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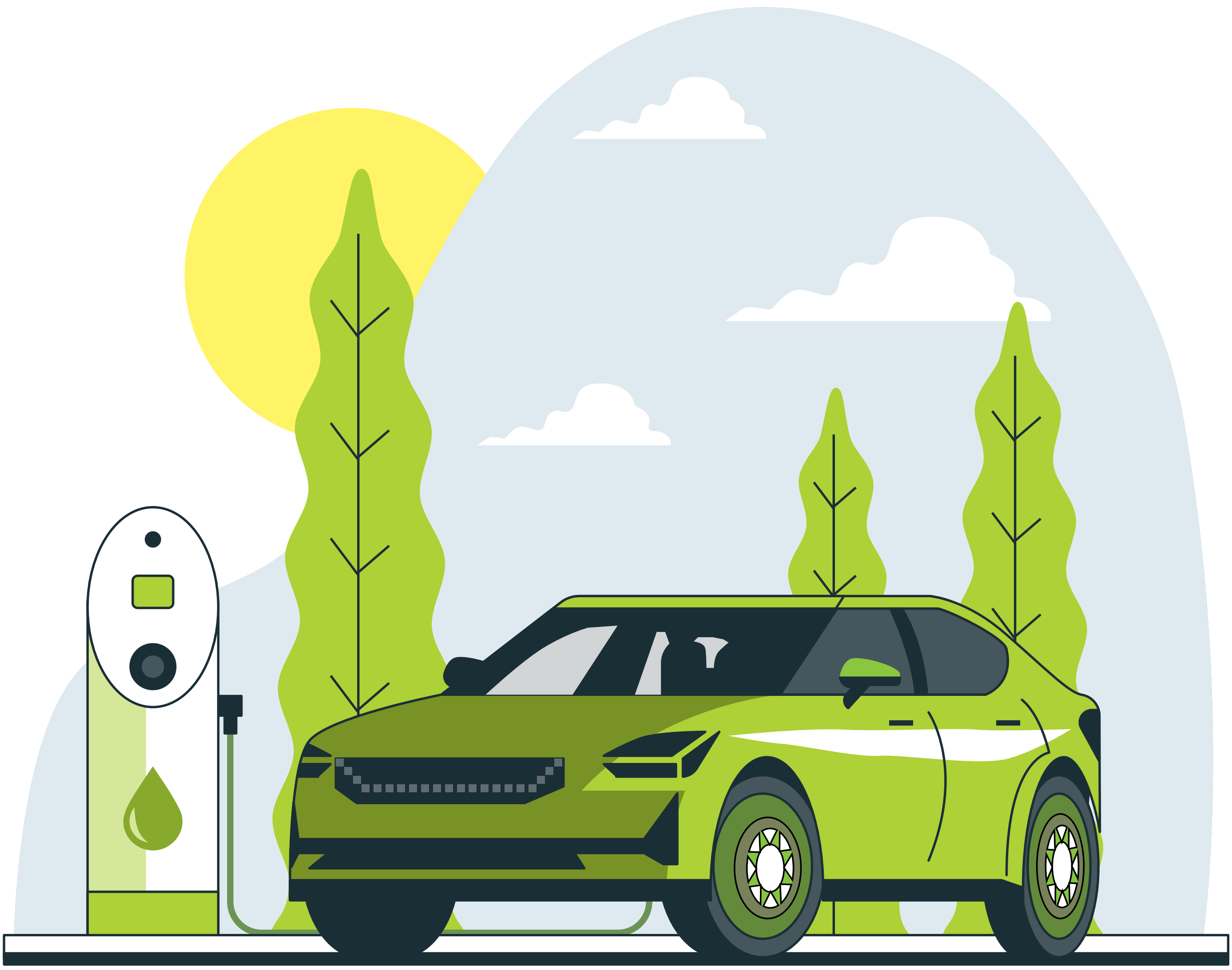
Ethanol Blending of Petrol in India

AN ASSESSMENT OF RAW MATERIAL AVAILABILITY



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Arcus Policy Research

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Abbreviations

APM	Administered Pricing Mechanism
ARIMA	Auto-Regressive Integrated Moving Average
BOD	Biochemical Oxygen Demand
BAU	Business As Usual
CACP	Commission for Agricultural Cost and Prices
CCEA	Cabinet Committee on Economic Affairs
CIMMYT	International Maize and Wheat Improvement Centre
DFPD	Department of Food and Public Distribution
DES	Directorate of Economics and Statistics
DDGS	Dried Distilleries Grain Soluble
ESY	Ethanol Supply Year
FRP	Fair and Remunerative Prices
FMCG	Fast Moving Consumer Goods
FAO	Food and Agriculture Organization
GOI	Government of India
GHG	Green House Gases
GCA	Gross Cropped Area
ISMA	Indian Sugar Mills Association
KMS	Kharif Marketing Season
LCA	Life Cycle Analysis
MAPE	Mean Absolute Percentage Error
MMT	Million Metric Tonnes
MOPNG	Ministry of Petroleum and Natural Gas
MSP	Minimum Support Price
NBCC	National Biofuel Co-ordination Committee
NFSA	National Food Security Act
NPB	National Policy on Biofuels
NSSO	National Sample Survey Office
OMC	Oil Marketing Companies
OECD	Organisation for Economic Co-operation and Development
PPAC	Petroleum Planning & Analysis Cell
PWP	Physical Water Productivity
PM-GKAY	Pradhan Mantri Garib Kalyan Anna Yojana
RSF	Revenue Sharing Formula
TNAU	Tamil Nadu Agricultural University
TCWU	Total Consumptive Water Use
TES	Total Energy Supply
USDA	United States Department of Agriculture
VOO	Value of Output
WMO	World Meteorological Organization
WRI	World Resource Institute

Introduction

INDIA'S fuel demand is growing and so is its crude oil import bill. In 2021-22, India imported crude oil worth USD 120 billion, which met about 86 percent of the country's total demand for petroleum products (PPAC). With increasing volatility in global crude oil prices and its impact on India's energy security (Rogoff 2022, World Bank, Dinakar 2022 and Sati et.al. 2022), the Government of India (GOI) has been trying to reduce its dependence on imported crude oil. One of the ways identified is to promote biofuels, especially by blending of ethanol with petrol. As per National Institution of Transforming India (NITI) Aayog's ethanol roadmap released in 2021, the country can annually save about USD 4 billion in foreign exchange by blending petrol with ethanol.

In addition to saving foreign exchange and reducing dependence on imported crude oil, ethanol blending in petrol is also expected to lower emissions in the country. A recent World Bank report finds that India may face heat waves that break the human survivability limit (threshold of 35 degree Celsius) (World Bank 2022). Petrol blended with ethanol is expected to burn in a cleaner way than petrol, resulting in lower emissions (USDOE 2022). Besides, ethanol blending supports India's COP-26 commitments, and help the country move closer to achieving

India's Petrol Consumption Outlook

2021-22

Ethanol blending 9.5%

Petrol 90.5%

2025-26

Ethanol blending 20%
(Annual cost savings: $4 billion)

Petrol 80%

> **From less than 2 billion litres in 2019-20, India supplied about 4.1 billion litres of ethanol for fuel blending in 2021-22, pulling up the average rate of blending in the country, from 5% in 2019-20 to about 9.5% in 2021-22.**

sustainable development goals (SDGs) relating to energy, innovation, and economic growth (Kumar 2021 and PIB 2022).

Since 2018, India has moved rapidly and impressively with its ethanol production and fuel blending plan. From less than 2 billion litres in 2019-20, the country supplied about 4.1 billion litres of ethanol for fuel blending in 2021-22 (Ethanol supply year, ESY[1]). This pulled up the average rate of blending in the country, from 5 percent in 2019-20 to about 9.5 percent in 2021-22. GOI has now advanced its target to achieve 20 percent ethanol blending (E20) from 2029-30 to 2025-26.

Performance on the E20 mandates has been exceptional. But the challenge is this: Is the country equipped to meet the E20 target in the next two years? Threats are on two accounts: First, the growing competition from other ethanol consuming sectors like potable alcohol which has been growing at a double-digit rate. Second, competition from the feed industry. The poultry sector has shown impressive growth and an increasing quantity of maize will be required for consumption by the sector. Farm yields of crops including paddy, maize, cotton, and chili have also been impacted by weather and climate changes. Therefore, the big question is: Does India have the ability to supply an adequate quantity of ethanol to its Oil Marketing Companies (OMCs) to meet the targeted mandate of E20 by 2025-26? Some related questions: Will India have a surplus crop for its feedstock? Will the plan to source ethanol from crops have an adverse impact on the country's food security? Is there credence in the ongoing worldwide debate on the food for fuel question? We address these questions in this Report.

The Report is divided in four parts. After a brief outline of the global energy mix, the paper discusses global and Indian policies and initiatives on ethanol in Part 1. Part 2 discusses the production, pricing, and distillation capacity for ethanol in India. Part 3 focuses on methodologies and estimates to assess feedstock availability to achieve E20 targets by 2025-26. Part 4 discusses the implications of E20 goals on foreign exchange reserves, agricultural land use, the environment, and consumers in India. The Report ends with conclusions and recommendations.

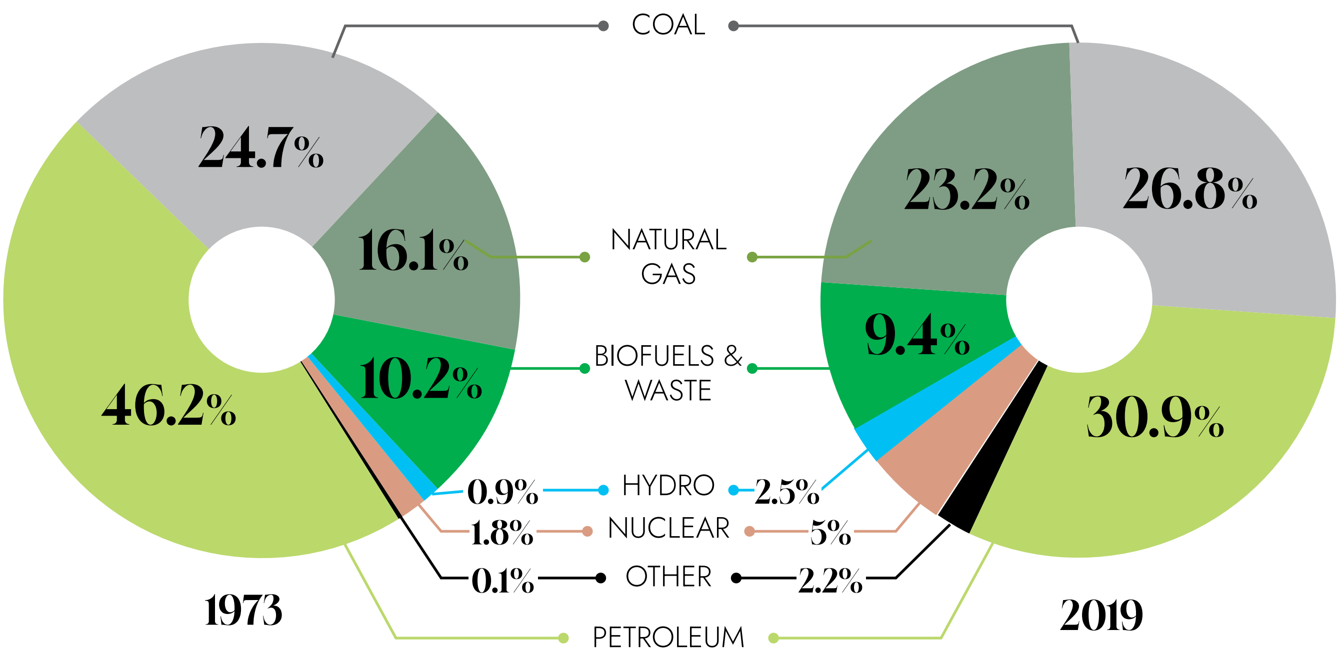
1 The Ethanol Supply Year (ESY) has recently been changed. Till ESY 2021-22, ESY was for 12 months, starting from 1 December to 30 November of the following year. Since 2022-23, ESY has been changed to 11 months, from 1 December to 31 October of the following year, with the plan to change the ESY to November 1 to October 31 of future years.

Global and India's Energy Mix

ACCORDING to the International Energy Agency (IEA), the global energy mix has been changing with time (Figure 1). In the 46-year period between 1973 and 2019, dependence on crude oil decreased (from 46.2 percent of the total energy supply (TES[2]) in 1973 to 30.9 percent in 2019). In the same period, reliance on coal increased (from 24.7 percent to 26.8 percent). Interestingly, global energy dependence on biofuels and waste decreased from 10.2 percent to 9.4 percent in this period. Natural gas, hydroelectric power, and nuclear sources have become more important. However, despite an increase in the share of energy from renewable sources, about 86 percent of the world's energy supply continued to be met from non-renewable sources in 2019[3].

FIGURE: 1

Share of different sources of energy in total global energy supply



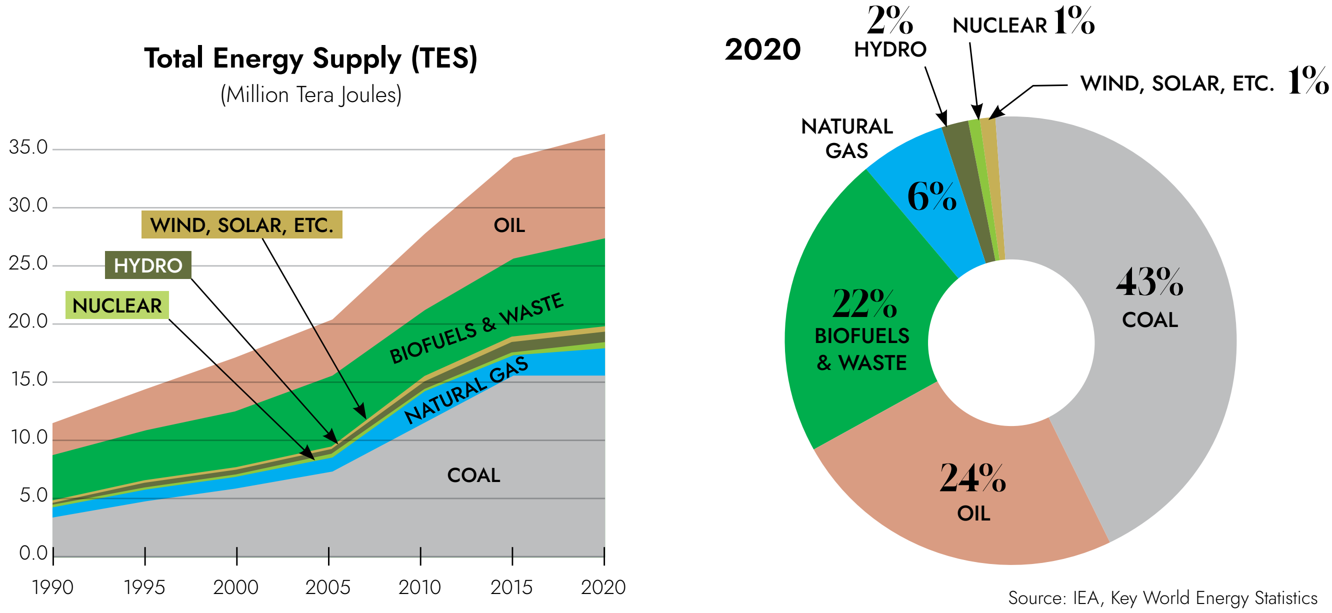
Source: IEA, Key World Energy Statistics

2 Total energy supply (TES) is made up of production + imports—exports—international marine bunkers—international aviation bunkers ± stock changes. For the world total, international marine bunkers and international aviation bunkers are not subtracted from TES.

