clean Development Mechanism (CDM) under the United Nations Framework Convention on Climate Change (UNFCCC) presents an opportunity for the Indian power sector to earn revenue by reducing greenhouse gas emissions, particularly carbon dioxide. While India receives high rankings in GHG emissions and energy use categories, it holds a medium ranking in climate policy and renewable energy, like the previous year. To increase the pace of renewable energy adoption, the Indian government has taken several initiatives aimed at ecosystem protection, conservation, and combating climate change.

In 2022, India updated its Nationally Determined Contribution (NDC) with enhanced targets for electric power generation through non-fossil fuel sources to 50 percent by 2030. Additionally, India aims to reduce the emission intensity of GDP by 45 percent compared to 2005 levels and create a carbon sink of 2.5 to 3 billion metric tons by 2030. Despite being the world's most populous country, India has relatively low per capita emissions, putting it on track to meet benchmarks for per capita GHG emissions well below 2°C.[21]

Bioenergy

Biomass power generation utilizes organic materials such as agricultural residues, forest residues, animal waste, and dedicated energy crops to produce electricity. According to the Ministry of New and Renewable Energy (MNRE), India's biomass power capacity surged to 10.8 GW in February 2024, contributing to the ambitious goal of meeting 50 percent of its energy requirements from renewables. Biomass bagasse, derived from sugarcane waste, holds significant potential as a renewable energy source in India. It is the largest source of biomass energy and the third largest renewable energy source overall, following solar and wind energy. The MNRE Biomass Co-firing Policy requires thermal power plants to blend 5 percent agro-residue based biomass pellets with coal to promote a healthy biomass ecosystem; the percentage is expected to rise to 7 percent by 2025/2026.[22]

National Greenhouse Gas Inventory

In the UNFCC report, India aimed to reduce the emissions intensity of its Gross Domestic Product (GDP) by 33 to 35 percent by 2030 from the 2005 level. Additionally, India aimed to achieve about 40 percent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030. As noted in a December 2023 communication to UNFCC, India already achieved a reduction of 33 percent in emissions intensity between 2005 and 2019.

Green Hydrogen

In India’s national (Union) Budget 2024/2025, it allocated $72.2 million (INR 6 billion) for the National Green Hydrogen Mission, a more than 100 percent increase from the previous year’s budget of $30 million (INR 2.97 billion). Under this mission, the Ministry of New and Renewable Energy (MNRE) encourages investment and innovation across the value chain. The

[21] Climate Change Performance Index
[22] Press Information Bureau. Release ID: 1945245

mission's goal is to develop a green hydrogen production capacity of at least 5 MMT per year by 2030, coupled with an expansion of about 125 GW of renewable energy capacity.

A state-owned energy corporation, Gas Authority of India Limited (GAIL) is set to commission the first green hydrogen plant of India in Madhya Pradesh. The facility is projected to produce 4.3 metric tons, against the total 5 MMT target of green hydrogen by 2030. According to industry sources, there is a possibility of a budget allocation to develop port infrastructure for hydrogen production. This multi-faceted approach aims to establish two green hydrogen hubs and focuses on job creation.

Environmental Sustainability and Certification

In the backdrop of India's investment in renewable energy is significant environmental and human health challenges, including high levels of particulate matter (PM) pollution in many cities and air toxins associated with vehicle exhaust. The country is actively working to increase its share of renewable energy within its energy mix, targeting a substantial portion of its energy requirements to be fulfilled by renewable sources by 2030. By 2070, India aims to achieve net-zero carbon emissions, a commitment that underscores its participation in global climate change mitigation efforts.

Energy security and climate change mitigation are also two of the goals of the government as per the National Biofuels Policy. India recognizes that ethanol is a clean and renewable fuel and burns cleaner than petrol, resulting in lower particulate matter (PM 2.4 and 10) and air toxins in tailpipe emissions. According to a government think tank NITI Aayog report, an E20 blend leads to greater reductions in carbon monoxide emissions, which were 50 percent lower in two-wheelers and 30 percent lower in four-wheelers.

International Commitments

At COP27, Prime Minister Narendra Modi announced that India will aim to attain net zero emissions by 2070. He also announced that India will draw 50 percent of its consumed energy from renewable sources like hydrogen and biofuels by 2030 and cut its carbon emissions by a billion tons. Subsequently, India submitted its Long-Term Low Emissions Growth Strategy to the UN Framework Convention on Climate Change (UNFCCC), indicating low carbon transition pathways in key economic sectors where it has updated its target to reduce the intensity of emissions of its gross domestic product by 45 per cent by 2030, from 2005 levels. India also emphasized an increased use of biofuels, especially ethanol blending in petrol, and shared how it's trying to reach 20 percent by 2025.

III. Ethanol

Table 7. India: Ethanol Used as Fuel and Other Industrial Chemicals (Million Liters)

Ethanol Used as Fuel and Other Industrial Chemicals (Million Liters)										
Calendar Year	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024f**
Beginning Stocks	75	61	128	150	300	112	309	150	205	400
Fuel Begin Stocks	15	20	20	50	50	80	100	150	10	70
Production	2,292	2,061	1,671	2,692	2,552	2,981	3,280	5,300	6,500	6,350
Fuel Production	430	450	705	1,500	1,920	2,120	3,745	5,000	6,400	6,275
Imports	204	432	722	607	670	669	648	370	400	600
Fuel Imports	0	0	0	0	0	0	0	0	0	0
Exports	165	136	141	129	50	133	87	109	132	90
Fuel Exports	0	0	0	0	0	0	0	0	0	0
Consumption	2,345	2,290	2,230	3,020	3,360	3,320	4,000	5,506	6,573	7,138
Fuel Consumption	425	450	675	1,500	1,890	2,100	3,695	5,140	6,340	6,245
Ending Stocks	61	128	150	300	112	309	150	205	400	122
Fuel Ending Stocks	20	20	50	50	80	100	150	10	70	100
Refineries Producing Fuel Ethanol (Million Liters)										
Number of Refineries	160	161	161	166	170	220	231	252	263	270
Nameplate Capacity	2,100	2,210	2,215	2,300	3,000	3,500	4,300	5,700	10,820	14,500
Capacity Use (%)	20	20	32	65	64	61	87	88	60	43
Co-product Production (1,000 MT)										
Bagasse	108,699	97,485	79,176	118,784	99,942	126,976	139,264	135,168	131,072	132,259
Press Mud	14,493	12,852	10,438	15,660	13,176	16,740	18,360	17,820	17,280	17,400
Feedstock Use for Fuel Ethanol (1,000 MT)										
Molasses (C-heavy)	1,980	2,075	3,245	5,500	4,500	1,200	900	800	600	1,600
Molasses (B-heavy)	0	0	0	750	2,271	3,550	6,667	9,000	11,400	10,800
Sugarcane syrup	0	0	0	0	1,951	5,263	10,000	14,274	18,400	17,500
Damaged food grains	0	0	0	350	603	1,600	2,000	2,000	2,100	2,800
Rice	0	0	0	0	0	118	471	1,610	2,000	260
Maize	0	0	0	0	0	0	0	0	32	1,100
Market Penetration (Million Liters)										
Fuel Ethanol Use	425	450	675	1,500	1,890	2,100	3,695	5,140	6,340	6,245
Gasoline Pool	30,823	32,994	37,098	40,367	42,496	40,741	45,453	50,150	53,000	54,500
Blend Rate %	1.4	1.4	1.8	3.7	4.4	5.2	8.1	10.2	12.0	11.5

Data source: Post research and historical data series, industry sources, and official government trade data as compiled and reported by Trade Data Monitor, LLC.
f =Year 2024 is projected; # Excess rice supplied by the Food Corporation of India (FCI); * Leftover sugarcane residue after juice extraction.
Note: For ethanol imports originating from the United States, data used is from U.S. Census Bureau. HS codes include (a) denatured, fuel 2207.20.0010, (b) ethanol denatured, other 2207.20.0090, (c) ethanol undenatured, fuel 2207.10.6010 and (d) ethanol undenatured, other 2207.10.6090.

Consumption

India's total non-potable ethanol consumption is forecast to rise by 13 percent to 7.2 BL in 2024. The majority remains fuel ethanol consumption, which is the case since 2019, and it is estimated to reach 6.2 BL this year. Fuel ethanol consumption is driven by the government's initiative to increase ethanol blending to meet its 2025 E-20 mandate. FAS/New Delhi's estimates take into account the government's restriction on the diversion of sugar feedstocks for fuel ethanol to prevent high domestic sugar prices, which in turn led to a decrease in fuel ethanol use compared to last year. In October 2023, India achieved a blending rate of 12 percent with gasoline, a new

record.[23] For the current year, FAS/New Delhi believes India is unable to maintain the 12 percent blending rate due to the restrictions on feedstock, amidst a low sugar production year. Post forecasts India's average blending rate at 11.5 percent for the current calendar year of 2024. Without loss of generality, post notes that over the last ten years, there is a noticeable trend for non-potable ethanol consumption exceeding production. This is largely due to an increased population and growing middle class demands. In the future, post expects India's total light duty vehicle fuel consumption will rise and subsequently increase demand for increased ethanol assuming blend rates do not reverse and trend downward.