3 Renewable sources include biofuels and waste, hydro power and 'other' sources of energy and non-renewable sources include oil, coal, natural gas, and nuclear energy. Even though nuclear energy is a renewable energy source, the material used in nuclear power plants are considered non-renewable.

FIGURE: 2

Level and composition of India's Total Energy Supply



Source: IEA, Key World Energy Statistics

Compared to the world average, India's energy basket is greener. The country has been diversifying from non-renewable sources of energy to renewable sources rather fast (Figure 2). In 2020, energy from biofuels (22 percent) had become the third largest source of energy, trailing closely the contribution from oil (24 percent). However, India's dependence on coal, is still very high at 43 percent. Interestingly, natural gas for the world (23.2 percent) and biofuels for India (22 percent) are of similar importance in the respective energy supply baskets.

Biofuels are defined as plant matter used either directly or in converted form (for example charcoal, electricity, or fire). Biofuels used in the transportation sector include ethanol, bio-diesel, renewable diesel, and bio-jet. Biofuel production for transportation was placed at approximately 157.4 billion litres in the triennium ending (TE) 2020 (IEA Renewable 2021). The share of ethanol was about 69 percent, followed by bio-diesel (27 percent) and renewable diesel (4 percent).

Indian policymakers have been increasingly focusing on bioethanol. Ethanol can be produced from grains, sugarcane, and agricultural/industrial waste using either First Generation (1G) or Second Generation (2G) technologies. 1G technology produces ethanol directly from food stocks (crops); whereas, advanced biofuel technologies such as 2G can produce ethanol from non-food crops, industrial wastes, and lignocellulose feedstocks (Susmozas et.al. 2020).

The NITI Aayog recommends that 2G technology be the preferred option for the production of ethanol (NITI 2021). According to a recent report from World Food Programme, India is still home to one-fourth of the total undernourished people in the world (WFP 2022). In such a scenario, manufacturing biofuels from 2G technologies (where by-products of crops can be used as feedstock) should be the preferred option compared to 1G technologies (where the crop is the feedstock) (Gunatilake and Abeygunawardena 2011). Although there have been some recent developments in 2G ethanol in the country (MOPNG), the technology has still not been found to be commercially viable, not even globally (Zhou et al. 2021). As we will find later in this report, ethanol production in the country has mostly been done through the use of 1G technology.

PART-1

Global and Indian Ethanol Policies

INTERESTINGLY, the discovery of ethanol predates petroleum. Petroleum was discovered by Edwin Drake in 1859 and ethanol, as an alternative fuel, by Samuel Morey in 1826 (Songstadet al. 2009). The two World Wars (1917–1919 and 1941–1945) significantly increased demand for ethanol in the United States, as domestic rationing of gasoline encouraged its substitution with ethanol. While gasoline was used for running tanks and war machinery, ethanol supported commercial transportation and services. US and Brazil are today the largest producers of ethanol in the world, accounting for 84 percent of total ethanol production (IEA data for TE 2020). The ethanol policies of the two countries are being reviewed in the sub-section down below.

THE USA

According to the Renewable Fuels Association, the USA produced 15,000 million gallons of ethanol in 2021—roughly 55 percent of the world's production. The country, primarily, produces ethanol through the use of 1G technology, mostly using corn as feedstock.

Historically, the USA has supported the production of ethanol for blending with petrol by way of subsidies and investments. The ethanol industry started with an *assured subsidy of 40 cents per gallon* (Energy Policy Act 1978) (Tyner 2008). Low oil prices throughout the 1980s took some sheen off the ethanol industry, but it picked up momentum once again following the Clean Air Act amendments of the 1990s. In 2005, the Energy Policy Act of 2005 was put in place, which created the Renewable Fuels Standard (RFS) mandate permitting the blending of ethanol with petrol. Under the Act, a variety of incentives ranging from *income tax credits, grants, subsidies, and loans* were extended to promote biofuel research and development (USEPA). In 2007, the Energy Independence and Security Act of 2007 was enacted with similar incentives to expand the production of renewable fuels in the country. In 2008, *the tariff on imported ethanol was 54 cents per gallon plus 2.5 percent of the import value* (Tyner 2008). For almost three decades, the subsidy amount was fixed and was independent of the ruling oil and corn prices. **Currently, the support has been removed, and ethanol price is market-driven.**

BRAZIL

Brazil's experience with ethanol as a gasoline-additive dates back to the 1920s, but ethanol made from sugarcane was not officially mixed with gasoline until 1931 (FAO 2008). Later, in response to the Arab oil embargo in 1973, Brazil built a ***'Proalcool'*** program in 1975 to replace petroleum-based fuels with ethanol (sugarcane-based). The program provided incentives such as agricultural and industrial financing, guaranteed purchases by the Institute for Sugar and Alcohol (Instituto do Açúcare do Álcool-IAA), and consumer incentives by fixing a maximum selling price.

In 1980, 95 percent of light vehicles produced in the country operated on ethanol-blended petrol (Lopes et al 2016). Over the years, the Brazilian government provided various incentives such as tax exemptions and subsidies along with changes in trade policies to increase the production and consumption of ethanol (USDA 2022). The policy for E27 has been in place since 2015 (IEA 2023). By February 2023, all petrol sold in Brazil had to contain at least 27 percent ethanol (E27) (ET 2022).

During the 2015 Conference of the Parties (COP-21) in Paris, participating countries—including Brazil—came up with a voluntary commitment to reducing domestic emissions of greenhouse gases (GHGs) by 37 percent until 2025 and by 43 percent until 2030 (Barros 2018). Brazil has consequently taken significant steps to incentivize the ethanol industry by promoting blending with petrol (ET Energy World 2022).

EVOLUTION OF ETHANOL POLICIES IN INDIA

India's ethanol initiative began in 1938 when the Power Alcohol and Molasses Committee in Uttar Pradesh (UP) and Bihar (BR) recommended sugar mills should convert molasses[4] into alcohol (Kovarik 1982). This paved the way for the country's first ethanol (for power) policy through the Power Alcohol Act of 1948. The main purpose of this Act was to allow the use of molasses to produce alcohol to be mixed with petrol.

> "[In Brazil] in 1980, 95 percent of light vehicles produced in the country ran on ethanol blended petrol (Lopes at al 2016). Over the years, the Brazilian government provided various incentives such as tax exemptions and subsidies along with changes in trade policies to increase the production and consumption of ethanol (USDA 2022)."

4 Molasses is a viscous substance resulting from refining sugarcane for sugar production

> **"The major thrust on ethanol blending was given after India introduced the National Policy on Biofuels (NPB) 2018. According to the new policy, E10 was to be achieved by 2021-22 and E20 was to be achieved by year 2030."**

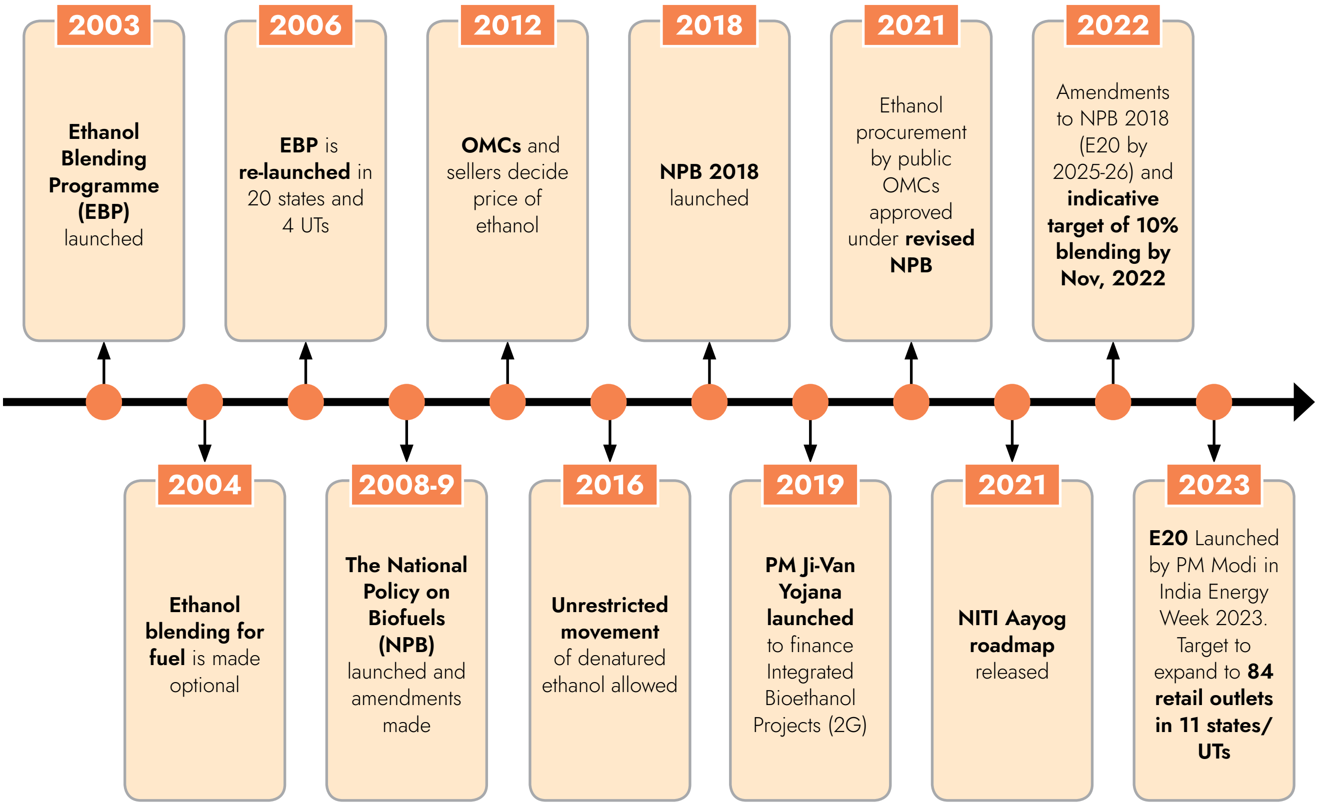
In 2003, GOI marked the launch of Ethanol Blending Programme (EBP), mandating 5 percent ethanol blending of petrol in nine states and four union territories (UTs). In the same year, a report by the Biofuels Development Committee under the *erstwhile* Planning Commission recommended a phased programme to introduce biofuels and blends of gasoline and diesel. However, due to supply shortages from 2004 to 2005, the ethanol blending obligation became optional in October 2004. In 2006, the Ministry of Petroleum and Natural Gas (MOPNG) directed public sector oil marketing companies (OMCs) to sell 5 percent ethanol-blended petrol in 20 states and four UTs (MOPNG 2021). In 2007, the GOI mandated a 5 percent blend in petrol across the country except in Jammu & Kashmir, the north-eastern states, and the island territories (Ray, Miglani & Goldar 2011). Next year, in 2008, the first National Policy on Biofuels on mandated phased implementation of EBP in different states was unveiled. The 2009 policy set an indicative target of 20 percent blending by 2017 (National Policy on Biofuels 2008); providing that blending targets would be managed by the OMCs. In the same year, the National Policy on Biofuels was approved by the Union Cabinet. It proposed the formation of the National Biofuel Coordination Committee (NBCC), headed by the Prime Minister and consisting of ministers of concerned ministries as members. The price of ethanol was determined by the Biofuel Steering Committee and the NBCC. Biofuel imports were controlled by the NBCC. The National Policy on Biofuels noted that bioethanol enjoys concessional excise duty of 16 percent, and duties and taxes would be levied on imports to promote domestic bioethanol growth. In 2012, the Cabinet Committee on Economic Affairs (CCEA) allowed OMCs and sellers to decide the price of ethanol (Dey et al. 2021).

Ethanol blending plans received a major boost after India introduced the National Policy on Biofuels (NPB) 2018 (Figure 3). According to the new policy, E10 was to be achieved by 2021-22, and E20 was by 2030. On World Environment Day in 2021, the Prime Minister announced the advancement of the target for E20 to 2025-26 (PIB 2021). Subsequently, in June 2022, GOI made amendments to the NPB (PIB 2022).

Prior to NPB 2018, ethanol was only allowed to be produced from C-heavy molasses. With the introduction of NPB 2018, ethanol production from B-heavy molasses, sugarcane juice, and grains was also allowed. After 2018, several measures were taken to increase the production and blending of ethanol.

FIGURE: 3

Evolution of Indian ethanol policy



Source: Compiled by authors

In March 2019, GOI launched the ***Pradhan Mantri Ji-Van Yojana*** to provide financial support to set up integrated bio-ethanol plants. Interest subsidy was announced on loans for ethanol projects from sugarcane, molasses, and grains, and a long-term procurement policy for ethanol was also unveiled to help producers plan investment decisions. A mechanism to fix ethanol prices—based on the cost of raw materials—was also announced. In 2020, use of surplus rice with FCI was allowed to be used as a raw material for ethanol production.

Broadly, there are two types of ethanol: denatured ethanol and un-denatured. Denatured ethanol has denaturant added to it, rendering it unfit for human consumption. It is used as fuel, or as inputs for medical and industrial purposes to produce sanitizers, etc. Un-denatured ethanol is mainly used as a concentrate for alcoholic beverages.

Between the financial years 2015-16 and 2021-22, India was a net importer of denatured ethanol (DGCIS). In FY 2021-22, the country imported 0.49 billion litres of denatured ethanol valued at USD 344 million. Imports increased from 2016-17 and peaked at 0.59 billion litres in 2020-21, official statistics show. India's denatured ethanol imports are mainly sourced from the USA and Brazil. The import of ethanol for fuel blending has been restricted since 2019 (DGFT 2019). However, in her Union Budget speech for the year 2023-24, Finance Minister Nirmala Sitharaman proposed to exempt basic customs duties on imported denatured ethanol (PIB 2023). This measure is likely to improve the availability of denatured ethanol for industrial use by chemical and other industries, releasing greater amounts to meet the ethanol-blending mandates.