Production

Post estimates the total annual production of ethanol used for fuel and other industrial markets (including medical applications) at 6.35 BL. Net imports for industrial use supplement this supply. This includes 6.27 BL of ethanol for fuel production, which is approximately two percent lower than last year (**Table 7**). This estimate accounts for the low sugar production year and depleted broken rice stocks from Food Corporation of India (FCI). Specifically, sugarcane production has decreased considerably in the current year at 34 MMT, which is 8 percent lower than the previous year. This is due to the late onset of rainfall and pest infestations in major sugarcane producing regions – Maharashtra, Karnataka, and Uttar Pradesh.[24] Domestic demand for sugar consumption is estimated to increase by more than 4 percent for food purposes. To adjust to the production and market realities, the Indian government limited the use of sugar for ethanol production to 2.37 MMT.[25]

Initially, on December 7, 2023, the Department of Food and Public Distribution (DFPD) notified the sugar mills and distilleries not to use sugarcane juice and C-heavy molasses for ethanol production during Ethanol Supply Year (ESY) 2023/2024.[26] The policy was established to support domestic sugar consumption amidst the adverse weather condition, and ethanol production was allowed only from B-heavy molasses.[27] However, on December 15, 2023, DFPD revised the notice by allowing ethanol production from all the three feedstocks for ESY 2023/2024.[28] The notification also instructed that no sugarcane juice and B-heavy molasses were to be diverted for rectified spirit or extra neutral alcohol. All these changes occurred during India's election year and a low sugar producing year.

Additionally, rice production for 2023/2024 is estimated two percent lower than the previous year due to water stress.[29] In August 2023, due to rising concerns about rice production and price, the Indian government stopped supplying ethanol producers with broken and unfit-for-human-consumption rice from FCI stocks. This took place despite the establishment of multiple grain-based ethanol distilleries. Only the rice which was already in the stock for fuel ethanol is considered for the current ESY.

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[23] Indian Sugar & Bioenergy Manufacturers Association
[24] India: Sugar Annual
[25] "Govt allows sugar mills to use 6.7 lakh tons of B-heavy molasses for ethanol production". Economic Times, Published on April 24, 2024
[26] Department of Food and Public Distribution
[27] "Ethanol blending: Just a 'pause', 20% target intact: Oil secretary". Financial Express, Published on December 9, 2023
[28] Department of Food and Public Distribution
[29] India: Grain and Feed Annual

At the same time, the government of India is working to raise maize/corn production as an alternative to meet the EBP target of E-20 by 2025. DFPD notified that National Agricultural Cooperative Marketing Federation of India *(*NAFED*),* National Cooperative Consumers Federation (NCCF) and Primary Agricultural societies (PACs) of the purchase of maize/corn from farmers at the Minimum Support Price (MSP). The procured maize would then be supplied to OMCs to meet the blending target.[30] The decision to offer procured maize to distilleries at MSP, with all incidental costs borne by the DFPD, reflects a specific approach to support both the ethanol industry and food security objectives. This move is expected to raise maize/corn production in India and prompt the growers to divert the production for ethanol fuel. India's maize/corn production is estimated at 35.5 MMT for the current MY (which runs from November to October) and forecasted to reach 37 MMT for the MY 2024/2025.[31]

More recently, on June 11, 2024, MoPNG declared that India reached its target of E-15 for the month of May 2024.[32] This announcement occurred after the 2024 general election.[33]According to FAS sources and analysis, India's ethanol blend rate is still hovering around 12 percent for the current ESY. However, post projections do not rule out India achieving the 15 percent target towards the end of the current ESY. After September 2024, when the sugar MY ends, there may be a greater diversion of sugar to ethanol due to India's ongoing ban on sugar exports and a relatively lower sugar price. This might encourage more sugarcane feedstock procurement and support India in meeting its E-15 target by the end of the current ESY.

However, to achieve the E-15 target, an approximate 20 percent increase in the availability of feedstocks is required. According to FAS sources, for the ESY 2023/2024, OMCs rolled out ethanol supply tenders for 8.25 BL. Out of the 8.25 BL, bids equivalent to 5.62 BL were received in the first two offers, representing approximately 70 percent of the tendered quantity. Of the 5.62 BL of ethanol bids received, approximately 2.69 BL is to be sourced from the sugarcane industry. The remaining 2.92 BL is to be sourced from grains. As of April 2024, approximately 2.11 BL of ethanol was contracted against 8.25 BL required for blending by OMCs for ESY 2023/2024 **(Table 8)**. This is almost 58 percent lower than the total ethanol contracted for ESY 2022/2023.

Table 8. India: Ethanol contracted Quantity from Feedstocks (Million Liters)

Feedstocks	**Ethanol contracted quantity during ESY 2023**	**Ethanol contracted quantity for ESY 2024 (November- April 2024)**
Sugarcane syrup	1.28	0.51
B-heavy Molasses	2.35	0.08
C-heavy Molasses	0.06	0.61
Damaged Food Grains (DFG)	0.32	0.45
Surplus rice available with FCI	0.74	0.01
Maize	0.32	0.45
Total	**5.06**	**2.11**

[30] "Government to launch scheme for assured procurement of maize for ethanol production". Times of India, Published on December 10, 2023

[31] India: Grain and Feed Annual

[32] "India achieves 15% ethanol blending; aims for 20% by 2025: Hardeep Singh Puri". Economic Times, Published on June 11, 2024.

[33] "India's Modi prevails over allies in cabinet line-up". Reuters, Published on June 11, 2024.

Data source: Post research, historical data series, and industry sources.

Currently, India has 270 sugarcane/molasses-based distilleries with a nameplate capacity of 8 BL of ethanol (denatured and undenatured) for use in fuel, industrial, food, and medical-grades (sanitizers, topical disinfectants, solvents), preservatives and portable liquor applications.[34] Additionally, there are 140 grain-based distilleries with an installed capacity of 6.5 BL. To comply with its E20 guidelines, the Indian government is pushing for more multi-feedstock and grain-based distilleries. Heavy investment in ethanol capacity building, rising domestic consumption, and a low production year for rice and sugarcane may open avenues for more multi-feedstock investment by India.

Trade

Imports

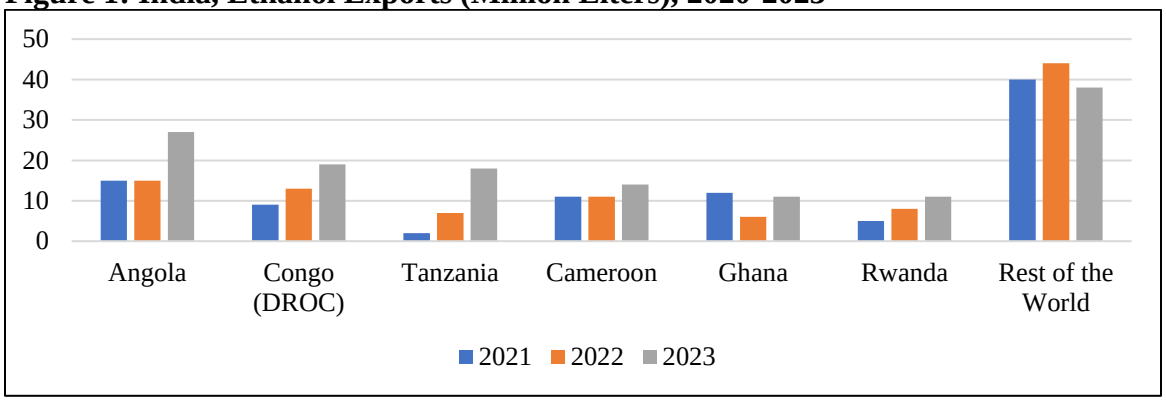
Post forecasts India's ethanol imports to increase to 600 ML in the outyear, almost 50 percent up from the previous year to meet India's medical, industrial, and beverage demand. Apart from fuel blending, India remains a net ethanol importer for all end uses. The United States is the largest ethanol supplier of denatured ethanol for medical-grade and industrial ethanol, exporting 275 and 355 ML in 2022 and 2023, followed by Brazil. For the last two years, India's ethanol imports from the U.S. reduced due to increasing costs in the supply chain coupled with higher U.S. ethanol prices. However, by the end of 2023, the price was below the record highs of the previous three years. Though the price elevated again from January 2024 to April 2024, it has decreased every month compared to the corresponding months of the previous year and previous two years before that.