PART-2

Ethanol: Production, Pricing, and Processing Capacity

ETHANOL production in India has been increasing in the last ten years, with a steep rise since 2019-20. In the ESY 2013-14, India produced about 0.38 billion litres of ethanol (NITI Aayog), which increased more than 10 times to 4.1 billion litres in ESY 2021-22 (MOPNG). In June 2022, India achieved the blending target of 10 percent and ended the year with an average blending rate of 9.53 percent (Figure 4).

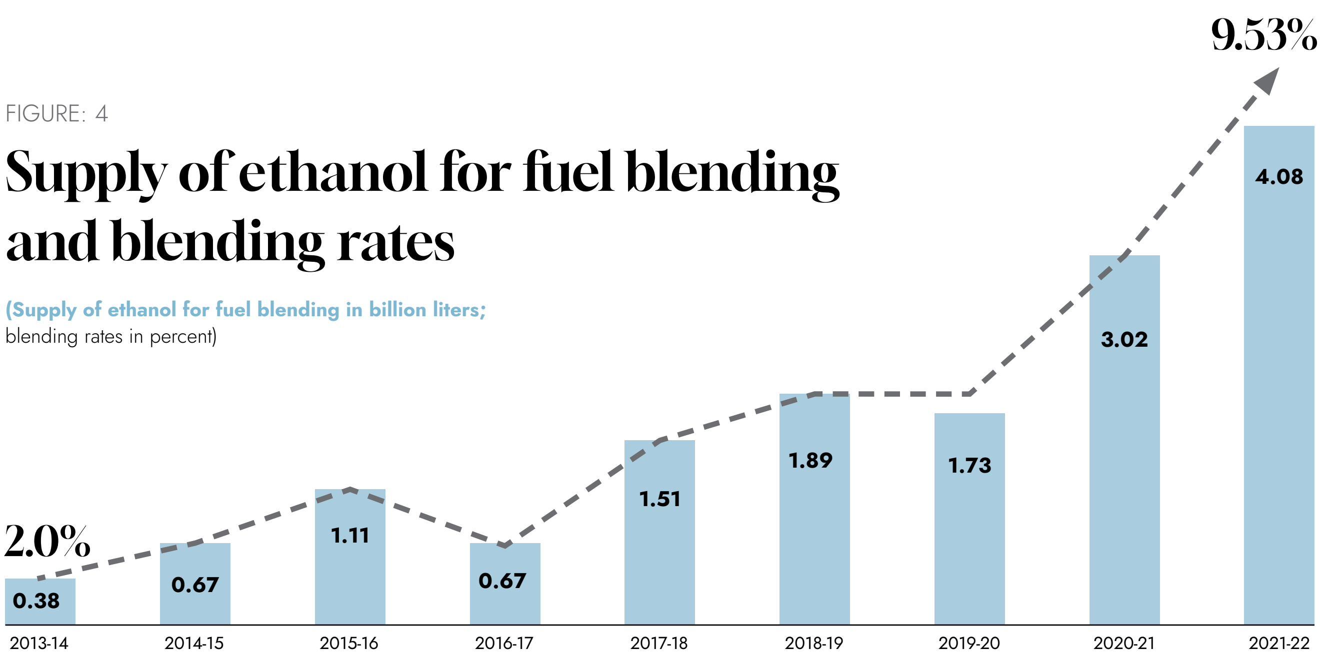
Out of 4.08 billion litres of ethanol supplied for fuel blending in 2021-22, about 84 percent was produced from sugarcane juice and molasses (B-Heavy and C-Heavy)—about 11 percent using *surplus rice* from the FCI, and the remainder of about 6 percent from damaged grains, including rice from the open market as well as maize (Figure 5).

Ethanol from sugarcane can be produced via three routes: (i) through sugar syrup or cane juice, (ii) from B-heavy molasses, and (iii) from C-heavy molasses. Before 2018-19, ethanol was mainly produced from C-heavy molasses (NITI Aayog 2021). With the change in regulations in 2018-19 that allowed the use of B-heavy molasses, sugar syrup, and grains (such as rice and maize) for ethanol production, increasing amounts of ethanol are being produced from B-heavy molasses and the sugar juice route, with C-heavy molasses only accounting for 2 percent of ethanol supply in ESY 2021-22.

FIGURE: 4

Supply of ethanol for fuel blending and blending rates

(Supply of ethanol for fuel blending in billion liters; blending rates in percent)



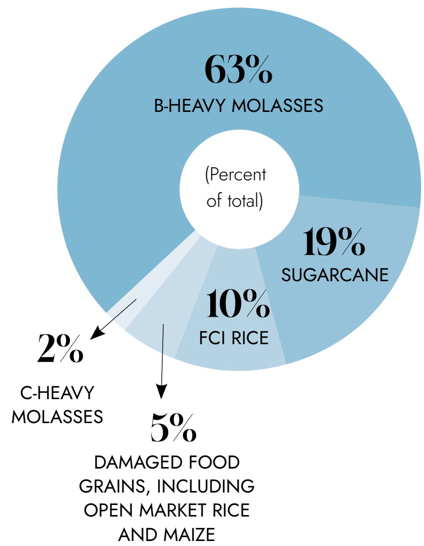
Five Indian states accounted for 50 percent of the total supply of India's ethanol for fuel blending in ESY 21-22. UP's share was the highest (15.5 percent), followed by Maharashtra (MH) (12.4 percent), Tamil Nadu (TN) (8.6 percent), Karnataka (KA) (7.8 percent), and Gujarat (GJ) (5.4 percent).

ETHANOL PRICING

Based on the type of feedstock used, the purchase price of ethanol by OMCs is fixed by the GOI. For ethanol produced from sugarcane and its sources, the prices are fixed by the Cabinet Committee on Economic Affairs (CCEA), and, for grain-based ethanol, the prices are fixed by OMCs (NITI Aayog 2021), while there is no differential pricing for ethanol produced from different food grains (broken rice, wheat, maize etc.). Pricing for ethanol produced from molasses-based feedstocks is done using the Administrative Pricing Mechanism (APM), introduced in ESY 2014-15 (NITI Aayog 2021). Under this regime, GOI approves the price for molasses-based ethanol on the basis of market conditions in the ethanol and oil markets, availability of feedstocks in the domestic markets and the import substitution requirement (NPB 2018). Since 2018-19, the GOI has been deciding differential pricing for ethanol produced from C-heavy molasses, B-heavy molasses, and sugarcane juice/syrup. The differential pricing is based on a variety of factors (NITI Aayog). For sugarcane juice/syrup, prices are based on the Fair and Remunerative prices (FRP) for sugarcane. To determine the administered price of ethanol from cane juice, the cost of conversion to ethanol and capital costs are added to arrive at the ex-mill price. For B-heavy molasses, ex-mill price of ethanol is calculated by considering the normative cost of producing sugar and capital costs of ethanol production. For C-heavy molasses, rates are calculated on the basis of the price of molasses and ex-mill price of sugar. For ESY 2022-23, ex-mill ethanol price from C-heavy molasses, B-Heavy molasses, and sugarcane juice has been fixed at Rs. 49.41, Rs. 60.73 and 65.61 per l litre respectively (PIB 2022) (Table 1).

FIGURE: 5

Composition of ethanol supply for ESY 2021-22



Source: MOPNG and ISMA data
Note: Surplus rice is assumed to be FCI rice based on the terminology used by NITI Aayog

TABLE: 1

Ethanol prices (Rs. per Litre)

	C-heavy molasses	B-heavy molasses	Sugarcane Juice/ Syrup/Sugar	Damaged Food Grains	Maize	Surplus Rice (FCI)
2015-16	42.0	NA	NA	NA	NA	NA
2016-17	39.0	NA	NA	NA	NA	NA
2017-19	40.9	NA	NA	NA	NA	NA
2018-19	43.5	52.4	59.2	47.1	NA	NA
2019-20	43.8	54.3	59.5	50.4	NA	NA
2020-21	45.7	57.6	62.7	51.6	NA	56.9
2021/22 (Dec 2021 – May 2022); first two quarters	46.7	59.1	63.5	52.9	NA	56.9
2021/22 (June 2022 - November 2022); last two quarters	47.8	60.6	65.1	55.3	NA	58.3
2022-23	49.4	60.7	65.6	55.54	56.35	58.5

Source: BPCL, PIB and NITI Aayog
Note: Additional relief was provided for ethanol producers in the last two quarters of ESY 2021-22 accounting for the increase in cost of production due to high coal prices.

In ESY 2020-21, the price of ethanol produced using damaged food grains was fixed at Rs. 51.6 per litre. This has been increased to Rs. 55.54 per litre for ESY 2022-23. In the case of ethanol produced from damaged rice supplied from the FCI, the price was fixed at Rs. 56.9 per litre in 2020-21, which was increased to Rs. 58.5 per litre in 2022-23 (BPCL 2022). It is important to note that rice diverted from FCI godowns to produce ethanol is supplied to distilleries at a subsidised rate, given that the economic cost of rice in FCI was Rs. 3918 per quintal for year 2023-24 (FCI). In 2021-22, rice from FCI was supplied to distilleries at Rs. 2000 per quintal (DFPD 2022). This price was applicable for participants in the OMC tenders. Rice prices in the open market in Punjab averaged about Rs. 2858 per quintal in November 2022 (DOCA[5]).

NITI AAYOG'S ROADMAP TO E20 BY 2025-26

In June 2021, NITI Aayog published the roadmap to achieving the E20 blending mandate by 2025-26, making it the guiding document for further policy action. The roadmap projects the demand of ethanol and identifies sources of its feedstock. The ethanol demand for fuel-blending is based on the country's projected petrol demand, which in turn is pegged to the expected vehicle population in the country by 2025-26. The estimates also account for likely impact of the uptake of electric vehicles (EVs) on fuel demand. As per NITI's roadmap, Indian petrol demand in 2025-26 is projected to be 50.8 billion litres. An E20 mandate translates to an ethanol demand of about 10.16 billion litres by 2025-26. In addition, the country's potable alcohol and pharmaceutical industry would continue to need about 3.34 billion litres of ethanol annually. In total, this implies that by 2025-26 the country would be needing about 13.5 billion litres of ethanol.

To meet the fuel-blending demand of 10.16 billion litres, close to 55 percent or 5.5 billion litres is expected to come from the sugar industry, and the remaining 45 percent or about 4.66 billion litres from grains and other damaged food grains sourced from either the FCI or the open market, according to projections made in the NITI Aayog document.

Unlike in the case of fuel blending, most of the ethanol required by the FMCG, pharmaceuticals and alcoholic beverage industry can be sourced from food grains, the NITI Aayog Roadmap states. Of the total demand of 3.34 billion litres, about 60 percent or 2 billion litres is expected to be sourced from grains, mainly rice—apart from a small component of maize, while the remaining 40 percent or 1.35 billion litres will be supplied by the sugar sector, according to the NITI Aayog estimates.

To meet the total ethanol demand by 2025-26, both the sugar and grain sectors would need to supply close to 7 billion litres of ethanol each.

UNDERSTANDING FEEDSTOCK REQUIREMENTS FOR E20 BY 2025-26

While the demand of sugarcane has been stated clearly, the NITI Aayog Roadmap remains ambiguous on strategies to meet the demands from food grains for ethanol production. In order to project feedstock availability, this report attempts to make assumptions on the basis of decomposition of grain-based ethanol requirements. Our assumption is that 4.66 billion litres of can be sourced equally from rice and maize.[6] This means that rice and maize will need to account for the production of 2.33 billion litres of ethanol each.

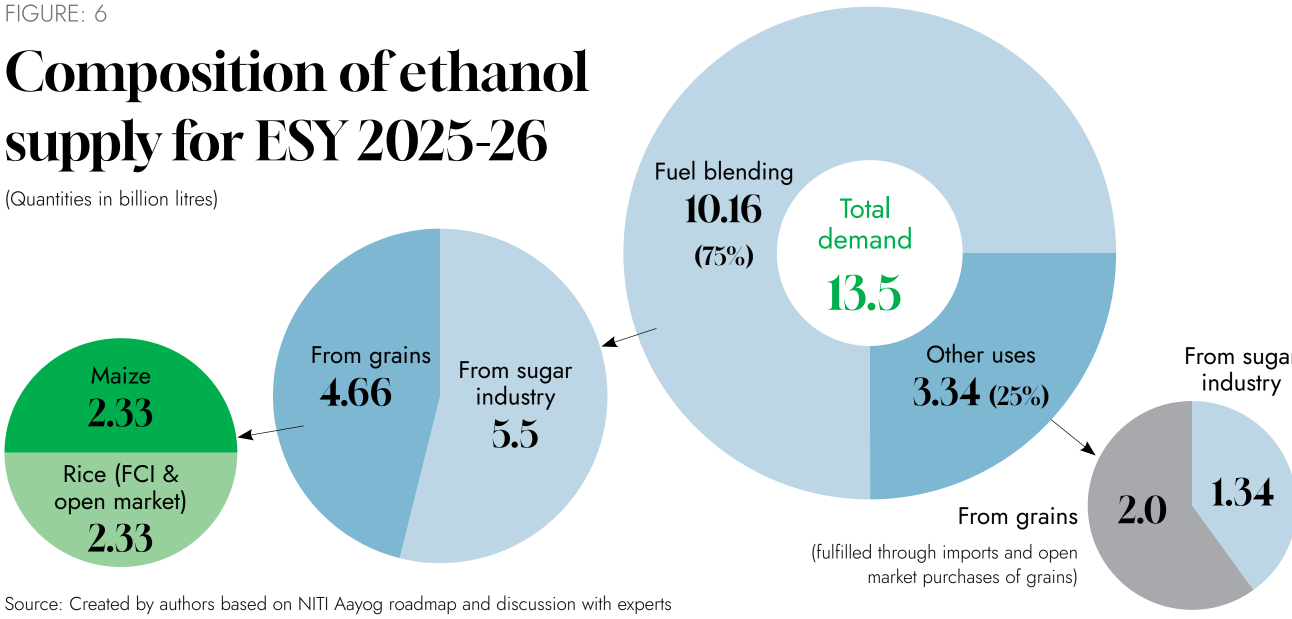
5 Department of Consumer Affairs, Government of India

6 As per NITI's roadmap, there is no bifurcation of ethanol requirement from grains. Rice and maize are identified feedstocks for ethanol production from grains. Going forward, maize will be in greater focus for producing ethanol, considering that rice is important to fulfill the country's food security mandate. Thus, caution is important on behalf of the reader. If these supply shares from the two crops change, then the calculations presented later in the paper will also change

FIGURE: 6

Composition of ethanol supply for ESY 2025-26

(Quantities in billion litres)



Source: Created by authors based on NITI Aayog roadmap and discussion with experts
Note: In TE 2021-22, about 0.53 billion litres of ethanol was imported for meeting demand for "other uses"

Figure 6 summarises the composition of ethanol supply in 2025-26. The circles in blue are sourced from NITI Aayog's documents and the ones in green follow from our assumptions.