Exports

Post estimates exports will decrease slightly to 90 ML for the current year, on account of strong domestic demand in the potable sector, the EBP program target, and a comparatively low sugar production year. In 2023, India's undenatured ethanol export grew to 132 ML, almost a 20 percent increase from 2022. Top ethanol export destinations in 2023 included Angola, Congo, Tanzania, Cameroon, Ghana, and Rwanda (**Figure 1**). The Indian government clarified in March 2023 that if biofuel is made from imported feedstocks and exported from special economic zones for fuel and non-fuel purposes, it won't be subject to tariff restrictions.[35]

[34] Nameplate capacity: Estimated ethanol manufacturing capacity estimated as of the 2024 sugar season, based on the number of operational days allowed by the Pollution Control Boards.
[35] Source: "Government amends export policy for biofuels." Economic Times, published on March 22, 2023.

Figure 1: India, Ethanol Exports (Million Liters), 2020-2023



Data source: U.S. Census Bureau, TDM and Ministry of Commerce, Indian government,

IV. Biodiesel

Table 9. India Biodiesel Production from Multiple Feedstocks (Million Liters)

Biodiesel (Million Liters)										
Calendar Year	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024f**
Beginning Stocks	11	13	13	18	25	23	16	26	22	29
Production	152	158	170	185	230	200	180	185	200	226
Imports	1	3	8	25	7	1	1	1	1	1
Exports	33	42	8	23	54	68	6	4	4	14
Consumption	118	119	165	180	185	140	165	186	190	220
Ending Stocks	13	13	18	25	23	16	26	22	29	22
Production Capacity (Million Liters)										
Number of Biorefineries	6	6	6	6	6	6	6	7	10	12
Nameplate Capacity	500	550	600	650	670	580	520	577	600	820
Capacity Use (%)	30	29	28	28	34	34	35	32	33	28
Feedstock Use (1,000 MT)										
Animal fats	5	6	6	7	10	6	12	7	6	8
Recycled oils (UCO)	55	55	56	60	70	45	65	65	70	125
Other (mostly palm stearin)	85	90	100	110	140	140	95	105	115	83
Total	145	151	162	177	220	191	172	177	191	216
Market Penetration (Million Liters)										
Biodiesel, On-road use	41	48	72	83	100	50	10	40	40	105
Diesel, On-road use	52,239	55,179	56,715	59,220	60,145	44,400	52,927	57,002	62,000	65,850
Blend Rate (%)	0.08	0.09	0.13	0.14	0.17	0.11	0.02	0.07	0.06	0.16
Diesel/Biodiesel Pool, Total	87,064	91,965	94,524	98,700	95,541	84,512	90,231	99,000	107,000	110,140

Data source: FAS New Delhi Research and historical data series, and official government trade data as compiled and reported by Trade Data Monitor, LLC. *f* =Year 2024 is projected; *Indicates theoretical estimate.

India, with its large transportation fleet, holds significant potential for the biodiesel market. Several schemes and policies by the Indian government supporting biodiesel capacity building are in place. However, the sector's expansion is hindered principally by the lack of a true mandate or obligation to produce or consume. There is also no procurement process like with fuel ethanol as well as other factors, including a lack of readily available feedstocks, limited investments resulting in virtually no production capacity, and virtually no infrastructure for storage and delivery. The new biofuels program heralded a switch from the failed program wholly depended on the jatropha plant to a program based mainly on used cooking oil, but the switch has landed no measurable results.

Consumption

Post estimates that 220 ML of biodiesel will be consumed in the forecast year (**Table 9**). This 15 percent increase from last year is driven by demand for cleaner fuels (transport and stationary power), and tax rebates for consumers.[36] Beyond transportation, biodiesel finds utility in diverse sectors at very small scale such as power generation, brick kilns, agricultural machinery, and telecommunication infrastructure. Additionally, there are some very limited usages by port authorities in maritime operations.

Production

Post forecasts India to produce 226 ML of biodiesel in 2024, a 13 percent increase from the previous year's estimate. India maintains 12 biodiesel plants with a production capacity of 820 ML. On October 31, 2023, Aemetis Inc.'s Universal Biofuels subsidiary secured a contract to supply biodiesel to OMCs, with 220 ML production capacity per year from the port-based biodiesel plant in the state of Telangana in India. With this venture, on-road biodiesel use is also expected to increase (Table 9).

Non-edible industrial oils, UCO, animal fats, and tallows are essential feedstocks for biodiesel production. However, their availability can be inconsistent, leading to intermittent production cycles. The Food Safety and Standards Authority of India (FSSAI) initiated the RUCO (Repurpose Used Cooking Oil), an initiative in 2018 to prevent the reuse of cooking oil in food preparation and support UCO use in biofuel.[37] India uses approximately 24 BL of cooking oil yearly and 60 percent of it goes back to the food value chain which poses a health threat. This 60 percent (1.8 BL) of UCO can be collected from the hotel industry and converted into 1.3 BL biodiesel annually. North America, Europe, Indonesia, and Brazil uses UCO, tallow, and corn oil to cover one-third of the feedstock as fuel.[38] With India currently consuming 7 BL of diesel per month, the Indian government's target is to blend 5 percent biodiesel by 2030.[39]

Trade

Post forecasts India's biodiesel imports will remain unchanged in 2024 considering the long-standing import restrictions. For the past three years, Malaysia is the main importer of Indian blends of biodiesel. The Indian government clarified in March 2023 that if biodiesel is made from imported feedstocks and exported from special economic zones, it won't be subject to tariff restrictions.[40]

[36] India Biodiesel Market Report by Feedstock, IMARC
[37] Food Safety and Standards Authority of India
[38] "Growing Demand for Fats and Oils Due to Global Biodiesel Expansion". Unted States Department of Agriculture, Trade Spotlight. Published on August 18, 2023.
[39] Petroleum Planning and Analysis Cell
[40] Source: "Government amends export policy for biofuels." Economic Times, Published on March 22, 2023.

V. Advanced Biofuels

Sustainable Aviation Fuel (SAF)

The National Biofuel Coordination Committee (NBCC) has set a target of blended Sustainable Aviation Fuel (SAF) at 1 percent by 2025 and 5 percent by 2030 for domestic flights. In early 2024, The Ministry of Petroleum and Natural Gas (MoPNG) mandated the SAF targets to 1 percent by 2027 and 2 percent by 2028 for international flights leaving India.

The Indian domestic airlines collaborated with the Council of Scientific and Industrial Research–Indian Institute of Petroleum for the creation and development of SAF. [41] The initiative for a SAF plant at Haryana's Panipat refinery by Indian Oil Corporation Limited (IOCL) in collaboration with LanzaJet aims to ramp up SAF production, using Alcohol-to-Jet (AtJ) technology.[42] With an investment of $122 million (INR 10 billion), this state-of-the-art facility will have the capacity to annually generate 110 million liters (ML) 88,000 MT of SAF, representing a substantial contribution to India's overall production target by 2030. On May 3, 2023, Indian airline Vistara operated a domestic flight with a blend of 17 percent SAF and 83 percent jet fuel.[43] On May 19, 2023, Air Asia India carried out the domestic commercial passenger flight with a 1 percent SAF blend. [44]

India would require about 300 ML of ethanol and 140 ML of SAF as feedstocks to meet the target of blending 1 percent SAF with jet fuel by 2025.[45] SAF output is expected to triple to 1.8 BL in 2024, having doubled to 600 ML in 2023 through AtJ technology, which accounts for 3 percent of all renewable fuels. Ramping up ethanol production capacity to meet the E20 mandate for road transport is already challenging, especially considering maintaining E20 as the gasoline fuel pool grows means ethanol supply growth must keep pace. Building new production capacity for SAF and supplying that industry with additional ethanol beyond the E20 requirement for road use adds new challenges.

Cellulosic Ethanol

The initiative to set up 12 second-generation (2G) bio-refineries by OMCs represents a significant investment of $ 1.68 billion (INR 140 billion) in expanding India's ethanol production capacity. These bio-refineries will utilize lignocellulosic biomass and other renewable feedstocks for ethanol production, thereby reducing reliance on traditional fossil fuels and promoting environmental sustainability.

The Pradhan Mantri JI-VAN Scheme underscores the Indian government's commitment to supporting integrated bio-ethanol projects by providing financial assistance of $217.7 million (INR 18 billion) to twelve such projects, along with support of $18.14 million (INR 1.5 billion)

[41] "Airbus: Will help India create a sustainable aviation fuel marketplace." Times of India; published February 28, 2023
[42] Indian Oil Plans Green Jet Fuel Plant to Meet Surging Demand." Bloomberg; published on May 3, 2023
[43] "Vistara operates first commercial India flight with sustainable fuel". The Times of India, Published on May 5, 2023.
[44] ICOL produced the SAF blend (1 percent). Source: "AirAsia India Conducts First Flight with Indigenous SAF." Bioenergy International, published on May 20, 2023.
[45] "Govt considering mandatory blending of sustainable aviation fuel in jet fuel: Hardeep Puri". Money Control, Published on February 8, 2024.

for ten demonstration projects for 2G technology, and $2.36 million (INR 195 million) to develop a "Center for High Technology."[46]

By integrating diverse biomass crops into farming practices, farmers can contribute to the production of feedstocks for cellulosic ethanol production, thus supporting India's renewable energy goals while enhancing their income opportunities. By ensuring a reliable supply chain and fair prices for ethanol, these mechanisms incentivize investment in the biofuel sector and foster a conducive environment for its growth. Bio-CNG as a potential by-product of cellulosic ethanol biorefineries offers another avenue for sustainable energy production and utilization. Assurances of offtake by OMCs further enhance the viability and attractiveness of bio-CNG production.