The other industrial demand of 2 billion litres of grain ethanol (marked in grey in Figure 6) is assumed to be met via open markets purchases, including imports, and does not enter our calculations in the current work. Though it is undisputed that the higher demand for feedstock by other industries is likely to crowd out availability for the ethanol (for fuel blending) industry. This is already being faced by the OMCs owing to higher demand from competing industries like poultry (as you will see later in case of maize) and alcohol. Ethanol used by the alcoholic beverage industry is sourced domestically mainly from rice and maize, then from molasses and other grains like wheat, rye, and sorghum. Similarly, maize has huge demand from the poultry industry, as it uses maize as its main feed ingredient.

Depending on traits of the feedstock, particularly its starch content, varying quantities are required to produce 1 litre of ethanol (Table 2). It appears that 20 litres of ethanol can be produced from 1 tonne of cane. In terms of rice, however, 1 tonne can produce about 425 litres of ethanol. In case of maize, one tonne can make about 380 litres of ethanol. Due to its high starch content, rice emerges to be a preferred feedstock for producing ethanol.

Using these crop to ethanol conversion factors, we estimate the total demand of the crop that will be required to meet the E20 blending targets (Column 4 in Table 2). It appears that about 275 MMTs of cane, 6.1 MMTs of maize, and 5.5 MMTs of rice will be required by the country to meet the E20 blending targets in ESY 2025-26. Of course, there are by-products from these crops, like sugar in case of cane, Distillers' Dried Grains with Solubles (DDGS) in case of the two other grains. However, this is the minimum quantity of grain that the country will require to meet demand of the OMCs and fulfill E20 targets.

TABLE: 2

Estimated area under cultivation for fulfilling ethanol demand in 2025-26

Feedstock	Supply target (Bill. Lt.)	Ethanol yield per tonne feedstock (Lt.)	Feedstock required (MMTs)	Land requirement (Million Ha.)*
Sugarcane**	**5.5**	**20**	**275**	**3.3**
Maize	**2.33**	**380**	**6.1**	**1.8**
Rice	**2.33**	**425*****	**5.5**	**2.0**
Total	**10.16**	**-**	**-**	**7.1**

Source: Estimated by authors

* Crop yields are taken for year 2021-22 as 8.4 tns/ha for sugarcane, 3.4 tns/ha for maize and 2.8 tns/ha for rice.

** It is assumed that all ethanol is produced through the B-Heavy molasses route. Ethanol yields have been taken from NITI Aayog's ethanol roadmap.

*** As per NITI Aayog, ethanol yield from FCI rice and (broken) rice sourced from the open market is 450 and 400 litres/tonne respectively. Here, we have assumed the average yield of 425 litres/tonne of rice.

Using the average yield of these crops in the country, we estimate the implication of the crop requirement on the land. We find that (Column 5 in Table 2) for producing these crops for fuel blending, the country on average would annually require about 7.1 million hectares of land. This is about 3 percent of the country's gross cropped area (GCA) of about 211.4 million hectares (2019-20). This is equivalent to saying that the entire GCA of states like Bihar (with 7.2 million hectares of GCA) or even Andhra Pradesh (with 7.3 million hectares of GCA) are dedicated to producing crops for fuel.

INDIAN ETHANOL PRODUCTION CAPACITY

To produce 13.5 billion litres ethanol (10.16 billion litres for fuel blending and the remainder for other uses) , the country would require a total distillation capacity of at least 15 billion litres (NITI Roadmap). Taking into account the ethanol supply targets from molasses and grain-based ethanol, a capacity of about 7.4 billion litres for grain-based ethanol distillation and 7.6 billion litres for molasses-based ethanol distillation will need to be created.

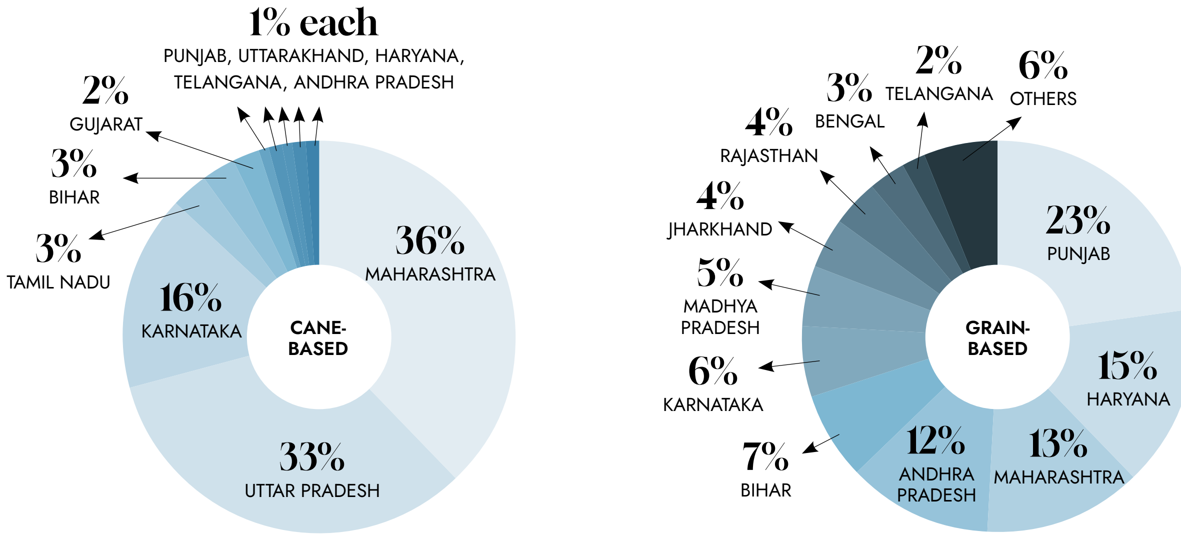
In 2020-21,India had the capacity to produce 4.26 billion litres of cane-based ethanol and 2.58 billion litres of grain-based ethanol. Recent data suggests that the distillation capacity of ethanol for fuel blending was 9.47 billion litres in 2022 (PIB 2022). Of this, 6.19 billion litres capacity was for production of cane-based ethanol and 3.28 billion litres for grain-based ethanol. In terms of distillation units, there were 263 cane-based and 123 grain-based units in the country in 2022. The state-wise share in the country's installed capacity for grain and cane-based ethanol is provided in Figure 7.

For molasses-based ethanol production, 12 states account for the total distillation capacity. The highest share is of Maharashtra (36 percent), followed by Uttar Pradesh (33 percent), Karnataka (16 percent), Tamil Nadu (3 percent), Bihar (3 percent), and Gujarat (2 percent). Andhra Pradesh, Haryana, Telangana, Uttarakhand, Punjab, and Madhya Pradesh account for about 1 percent each (Figure 7 LHS).

> “NITI Aayog, in its ethanol roadmap, states that supply chains for OMCs would need to be augmented to support E20 blended petrol.”

FIGURE: 7

State-wise cane and grain-based distillation capacity (%) in 2022



Source: PIB 2022

Of the total grain-based distillation capacity of 3.28 billion litres, 94 percent of the capacity is in 11 states. Punjab has the highest share of 23 percent followed by Haryana (15 percent), Maharashtra (13 percent), Andhra Pradesh (12 percent), Bihar (7 percent), Karnataka (6 percent), Madhya Pradesh (5 percent), Jharkhand (4 percent), Rajasthan (4 percent), West Bengal (3 percent), and Telangana (2 percent) (Figure 7 RHS).

As the distillation capacity for both sugarcane and grain-based ethanol is geographically concentrated, there exist issues with ethanol logistics related to transportation of ethanol to deficient areas/states. NITI Aayog, in its ethanol roadmap, states that supply chains for OMCs would need to be augmented to support E20 blended petrol.

PART-3

Quantitative Assessment of Feedstock Availability for Achieving E20 by 2025-26

FOLLOWING an assessment of the requirements of specific crops (Table 2), we move to projections on the balance sheet of crops. As ethanol production in the country revolves around sugarcane, maize, and rice (both from the FCI and the open market), we project the balance sheets of these crops for the year 2025-26.

CONCEPT OF CROP BALANCE SHEETS

The concept of balance sheet has two key elements of demand and supply. By subtracting the projected demand from supply, we estimate residue of the crop that can be made available for ethanol production. We compare this estimate of residue with ethanol demand benchmarks based on NITI Aayog's roadmap document. If the residue exceeds or equals the benchmark demand, we interpret it as a surplus or sufficiency. But in case the residue is negative, we deduce a deficit (Figure 8).

The supply or availability of any crop at any point constitutes the sum total of a year's production of a crop, besides factoring in available previous stocks and exports and imports. Additionally, supplies for any types of physical losses along the value-chain are adjusted. Although the underlying method for estimating surpluses has been kept identical across three crops in our estimates, some adjustments have been made while considering specific situations. The crop-specific methodologies have been detailed in the respective sections.

FIGURE: 8

Balance sheet approach to assess availability of feedstock

SCENARIOS FOR PREDICTIONS

For understanding future availability or supply of crops, we project the following scenarios:

a. As production is a function of area and yields, the data of previous years on area under the crops and yields have been taken into account and projected for the future, using econometric modelling. Future production has been estimated by multiplying the projected area and yields for the three crops, respectively. These supply projections for each of the three crops have been considered as the base case or a Business-As-Usual (BAU) case.

b. Scenarios of supply shocks in BAU case: Negative shocks may happen because of climate change and loss of acreage under the crops, in a scenario when farmers move to other lucrative crops. Positive shocks may come from technology improvements, better farming practices, or because of increased area under cultivation for the crop. We simulate for both positive and negative supply shocks.

c. Secondary sources of projections: In addition to our own projections, we utilize existing sources of supply projections from international organisations like the Organisation for Economic Co-operation and Development (OECD) and the United States Department of Agriculture (USDA). These agencies regularly release projections of demand and supply for major Indian crops.

The demand (or absorption) in the economy at any point in time constitutes the sum of household domestic consumption demand, industrial use demand, and the level of stocks statutorily or normally required to be kept in the economy (like in the case of sugar and rice). Based on past data, imports have also been accounted for, wherever required. The demand on crops for ethanol production has been studied via the residue method, as explained before.

To understand the future demand for crops, we project different scenarios, based on the following:

a. Future consumption of the crop is based on the actual data of previous years. The projected consumption is also adjusted for changes in income levels of consumers (using macro-level GDP projections) and the relative demand elasticity of the commodity. This has been done to account for changes in consumption patterns over the years.

b. Existing sources for demand projections such as OECD and USDA.

While making the projections and arriving at estimates on future demands of crops, several assumptions have been made, based on factors such as exports, opening and closing stocks for crops, wastages in the supply chain, etc. Estimates for each crop are given in the following pages.

Sugarcane projected to be the largest feedstock for meeting E20 targets

INDIA and Brazil are the largest sugarcane producers in the world (FAOSTAT). In 2021-22, India produced 439 MMTs of sugarcane. As per GOI's second advance estimates (SEA), in 2022-23, around 469 MMTs of sugarcane was produced in the country. Sugarcane production is concentrated in a few Indian states, with just three states accounting for about 77 percent of total cane production. The states are Uttar Pradesh (UP) (47 percent), Maharashtra (MH) (21 percent), and Karnataka (KA) (9 percent) (TE 2019-20). Production of ethanol from molasses is also concentrated in these three states. As stated earlier, close to 85 percent of the country's cane-based distillation capacity is situated in MH (36 percent), UP (33 percent), and KA (16 percent) (2022).

The Indian sugar industry is highly regulated, with clear guidelines on cultivation of sugarcane and production of sugar and its by-products, such as molasses and ethanol. These regulations are in the form of area reserved for sugarcane cultivation, minimum distance between sugar mills, price fixation, buffer stocks, sale of sugar by mills, and trade policy for regulation of tariffs. Regulatory powers are exercised by both the central and state governments. To deliver remunerative prices to cane farmers, GOI annually announces a minimum price for sugarcane, known as Fair and Remunerative Prices (FRP). For the year 2022-23, the FRP for sugarcane has been fixed at Rs. 305 per quintal. India pays the highest price for its sugarcane, across major sugarcane producers in the world (Figure 9).

Compared to other crop combinations, sugarcane in India delivers among the highest rates of assured profitability to farmers (CACP). This is because the sugar mills are mandated by Sugarcane Control Order 1966 to pay the FRP to farmers. In year 2019-20, on an average, sugarcane farmers in the three largest cane producing states of UP, MH, and KA, made substantial profits: Ranging from Rs. 1,00,000 to per hectare in MH Rs. 1,36,000 per hectare in KA. Their profitability rates (over paid-out costs and cost of family labour) ranged from 87 percent in MH to 276 percent in KA. The values of UP were within these ranges. Sugarcane farming in MH is the costliest among the three states. Compared to the other two states, the exceptionally high usage of fertilisers and heavier dependence on labour for cultivation pulls up the cost of cultivation in MH.

Close to 7.3 percent of the total sugarcane is lost in India along the supply chain that involves processes such as harvesting, collecting, grading and sorting, transportation

FIGURE: 9

Average price of sugarcane in 2021-22 (Rs. / tonne)

Source: The data on sugarcane prices in Australia is taken from the Australian Government—Department of Agriculture, Fisheries and Forestry (ABARES), and the exchange rate data is taken from the Reserve Bank of Australia. The data on Brazilian sugarcane prices are taken from the United States Department of Agriculture (USDA)—Sugar Annual Report 2022. The exchange rate data is collected from the Board of governors of the Federal Reserve System.

to sugar millsand processing etc (NABCON[7] 2022). In addition, about one-quarter or approximately 25 percent of the sugarcane gets used up for production of jaggery/ *khandsari* [8] (ISMA 2020). Sugar mills utilise the remaining sugarcane to produce sugar, bagasse, press mud, and molasses that gets used for the production of alcohol, ethanol, and cattle feed.

India produced about 35.9 MMTs of sugar in 2021-22. In 2021, domestic consumption of sugar was estimated to be between 26 to 27.5 MMTs (GOI and ISMA respectively). Since 2018-19, increasing quantities of sugarcane are being diverted toward ethanol production (3.5 MMTs equivalent of sugar in 2021-22). This is expected to rise to around 4 to 4.5 MMTs in 2022-23). India has continued to produce surplus sugar. In TE 2021-22, India exported 7.6 MMTs of sugar, making it the second largest sugar exporter in 2021-22 after Brazil.

PROCESS OF PRODUCING ETHANOL: AS MAIN AND BY-PRODUCT

As our objective is to predict future supplies of sugarcane and assess its sufficiency for meeting the ethanol fuel-blending targets, this section—providing brief details of the physical process of ethanol production—becomes critical on two counts: First, it outlines the method that Indian mills and distilleries use to produce sugar and other products. Second, it lists the assumptions that we have made for making the predictions.

Process of making ethanol: It is critical to understand that ethanol can be produced both from molasses (A, B and C-Heavy) and as a fresh product made directly from sugarcane juice. A higher value of sucrose in the feedstock enables higher efficiency in ethanol production. For example, if ethanol is produced directly from sugarcane juice, a mill can get about 62 to 70 litres of ethanol per tonne of sugarcane. However, if ethanol is produced as a by-product—when mills extract other ingredients including sugar—every tonne of sugarcane is likely to give anywhere between 18 to 20 litres of ethanol. We explain this below.

1. **Extraction of juice/sucrose from sugarcane:** Depending upon the recovery rate of sugarcane (defined as the rate of sucrose that every tonne of cane yields), a mill extracts juice. Based on the difference in milling efficiency and the amount of sucrose content (total recoverable sugar) in sugarcane, the recovery rate across the county is found to be anywhere between 10.75 to 11.04 percent (based on ISMA data and discussions with distilleries). The recovery rates differ across Indian states. For major sugarcane producing states such as UP, MH and KA, the recovery rates are found to be 11.43 percent, 11.21 percent, and 10.92 percent respectively (ISMA 2020-21).

2. **Ethanol produced directly from sugarcane juice:** Raw sugarcane juice can be directly diverted for ethanol production. This process yields no sugar in the process. Accounting for differences in milling/distillation efficiency, sugarcane juice from 1 tonne of sugarcane yields anywhere between 62 to 70 litres of ethanol.

3. **Ethanol as by-product of sugar production:** In this method, raw juice is processed to produce sugar. This process produces A, B and C-Heavy molasses. This molasses can be used to produce ethanol. Both sugar and ethanol can be produced by using A, B, and C-Heavy molasses routes, with different per tonne sugarcane to sugar and ethanol conversion rates (Mohan, Swain and Paroha 2017). Based on discussions with sugarcane-based ethanol distilleries and data from ISMA, the recovery rate of sugar from sugarcane is found to be between 10.75 to 11.04 percent, meaning that one tonne of sugarcane yields anywhere between 107.5 to 110.4 kilograms of sugar.

7 NABARD Consultancy Services Private Limited

8 Jaggery is a traditional non-centrifugal cane sugar and *Khandsari* is a type of unrefined raw white sugar made from thickened sugar cane syrup

As stated earlier, with amendments to NPB 2018, more distilleries are focusing on B-heavy molasses route for sugar and ethanol production. Based on discussion with distilleries in the two high ethanol producing states of UP and MH, the following conversion rates for ethanol from one tonne of sugarcane during the process of making sugar are observed:

i. High efficiency conversion rates: In efficient distilleries, one tonne of sugarcane yields 20 litres of ethanol.

ii. Low efficiency conversion rates: One tonne of sugarcane yields 18 litres of ethanol.

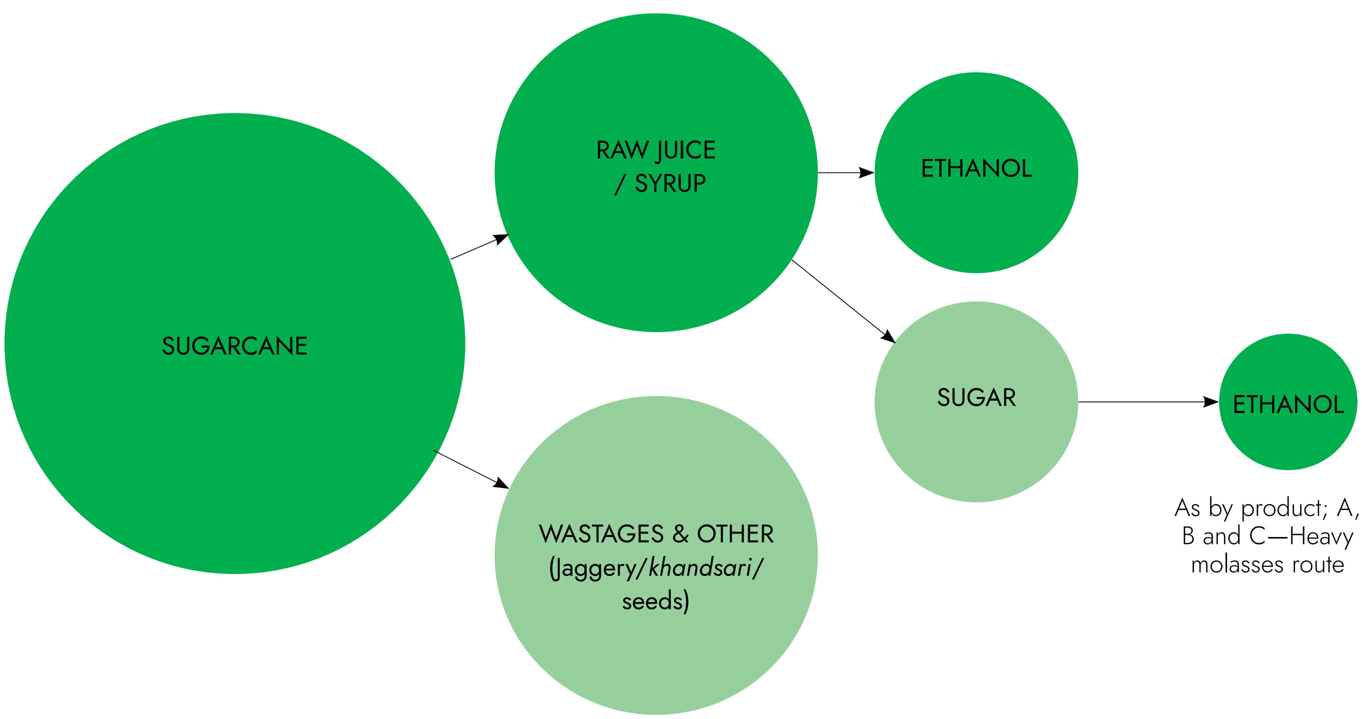
Figure 10 below summarises the sugar and ethanol production process from sugarcane. Our approach to estimate sugarcane availability for ethanol production has been based on this process. It is important to note that in no scenario has ethanol supply prioritised over fulfilling aggregate sugar demand (without exports) in our balance sheet calculations.

METHODOLOGY FOR ESTIMATING ETHANOL SUPPLY IN 2025-26

The NITI Aayog Roadmap enlists the proportionate share of supply from sugarcane juice/ syrup, B-heavy molasses, and C-heavy molasses. Experts and sugar/ethanol manufacturers said during discussions that the industry would produce enough sugar to meet domestic consumption and stocking requirements in any given year. As per ISMA, two to three months' worth of estimated sugar consumption is advisable to be kept as stocks at any point in time in a year.

FIGURE: 10

Diversion of sugarcane to sugar and ethanol



Source: Authors' interpretation based on discussions with sugar mills and distilleries.

For the balance sheet calculations to project the availability of sugarcane for sugar and ethanol production, we adhered to the following steps:

STEP 1: Forecast the level of sugarcane production and supply through use of econometric techniques. Different sugarcane supply scenarios have been discussed below.

STEP 2: Adjust cane supply forecast by factoring in for wastages, seed/feed use and diversion to jaggery/*khandsari* production to arrive at estimates on net availability of sugarcane for sugar and ethanol production.

STEP 3: Forecast level of domestic sugar demand and estimate the sugar stocking requirements. Based on the conversion rates, sugarcane equivalent of aggregate sugar demand has been estimated.

STEP 4: Divert sugarcane to fulfil aggregate sugar demand. This process will also produce ethanol as a by-product.

STEP 5: Estimate excess sugarcane available after accounting for diversion to fulfil aggregate sugar demand. The sucrose/juice equivalent extracted from this excess sugarcane is directly diverted for ethanol production.

STEP 6: To estimate the total ethanol supply in 2025-26, ethanol supply estimated in Step 4 and 5 has been added.

While estimating demand and supply of cane in 2025-26 for fulfilling E20 targets, some assumptions have been made. These are listed in Table 3 below.

TABLE: 3

Assumptions made for estimating ethanol supply from sugarcane

Variable	Description
Recovery rates	The conversion rates for sugarcane to cane juice, ethanol and sugar mentioned above are assumed to remain at the same levels in 2025-26.
Wastages	As per the latest NABCON 2022 report on post-harvest losses, the losses in sugarcane value chain are about 7.3 percent; we assume wastages at the same level in 2025-26.
Diversion of sugarcane to uses other than sugar/ ethanol	As per ISMA, the diversion of sugarcane for jaggery/*khandsari* production is currently 25 percent, and we assume that in the presence of more lucrative avenues like ethanol, this diversion will fall. We have assumed this diversion to be around 17 to 18 percent.
Stocks of sugar	Sugar stock of 6 MMTs of sugar is to be maintained. Based on the conversion rates, this diversion of sugarcane for fulfilling sugar stocking requirement has also been accounted for in the balance sheet calculations.
Opening stocks	Opening stocks in the current year are assumed to be last year's closing stocks of sugar.
Exports	To estimate the aggregate demand for sugar, exports have not been considered for the balance sheet calculation.
Distillation capacity	It is assumed that required infrastructural capacities, i.e., distillation units, are available for processing sugarcane for ethanol production.

TABLE: 4

Scenarios for forecasting sugarcane production in India

Scenario	Rationale
BAU	Based on ARIMA forecasts
P2	BAU (–) 5 percent (impact of climate change, fall in acreages due to more lucrative competitive crops)
P3	Based on OECD projections (Outlook 2022-2031)

FORECASTING SUPPLY OF SUGARCANE

In forecasting sugarcane availability in the country, three scenarios have been projected (Table 4). The BAU scenario for sugarcane production in 2025-26 is based on area and yields forecast, using data of previous years. As stated earlier, we have modelled area and yields separately in order to forecast production. Based on the forecasted area and yield, production estimates have been calculated.

In forecasting area under sugarcane, an Auto-Regressive Integrated Moving Average (ARIMA) model has been used. For this, GOI's data on area under sugarcane from 2000-01 to 2021-22 has been used. In forecasting yields, an exponential smoothening forecasting technique has been used. This is because of the recent increases in sugarcane yields since 2017-18. Exponential smoothening is preferred over the ARIMA forecasting technique when the forecasts are based on data of previous years, with higher value for more recent observations. In forecasting sugarcane yields, GOI's data from 2010-11 to 2021-22 has been used.

FIGURE: 11

Sugarcane production forecast for 2025-26

Source: Estimated by authors

The prediction efficiency of forecasts can be estimated by the Mean Absolute Percentage Error[9] (MAPE). Econometric literature suggests that the lower the MAPE, the better is the prediction accuracy. MAPE below 10 percent is considered a good indicator of prediction efficiency. The MAPE for area and yield forecasting models are 4.4 percent and 3.4 percent, respectively.

Other production scenarios are: P2 scenario accounting for a 5 percent decrease in availability over BAU scenario because of yield losses due to climate change and/or fall in acreage as farmers shift to more sustainable or lucrative crops. Under the P3 scenario, production of sugarcane is based on an 'as is' assessment from OECD's commodity outlook report 2022-31. Scenario BAU is assumed to be the most likely scenario.

ESTIMATING SUGARCANE AVAILABILITY AFTER ACCOUNTING FOR AGGREGATE SUGAR DEMAND

For the projected balance sheets, two scenarios for estimating sugar consumption demand have been considered. Scenario D1 is based on ISMA data on domestic sugar consumption. Sugar demand in this scenario is extrapolated for 2025-26, using the Compound Annual Growth Rates (CAGR) for the past 5 years (2017-18 to 2021-22). D2 scenario is based on discussions with sugar industry.

By 2025-26, the demand for sugar will range between 28.8 MMTs (D1 scenario) and 29.8 MMTs (D2 scenario). A stock of 6 MMTs of sugar as buffer or carry over stock at the beginning of the year has been considered. For fulfilling this sugar demand in 2025-26 (consumption + stocks) it is estimated that anywhere between 315 to 333 MMTs of sugarcane would be required to fulfill the aggregate demand. These estimates are based on the 10.75 percent and 11.04 percent recovery rates of sugar from sugarcane.

As stated earlier, in all the projections of the supply and demand scenario, meeting sugar demand (domestic consumption, stocks, and excluding export demand) has been prioritised over ethanol production by the sugar mills. To assess the surplus/deficit of

9 The mean absolute percentage error (MAPE) is the mean or average of the absolute percentage errors of forecasts. Error is defined as actual or observed value minus the forecast value. Percentage errors are summed without regard to sign to compute MAPE

sugarcane, we mapped the sugarcane availability situation after accounting for wastages and diversion to other sources such as jaggery/*khandsari*/seeds) as also factors concerning the additional consumption demands plus the requirement for stocks.

It emerges that in 2025-26, sugar demand will be met in all scenarios except a) demand for sugar is higher (D2 scenario) or b) sugarcane supply is lower (P3 scenario) or c) the recovery rate of sugar from sugarcane is lower at 10.75 percent.

We assume that in scenarios where sugar demand is higher than supply, diversion of sugarcane for ethanol or other uses will adjust/ reduce and focus will turn towards fulfilling the domestic demand of sugar first. After meeting the aggregate domestic sugar demand including stocks of sugar, Table 5 presents estimates of excess sugarcane available in case of 11.04 percent recovery rate (most likely scenario).

PROJECTING 2025-26 ETHANOL PRODUCTION FROM MOLASSES

As discussed earlier, molasses is a by-product of the sugar manufacturing process and ethanol can be produced from molasses or directly from sugarcane juice. Estimates on ethanol supply in 2025-26 have been done by way of aggregating the two methods of ethanol production. Assuming a recovery rate of 11.04 percent and the demand scenario 2 (D2) (considered to be the most likely scenario) in 2025-26, our estimates indicate the scenario on ethanol availability as follows:

i. Ethanol as by-product: Anywhere between 5.7 and 6.5 billion litres of ethanol will be produced, while fulfilling the aggregate sugar demand in the country.

ii. Ethanol from cane juice: Between 0.4 and 1.9 billion litres will be produced.