The Indian government's aims to incorporate 5-10 BL of cellulosic ethanol into the fuel mix by 2030. These figures outlined in the 2018 National Biofuels Policy present a significant opportunity for India to harness its biomass resources to produce cellulosic ethanol. India produces an estimate of 120-160 MMT biomass which can potentially be converted to 30 BL of cellulosic ethanol annually.

The development of technologies to convert waste into biofuels and biochemicals presents a promising avenue for addressing waste management challenges while promoting renewable energy production (**Table 10**). Although these technologies are still in their early stages and require validation at a commercial scale, they hold immense potential for transforming organic waste into valuable resources. The operational advanced biofuel plants, including pilot and demonstration plants, with a cumulative annual production capacity of 32 ML of cellulosic ethanol.[47]

India's 2G ethanol capacity is gradually evolving, with the following projects underway to harness diverse feedstocks for ethanol production:

- The Indian Oil Corporation's Panipat Refinery in Haryana is to operate the first commercial 2G ethanol plant in India by mid-2024. With an annual capacity of 30 ML, this facility can utilize approximately 200,000 metric tons of crop residue, demonstrating the feasibility of utilizing agricultural waste for ethanol production.

- Bharat Petroleum's integrated ethanol refinery in Bargarh, Odisha, is expected to commence operations by 2024. This facility will adopt a combined 1G-2G approach, utilizing biomass, grains, and sugarcane feedstocks to produce ethanol, thereby diversifying the feedstock base, and enhancing production efficiency. The plant has submitted tenders for procuring raw material in early January 2024.

- Hindustan Petroleum Corporation Limited is constructing a 1043 ML capacity plant in Bhatinda, focusing on utilizing waste food stocks for ethanol production.

[46] India: Biofuels Annual
[47] "Curtain Raiser: India's first cellulosic alcohol technology demonstration plant to be inaugurated in Kashipur, Uttarakhand"

- Numaligarh Refinery Limited in Assam is pioneering the development of a 2G distillery that utilizes bamboo feedstocks for ethanol production. Leveraging locally abundant bamboo resources, this project demonstrates the importance of utilizing region-specific feedstocks to enhance sustainability and promote rural development. The plant was to be set up by 2024, which is now moved to May 2025.

Table 10. India: Biofuel Research and Development Classification

Fuel	Substitute	Technologies Deployed
Diesel	*Biodiesel, **HDRD (Green Diesel), Bio-based oxygenates (alcohols and ethers)	Esterification, Hydroprocessing, Fermentation, Syngas conversion
Aviation Turbine Fuel (ATF)	**Sustainable Aviation Fuel (or, Bio-ATF)	Hydroprocessing, Sugar conversion, alcohol-to-jet, Fischer–Tropsch process
Gasoline (Petrol/Motor Spirit)	*Ethanol (1G), **Ethanol (2G), **Methanol, Green (drop-in) gasoline	Fischer–Tropsch process, Gas Fermentation, Alcohol-to-gasoline, Hydroprocessing, Pyrolysis/Catalytic Cracking
Compressed natural gas (CNG)/piped natural gas (PNG)	*Bio-CNG/Bio-PNG, HCNG, Bio-H2	Waste Fermentation
Marine Fuel/Industrial Fuel Oil	**Green heavy distillate, biomass-derived oils	Hydroprocessing, Pyrolysis/Fluid catalytic cracking, Hydrothermal Liquefaction, MSW-thermochemical processing

*Indicates technologies are available | **Indicates emerging technologies (in development)
Source: DBT, Ministry of Science and Technology

VI. Notes on Statistical Data

India's motor gasoline pool demand: According to FAS's analysis, which incorporates the government of India's data from its Petroleum Planning & Analysis Cell,[48] a unit within the Ministry of Petroleum and Natural Gas, India's expected motor gasoline pool demand for the current ESY is around 54,000 ML. From November 2023 to June 2024, India's gasoline pool reached 36 ML. The monthly average was 4.5 ML. For this report, FAS took into account India's density use of petrol and applied the PPAC's conversion from MT to ML[49] for the 2024 estimated motor gasoline pool. As a result, post forecasted the gasoline pool at 54,500 ML as noted in Table 7.