Adding the two estimates—ethanol produced directly from juice and ethanol produced while fulfilling aggregated sugar demand—overall ethanol production from the

TABLE: 5

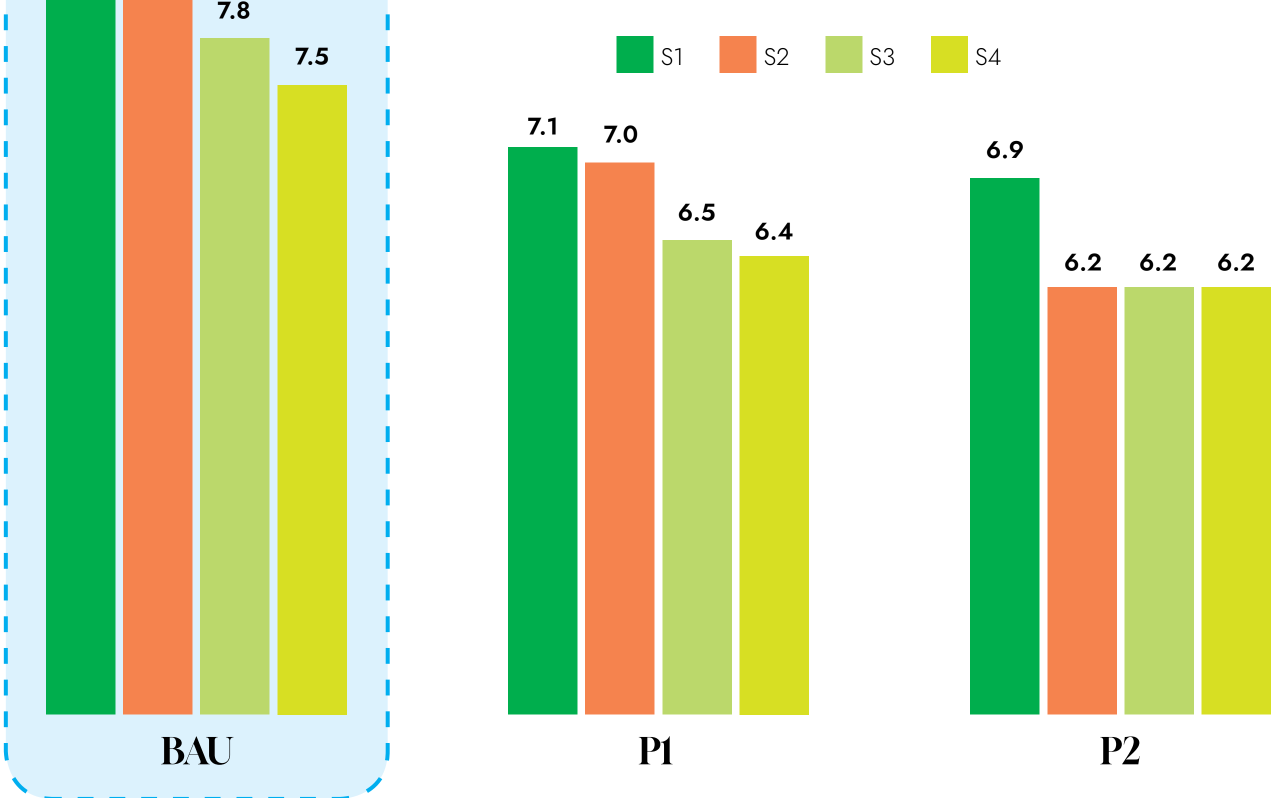
Excess sugarcane after meeting sugar consumption and stocking demand (MMTs)

Scenario	At 11.04 % recovery rate	
	D1	D2
BAU	36	27
P2	19	10
P3	16	7

Source: Estimated by authors. Note: Green means excess availability of sugarcane after accounting for diversion to fulfil domestic sugar demand and stocks requirements.

FIGURE: 12

Estimated total ethanol supply from sugar industry in 2025-26



Source: Estimated by authors. Note: S1, S2, S3 and S4 are scenarios for difference in conversion rates where 'S1'—20 Lt. B-Heavy ethanol and 70 Lt/tn sugarcane from cane juice scenario. 'S2'—20 Lt. B-Heavy ethanol and 62 Lt/tn sugarcane from cane juice. 'S3'—18 Lt. B-Heavy ethanol and 70 Lt/tn sugarcane from cane juice. 'S4'—18 Lt. B-Heavy ethanol and 62 Lt/tn sugarcane from cane juice.

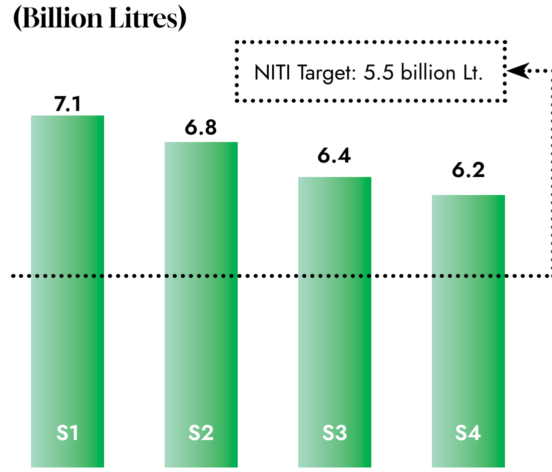
sugarcane industry (assuming 11.04 percent recovery rate) is estimated to be anywhere between 6.2 to 8.4 billion litres (Figure 12).

It is important to note that ethanol demand exists for both fuel blending and other uses. Considering diversion to other uses—estimated at 1.35 billion litres in the most likely scenario—the ethanol supply available for fuel blending is estimated to be between 6.2 to 7.1 billion litres (Figure 13). Data suggests that there will be enough sugarcane feedstock available in 2025-26 to reach the NITI Aayog's target of 5.5 billion litres, while meeting aggregate sugar demand in the country. However, in case production is lower (P2 and P3 scenarios), ethanol supply for fuel blending is expected to fall below the target of 5.5 billion litres and be lower by 0.4 to 0.7 billion litres.

FIGURE: 13

Cane-based ethanol supply for fuel blending in 2025-26

(Billion Litres)



Source: Estimated by authors. Note: Most likely scenario: recovery rate of 11.04%, aggregate sugar demand scenario 'D2' and 'BAU' production scenario.

Maize: not enough to meet the food and feed demand

MAIZE is one of the most important cereal crops and is consumed by more than 900 million human beings globally (CIMMYT). In 2020, 14,232 MMTs of maize was produced worldwide (FAO). USA was the largest producer with a 25 percent share in global production, while India ranked sixth with a production share of 2 percent. In India, maize production has been increasing over the years due to widespread acceptance of hybrid seeds. In TE 2021-22, 31.3 MMTs of maize were produced in the country (Figure 14). In the last decade, production grew on average 4.7 percent annually.

Indian maize consumption is annually about 28.7 MMTs (TE 2021-22) (OECD). Its largest consumer is the feed industry (both cattle and poultry) that absorbs about 55-60 percent of country's maize. The second largest consumer is the starch industry, including pharma, textile, and cosmetic industries. Maize consumption as food is low in the country. Usually in the non-tradable zone, Indian maize exports are residual in nature and not a regular feature. However, in the last three years (TE 2021-22), India exported about 2.1 MMTs of maize annually.

TABLE: 6

Scenarios for estimating maize production

Scenario	Rationale
BAU	Based on ARIMA forecasts
P1	BAU + 5% (likely impact on yields due to technology upgradation, increase in area)
P2	BAU – 5% (impact of climate change, fall in acreages due to more lucrative competitive crops)
P3	Based on changes in area under maize (using regression coefficients)
P4	Based on OECD projections (outlook 2022-2031)

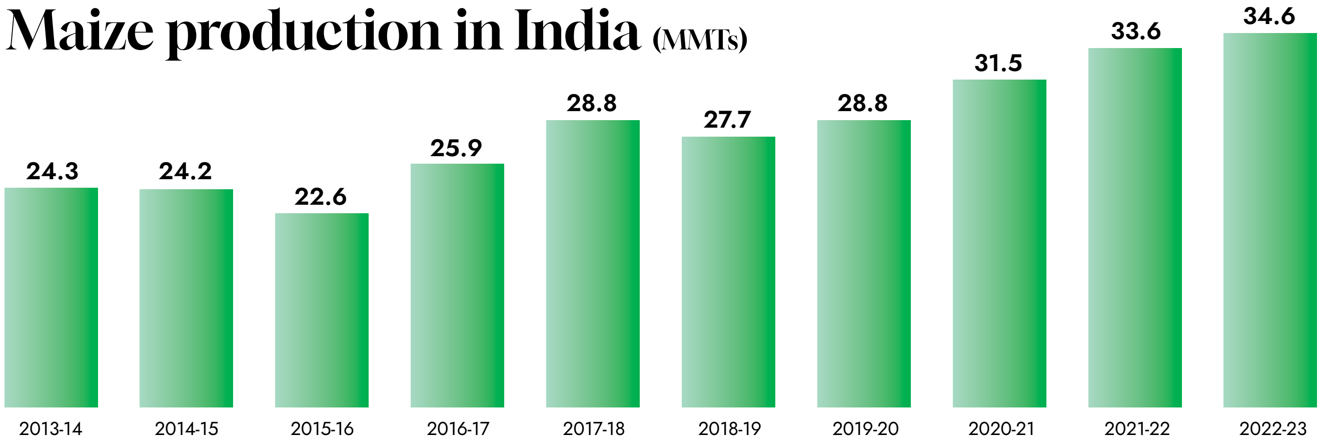
TABLE: 7

Scenarios for estimating maize demand

Scenario	Rationale
D1	Based on OECD projections (outlook 2022-2031)
D2	Extrapolated, with FSI and feed having the same share in production
D3	Extrapolated, with FSI maintaining the same share in production and pegging feed use to growth in the poultry sector value of output (VOO) (using regression coefficients)
D4	Extrapolated, with FSI maintaining the same share in production and pegging feed use to growth in the livestock VOO (using regression coefficients)

FIGURE: 14

Maize production in India (MMTs)



Source: GOI. Note: * data is provisional based on GOI's second advanced estimates.

FIGURE: 15

Approach for estimating surplus/deficit maize for achieving E20

Based on NITI Aayog's Roadmap and our assessment of these targets, 45 percent (4.66 billion litres) of ethanol supply for E20 blending by 2025-26 is expected to be manufactured from grains. As stated in Part 1, we assume that 50 percent of grain-based ethanol will come from maize. This amounts to 2.33 billion litres. Based on maize to ethanol conversion rates reported in the NITI Aayog document, 6.1 MMTs of maize will be required to make 2.33 billion litres of ethanol in 2025-26.

Based on the balance sheet approach, we now assess the net availability of maize to be diverted for ethanol production to achieve the E20 targets by 2025-26. For this, we have estimated the demand and supply position of maize in 2025-26, considering various scenarios of production and consumption. After estimating the net availability of maize, we have arrived at an approximation on the surplus and deficit position of maize vis-à-vis the 2.33 billion litres benchmark. Figure 15 summarises our approach.

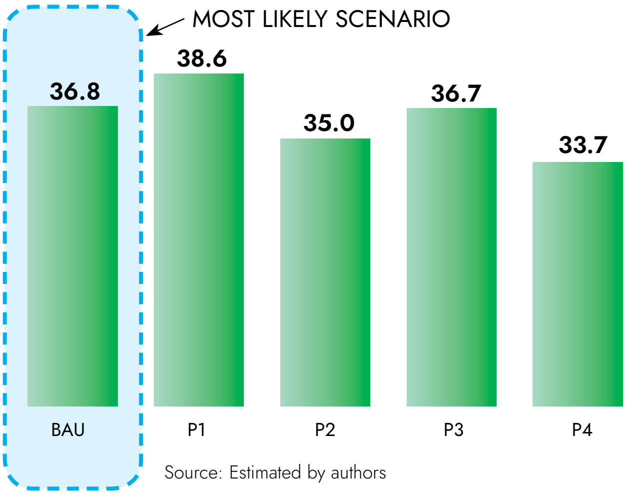
While estimating the demand and supply of maize, the following assumptions have been made:

i. Wastages: As per NABCON's 2022 report on post-harvest losses, the losses in the maize value chain are about 3.8 percent; while assessing availability of maize for consumption, we use the same level of wastages.

ii. Imports and exports of crop have not been considered for assessing surplus/deficit of maize.

FIGURE: 16

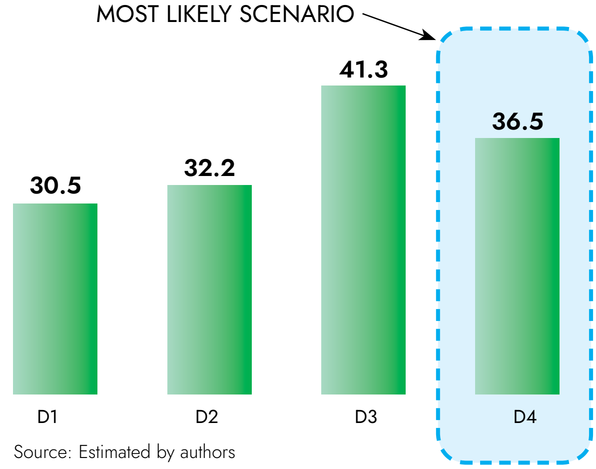
Projected maize supply in 2025-26 (MMTs)



Source: Estimated by authors

FIGURE: 17

Projected maize demand in 2025-26 (MMTs)



Source: Estimated by authors

To estimate availability of maize in 2025-26, five scenarios of supply and four scenarios of demand have been considered. The details of the scenarios are given in Table 6 and Table 7. The BAU supply estimates are based on ARIMA forecasts for area and yields separately. For projecting area and yield, data from GOI sources for 2000 to 2022 has been used. The MAPE for the best fit models for area and yield has been found to be 2.2 and 6.4 percent respectively.

Production scenario P1 assumes an increase in production due to technology upgradation and/or increase in area due to better price realisation by farmers. The P1 scenario is calculated by adding 5 percent to the BAU scenario of maize production. The P2 scenario, on the other hand, tries to estimate the decrease in maize production due to climate change and/or fall in area under maize as farmers shift to more lucrative crops. Scenario P3 is calculated using the relationship between area under maize and production levels. This has been estimated through use of regression coefficients, where production is the dependent variable and area under maize cultivation is the independent variable. Finally, scenario P4 represents OECD production projections taken from OECD's Outlook 2022-31 report.

Demand scenarios are based on maize consumption data from OECD and USDA. Demand scenario D1 represents the 'as-is' OECD projections. Demand scenario D2 has been calculated using USDA data by assuming that FSI (Food, Seed and Industrial) and feed use maintain the same share in production levels of maize. In scenarios D3 and D4, FSI is assumed to maintain the same share in total maize production. However, in D3, feed use is pegged for growth in the poultry sector's value of output (VOO), while in D4, feed use is estimated to grow in the livestock sector's VOO. Considering the recent growth of the Indian poultry sector, demand scenario D3 and D4 are the most likely scenarios of demand.

TABLE: 8

Net availability of maize for ethanol production in 2025-26 (MMTs)

Scenario	D1	D2	D3	D4
BAU	4.8	3.2	-5.9	-1.1
P1	6.6	5.0	-4.2	0.6
P2	3.1	1.4	-7.7	-2.9
P3	4.7	3.1	-6.1	-1.3
P4	1.9	0.2	-8.9	-4.1

Source: Estimated by authors. Note: Blue means excess, and orange means deficits

Based on the above scenarios, maize production is expected to range between 33.7 MMTs and 38.6 MMTs (Figure 16), and maize demand is likely to range between 30.5 MMTs and 41.3 MMTs in 2025-26 (Figure 17).

ESTIMATING NET AVAILABILITY OF MAIZE FOR ETHANOL PRODUCTION

We have estimated net availability of maize by subtracting production[10] from demand. In these estimates, production has been adjusted for wastages. Estimates for surplus/deficit are presented in Table 8 below. It is important to note that export has not been considered while calculating net availability. The results suggest that the availability of maize—a critical input for livestock—is already expected to be in deficit by 2025-26 for the most likely demand-scenarios of D3 and D4.

SURPLUS/DEFICIT OF MAIZE FOR ACHIEVING ETHANOL SUPPLY TARGET

As estimated in the previous section, the country needs about 6.1 MMTs of maize, to meet E20 target for 2025-26 for supply of 2.33 billion litres of ethanol. This implies that in 19 out of the total 20 scenarios, there is no scope for maize availability to achieve the 2.33 billion litres supply target. In the most likely scenario (BAU-D4), there is a deficit of (—) 7.3 MMTs of maize.

10 Within a year, stocks of maize are assumed to have exhausted and thus closing stock is taken to be 0.

Rice: among the most efficient feedstock, but competes with food needs

RICE is amongst the most important food crops of the country. Its production in India has increased significantly in recent years (Figure 18). Between 1950-51 and 2021-22, production increased from 20.58 MMTs to 129 MMTs. In 2022-23, as per GOI's second advanced estimate, rice production is expected be around 130.8 MMTs. In TE 2020-21, 44.29 million hectares was under rice cultivation. The average yield for TE 2020-21 was 2.69 tonnes per hectare (Agriculture Statistics at a Glance 2021).

Between 2016-17 and 2019-20, the major rice producing states were West Bengal (13 percent), Uttar Pradesh (13 percent), Punjab (11 percent), Andhra Pradesh (7 percent), Odisha (6 percent), Telangana (6 percent), Tamil Nadu (6 percent), Chhattisgarh (5 percent), Bihar (6 percent), Assam (4 percent), Haryana (4 percent), and Madhya Pradesh (4 percent). India is also a large exporter of rice. In 2021-22, India exported about 20.5 MMTs of rice (Ministry of Commerce and Industry). Of this, 3.9 MMTs were basmati rice exports.

In addition, the FCI and other state procurement agencies obtain a share of the total rice produced in the country. This is to fulfil commitments under the National Food Security Act (NSFA) 2013.[11] As per NSFA, 67 percent of the Indian population is eligible for subsidised rations, comprising mainly of rice and wheat. Currently, 813 million persons are under the coverage of the NSFA and about 35 to 38 MMTs of rice is distributed annually among the identified beneficiaries under various governmental programs.

To distribute rice under these programs, GOI undertakes paddy procurement operations at Minimum Support Prices (MSP). There are detailed guidelines of the Union Government for procurement of paddy and its conversion into rice. Food grains, including rice, are required to be procured within a stipulated time, passing the quality specifications criteria decided by Department of Food and Public Distribution (DFPD). Over the years, the MSP of paddy has increased. For the *kharif* marketing season (KMS) 2022-23, the MSP for paddy was set at Rs. 2040/quintal as compared to Rs. 1940/quintal for the 2021-22 KMS. Rice procurement operations are undertaken at *mandis*[12] and Primary Agricultural Co-operative societies (PACs). In TE 2021-22, 57.1 MMTs of rice was procured in the country (DFPD), accounting for 46 percent of the total production and 59 percent of the total marketed surplus[13] of rice.

On the distribution side, the offtake of rice from the central pool (FCI) was 48.2 MMTs in TE 2021-22. Offtake includes allocation of rice under NSFA, defence, OMSS-D (open market sale scheme-domestic) operations, and allocations made to the World Food Programme (DFPD). On account of the Covid-19 pandemic in 2020-21, the PM-GKAY (*Pradhan Mantri Garib Kalyan Anna Yojana*) scheme was launched, providing for an additional 5 kg of food grains every month to eligible households under the public distribution system, thus increasing overall offtake. Due to lower availability of wheat in Government Stock (central pool), the Government allocated rice in place of wheat even in states where wheat is the staple food.

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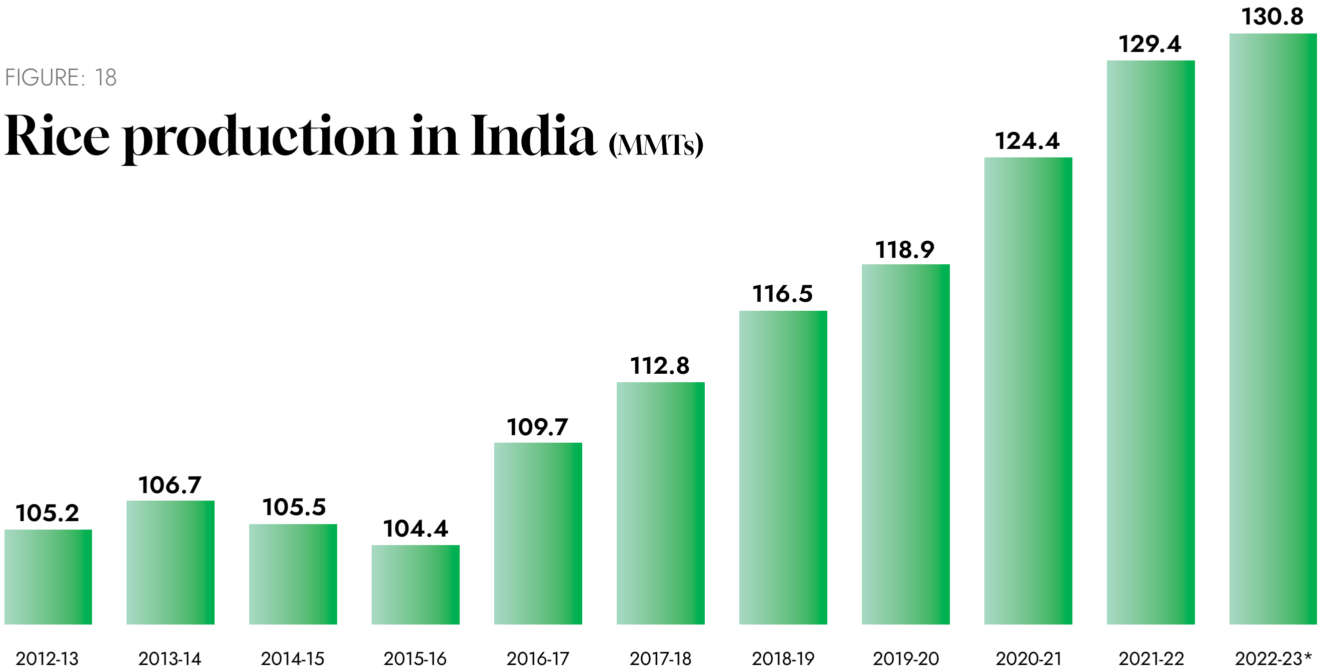
11 India enacted NSFA in 2013. The Act legally entitles up to 75 percent of the rural population and 50 percent of the urban population to receive subsidised food grains under the targeted public distribution system (NSFA).

12 Primary agricultural markets.

13 Marketable surplus is the quantity available for sale in markets after accounting for quantity retained for self-consumption by farmers. A 2015 study finds that 78 percent of total rice production is available for sale in the markets and the rest is retained by producers (Sharma 2016).

FIGURE: 18

Rice production in India (MMTs)



Source: Department of Economics and Statistics. Note: * Data is provisional, based on GOI's second advanced estimates

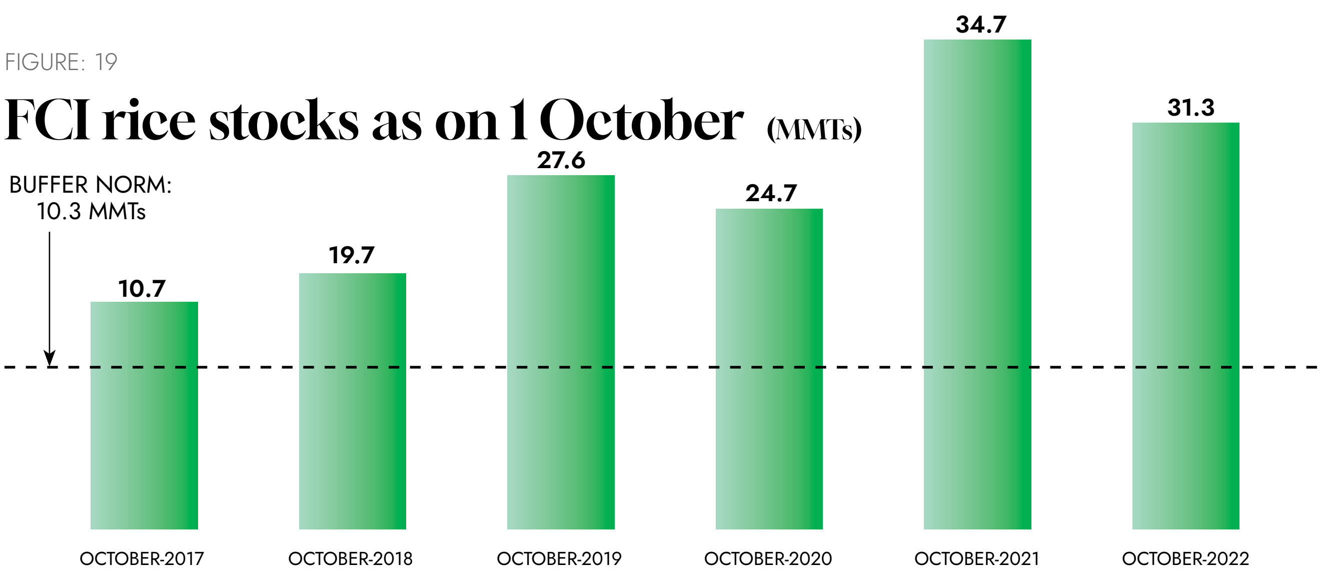
TABLE: 9

Assumptions for estimating ethanol supply from rice

Variable	Description
Wastage	As per NABCON's 2022 report on post-harvest losses, 4.77 percent of total paddy production is lost. For the rice balance sheets, the estimated production in 2025-26 is adjusted downwards with this factor. As production estimates are for rice, we use the conversion factor of 0.67 to assess the level of paddy. This factor is taken from FCI.
Stocks with FCI	Based on previous years' data, it is assumed that FCI will stock a minimum of 20.6 MMTs (2x the stocking norm of 10.3 MMTs)
Stocks with trade	It is assumed that private trade will hold three months' worth of domestic rice consumption as stocks.
Exports and imports	Based on current data, discussions with experts and OECD projections, it is assumed that the country will export a minimum of 20 to 21.4 MMTs of rice in 2025-26. Imports are assumed to be 0 MMTs.
Opening stock	Opening stock is last year's closing stock.

FIGURE: 19

FCI rice stocks as on 1 October (MMTs)



Source: Food Corporation of India (FCI)

In December 2022, GOI merged PM-GKAY with NFSA and reverted the NFSA to its original pre- Covid-19 status, providing for entitlements of rice and wheat completely free. GOI discontinued the additional grain allocations under the PM-GKAY. Excluding the PM-GKAY years, the average offtake of rice reported by the DFPD was about 35 MMTs.

In addition to supply of rice and wheat under the GOI's food-based welfare programs, GOI mandates FCI to hold additional stocks (referred to as strategic stocks) that are to be utilized by GOI to smoothen any inter or intra-year supply shocks. To meet these needs, FCI is mandated to maintain minimum stock levels of these grains, referred to as buffer stock norms. As on October 1 (starting of the new rice season), minimum rice stock norm is 10.3 MMTs, but, FCI has held more than 2 times these norms (Figure 19).

To estimate the level of rice surplus/deficit for meeting ethanol production, the following steps have been followed:

STEP 1: Forecast the level of rice production. Different rice production scenarios have been discussed below.

STEP 2: Adjust the production forecast for wastage to estimate net availability of rice for consumption and other uses.

STEP 3: Assess the consumption of rice. This has been based on OECD and NSSO (extrapolated) estimates.

STEP 4: Estimate net availability of rice after accounting for wastages, aggregate domestic consumption and export demand.

STEP 5: Map net availability of rice with feedstock required for fulfilling supply target and estimate surplus/deficit of feedstock in 2025-26.

While estimating demand and production of rice in 2025-26, some assumptions have been made. These are listed in Table 9.

RICE PRODUCTION AND CONSUMPTION IN 2025-26

For production of rice in 2025-26, three scenarios have been considered. These are listed below:

1. The BAU method: These estimates have been done by using ARIMA-based modelling on GOI data from 2000-01 to 2021-22. Separate forecasts for area and yield have been done. The MAPE of the area and yield forecast models were found to be 2.9 and 3.38 percent, respectively.

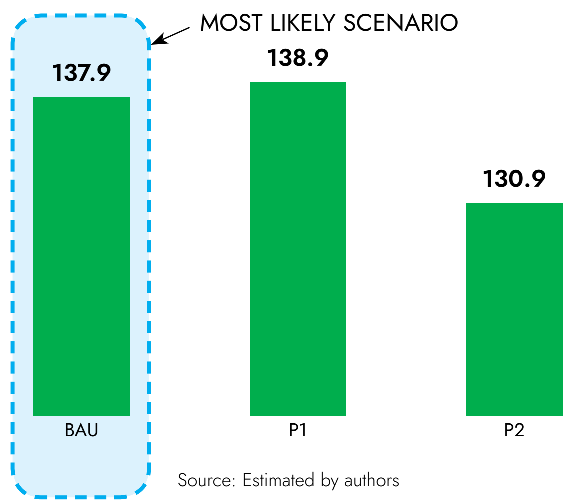
2. P1: Based on OECD projections (OECD outlook 2022-31)

3. P2: BAU (—) 5 percent. This scenario assumes a negative impact on yields due to climate change.

Based on these three scenarios in 2025-26, rice production is expected to be anywhere between 130.9 to 138.9 MMTs against the current production of about 131 MMTs (Figure 20).

FIGURE: 20

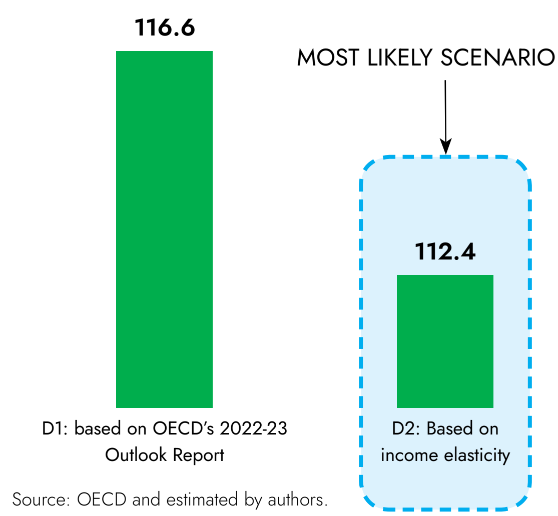
Projected rice production in 2025-26 (MMTs)



Source: Estimated by authors

FIGURE: 21

Rice consumption in 2025-26 (MMTs)



Source: OECD and estimated by authors.
Estimates of rice surplus or deficits

TABLE: 10

Net available rice for diversion to ethanol production

Scenarios	D1	D2
BAU	-7.8	-1.2
P1	-6.2	0.4
P2	-14.5	-7.8

Source: Estimated by authors. Note: **Blue** indicates excess and **orange** denotes deficits.