Table 11. Select Biofuel Conversion Factors

Damaged Food Grains – 1 MT = 250 liters (Source: Arcus Policy Research)
Broken Rice – 1 MT = 425 liters
Sugarcane Juice – 1 MT = 76 liters
B-Heavy Molasses – 1 MT = 300 liters (Source: Triveni, and National Sugar Institute, Kanpur)
C-Heavy Molasses – 1 MT = 217 liters (Source: Triveni)
Corn/Maize – 1 MT = 380 liters (Source: Arcus Policy Research)
Ethanol – 1 MT = 1,267 liters

[48] Domestic Consumption of Petroleum Products (P): https://ppac.gov.in/consumption/products-wise
[49] Snapshot of India's Oil & Gas Data – May 2024
https://ppac.gov.in/download.php?file=whatsnew/1718369963_Snapshot-of-India-Oil-Gas-Data-May-2024.pdf

Table 12. Select Biodiesel Conversion Factors

Non-edible industrial – 1 MT = 1050 liters of feedstock weight
Used cooking oil (UCO) – 1 MT = 1043 liters of UCOME (UCO methyl ester)
Animal fats and tallows – 1 MT = 1282 liters

The National Policy on Biofuels 2018 defines biofuels and permits the following feedstocks:

1) Bioethanol: ethanol produced from biomass such as sugar containing materials, like sugar cane, sugar beet, sweet sorghum etc.; starch containing materials such as corn, cassava, rotten potatoes, agrofood/pulp industry waste, algae etc.; and cellulosic materials such as bagasse, wood waste, agricultural and forestry residues or other renewable resources like industrial waste, vegetable wastes, industrial waste off gases or any mix combination of above feedstock.

2) Biodiesel: A methyl or ethyl ester of fatty acids produced from non-edible vegetable oils, acid oil, used cooking oil or animal fat.

3) Advanced Biofuels: Fuels which are (1) produced from lignocellulosic feedstocks (i.e., agricultural and forestry residues, e.g., rice & wheat straw/corn cobs & stover / bagasse, woody biomass), non-food energy crops (i.e., grasses, algae), animal dung or industrial waste and residue streams, or any mix combination of above feedstock. (2) having low CO_2 emission or high Green House Gas reduction and do not compete with food crops for land use. Fuels such as Second Generation (2G) Ethanol, biodiesel made from UCO, non-edible tree borne oils, short gestation non-edible oil rich crops; green diesel from renewable sources and Industrial waste, biofuels produced from synthesis gas, drop-in fuels from renewable sources and industrial waste, algae based 3G biofuels, halophytes based biofuels, bio-CNG, bio-methanol, Di Methyl Ether derived from bio-methanol, bio-hydrogen, drop-in-fuels from MSW resource/feedstock material

Drop-in Fuels: Any liquid fuel produced from biomass, agricultural-residues, wastes such as municipal solid wastes (MSW), plastic wastes, industrial wastes etc. which meets the Indian standards for motor spirit (MS), high speed diesel (HSD) and jet fuel, in pure or blended form, for its subsequent utilization in vehicles without any modifications in the engine systems and can utilize existing petroleum distribution system.

Bio-CNG: Purified form of biogas whose composition and energy potential is similar to that of fossil based natural gas, and is produced from agricultural residues, animal dung, food waste, MSW and sewage water.

Potential domestic raw materials for production of biofuels in the country include:

For Ethanol Production: C and B- Heavy Molasses, sugarcane juice, sugar, sugar syrup, biomass in form of grasses, agriculture residues (rice straw, cotton stalk, corn cobs, saw dust, bagasse etc.), sugar containing materials like sugar beet, sweet sorghum, etc. and starch containing materials such as corn cassava, rotten potatoes, agro-food/pulp industry waste, etc., broken rice, food grains unfit for human consumption, food grains during surplus phase as

declared by National Biofuel Coordination Committee, industrial waste, industrial waste off-gases, etc. Algal feedstock and cultivation of seaweeds can also be a potential feedstock.

For Biodiesel Production: Non-edible Oilseeds, UCO, Animal tallow, Acid Oil, Short Gestation non-edible oil rich crops, algal feedstocks, etc.

Refer to 2018 National Policy on Biofuels and Amendments for complete information.

Attachments:

No Attachments

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No Attachments