For assessing domestic consumption in 2025-26, two scenarios have been considered. In the first case, consumption estimates are based on 'as-is' assessments from OECD's 2022-31 outlook report. The other consumption estimate has been determined by using NSSO's 2011-12 Household Consumption Expenditure survey. For extrapolation of 2011-12 consumption estimates per capita GDP growth rates (sourced from IMF), income elasticity of rice (sourced from Kumar 2017) and population projection based on Census 2011 data are used. Based on the two estimates, rice consumption demand is projected to be anywhere between 112.4 to 116.6 MMTs (Figure 21) in 2025-26.

ESTIMATES OF RICE SURPLUS OR DEFICITS

Based on the requirement of rice presented in Table 2, the country is likely to need about 5.5 MMTs of rice for producing ethanol to meet the fuel-blending needs of E20 by 2025-26.

If the country wishes to continue annual exports of about 20 MMTs of rice (including about 4.5 MMTs for basmati) and both the FCI and private sector continue to maintain stock as per their respective past stocking behaviour, India is not likely to even have enough rice to meet its domestic rice demand in year 2025-26 (Table 10). But if the exports fall and/or FCI and private stakeholders reduce their stocks, rice may be available for ethanol production.

In 2021-22, around 1 MMTs of FCI's surplus rice was diverted for ethanol production (DFPD). As per the calculations above, if this diversion from FCI's stock is to continue in future, projections are that either FCI will be willing to hold smaller level of stocks. Or, rice exports will get lower. If exports fall to 15 MMTs, after fulfilling the existing deficit of 1.2 MMTs, the net surplus of 3.8 MMTs can be utilised towards producing about 1.62 Billion litres of ethanol.

Connecting the dots for the three crops

AS per NITI Aayog document, the country needs about 10.16 billion litres of ethanol in order to meet the E20 mandate by 2025-26. Our estimates are that the possible supply of ethanol from the three crops can range anywhere between 7.5 and 10.02 billion litres (Table 11). In case there are production shocks owing to climate change or diversion of area under rice to more sustainable crops, especially in northwest India, the availability of rice for ethanol is likely to shrink further. It is important to note that as per NITI Aayog's Roadmap, the country needs about 13.5 billion litres of ethanol in 2025-26, of which 10.16 billion litres will be required for fuel-blending. Our estimates show that **the three crops together cannot even meet the fuel-bending requirement**, let alone the additional requirement of about 3.34 billion litres for other uses.

TABLE: 11

Ethanol 2025-26 supply: most-likely scenarios for sugarcane, maize, and rice

Feedstock	Most-likely scenario	Estimated ethanol supply (Billion Litres)
Sugarcane	Production scenario 'BAU' @ 469 MMTs, demand scenario 'D2' @ 35.8 MMTs of sugar, 11.04 percent cane to sugar recovery rate, 20 lt/tn cane B-Heavy ethanol production and 70 lt/tn cane ethanol produced directly from sugarcane juice.	7.5 to 8.4
Maize	Production scenario 'BAU' @ 36.8 MMTs, demand scenario 'D4' @ 36.5 MMTs and ethanol yield at 380 litres per tonne maize.	0
Rice	Production scenario 'BAU' @ 137.9 MMTs, demand scenario 'D2' @ 112.4 MMTs, exports @ 20 MMTs or 15 MMTs and ethanol yield at 425 litres per tonne rice.	0 to 1.62

Source: Estimated by authors. Note: If rice exports remain at 20 MMTs, then ethanol supply is estimated to be 0 and if exports fall to 15 MMTs, ethanol supply is estimated to be about 1.62 billion litres.

It is important to note that these estimates are based on certain assumptions. A change in these assumptions might alter the overall ethanol supply. Special considerations are required for the following:

1. **Ethanol demand can be higher than 13.5 billion litres:** As stated earlier, the ethanol demand for fuel-blending is estimated by NITI Aayog based on the demand for petrol and the level of adoption of electric vehicles in the country. However, the industry expects that the overall petrol fuel demand will be higher by about one or two percent, compared to NITI Aayog's forecast. It will be interesting to watch the impact of increased electric vehicle adoption and the resulting impact on the petrol and ethanol demand. In addition, the alcoholic beverage industry in India is one of the fastest growing in the world due to rapid increase in urban population and rising incomes. Different studies have estimated that in the next few years, the segment is likely to grow anywhere between 4 and 8 percent per annum (IMARC 2021 and Singla 2023). Thus, the 3.34 billion litre quota for ethanol for other uses, as estimated by NITI Aayog, might be an underestimation. This means that if ethanol demand is above 13.5 billion litres, then the estimated supply would be even in bigger deficit vis-à-vis supply targets in 2025-26.

2. **Distillation works at lower capacity:** In discussions with distilleries, it was observed that due to unavailability of crop feedstock around the year, distillation plants work at around 30 to 40 percent of their total capacity. In addition, efficiency rates for refineries also differ. Therefore, the shortfall in actual ethanol supply vis-à-vis the targets may increase considerably, if these factors are taken into consideration.

3. **Impact of climate change:** In recent times there have been increased instances of yield losses of all crops due to untimely and excessive rains, dry spells, and droughts (Mishra 2022, Palanisami et al. 2017). The scenarios for production considered in our balance sheets for the three feedstocks account for the impact of climate change. However, if the impact of climate change magnifies, leading to further reduction in yields, then the availability of feedstock of the three crops would reduce further.

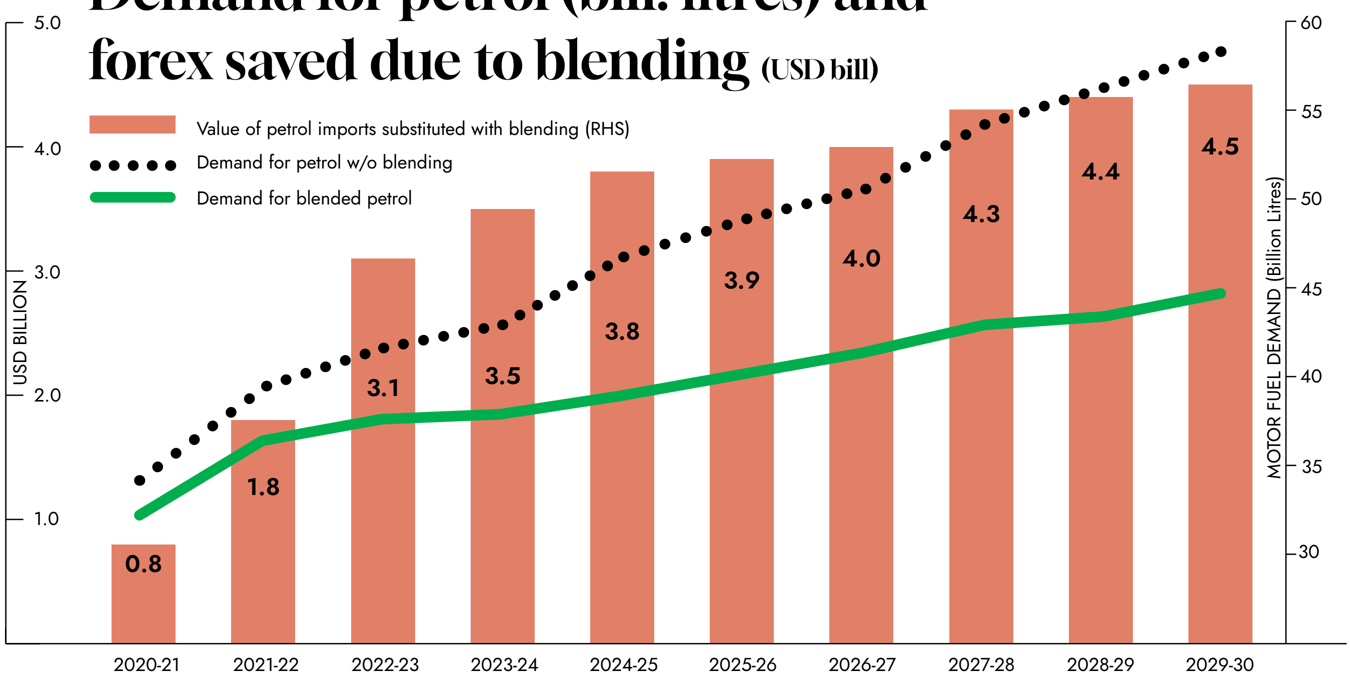
PART-4

Assessing the E20 Mandate

THE policy thrust on ethanol for fuel blending is anchored on the idea of reducing the country's dependence on imported fuel. The argument is not unfounded. Using demand projections for motor gasoline (petrol) by NITI Aayog and the per barrel rate of crude oil from the World Bank, we find that India will increasingly save foreign exchange as ethanol blending increases. In Figure 22, the dotted line indicates the demand for petrol in a scenario when there is no blending of ethanol in petrol. The solid line shows the demand for petrol if ethanol blending is considered. The bars represents the amount of forex saved in USD through the blending of ethanol in petrol. It is estimated that if E20 plays out by 2025-26, India is likely to save about USD 4 to 4.5 billion of foreign exchange annually. Of course, if any of the assumptions[14] turn out to be incorrect, the projections are likely to vary. NITI Aayog also estimated that E20 blending could save India USD 4 billion in foreign exchange each year.

FIGURE: 22

Demand for petrol (bill. litres) and forex saved due to blending (USD bill)



Source: Estimated by authors based on data from NITI Aayog, World Bank

14 Projected data on oil prices was available only until 2023-24; the, per barrel price of oil since 2024-25 is assumed to be same as last five-year average including 2022-23 and 2023-24 projections. Blending rates after 2025-26 are assumed to be at 20 percent levels.

But is E20 achievable? As the analysis above indicates, it is unlikely if it is dependent only on business-as-usual (BAU) situation and domestic crop surpluses. India cannot afford to have OMCs compete with consumers for grains.

We discuss some of these issues below.

ADDITIONAL LAND AND WATER REQUIREMENT TO ACHIEVE E20

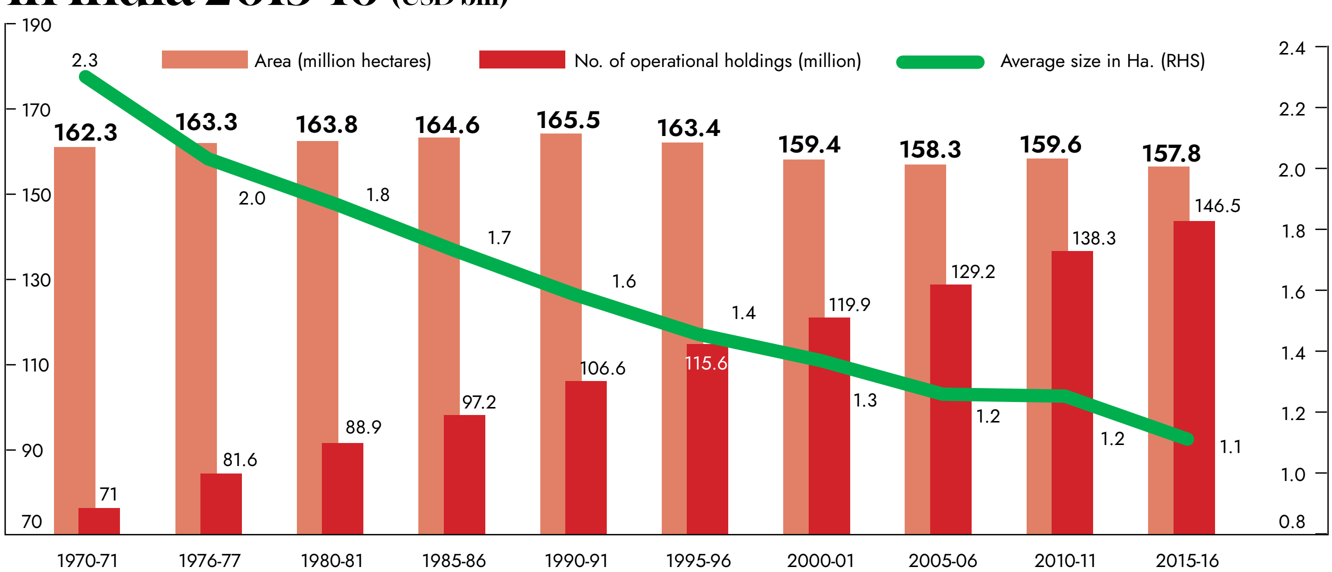
As shown in Table 2, the country is likely to need about 7.1 million hectares of land dedicated to production of crops required to process ethanol for fuel blending. As per data from India's Agricultural Census (various years), India has been losing close to 0.1 million hectares of its agricultural land (operated area) every year since 1970-71 (Figure 23). From 162.3 million hectares in 1970-71, India's operated area under agriculture declined to about 157.8 million hectares by 2015-16. This implies that the country has lost about 4.5 million hectares of agricultural operated area in 45 years. This is largely an outcome of the urbanization push (Pandey & Seto 2015). Hoda 2018 estimated an additional 10 percent cropland loss by 2050. In such situations, how can the country offer a larger proportion of land for growing crops for fuel and not food?

SUGARCANE AND RICE ARE WATER-GUZZLING CROPS

The annual per capita availability of water has been decreasing constantly. Water availability decreased from 5177 cubic meters in 1955 to 1544 cubic meters in 2011 (CWC 2015). Besides, 78 percent of all water resources in India are used by agriculture (CWC 2014). India ranks first in terms of terrestrial water loss, especially in the northern parts of the country (WMO 2021). WMO defines terrestrial water as the sum of surface and sub-surface water. Northern states such as Punjab and Haryana are big producers of rice, while Uttar Pradesh and Maharashtra are the largest producers of sugarcane. As stated above, Punjab and Haryana accounted

FIGURE: 23

Number and area of operational holdings in India 2015-16 (USD bill)



Source: Agriculture Census, various years for 38 percent of total grain-based distillation capacity in India in 2022, while Maharashtra and Uttar Pradesh accounted for about 36 percent and 33 percent of total molasses-based distillation capacity. Research finds that water use in India is inefficient (Gulati and Mohan 2018). For instance, in Maharashtra, only 4 percent of the area is under sugarcane cultivation but it uses 64 percent of the total available irrigation water. Water use efficiency is measured by the Physical Water Productivity (PWP) method. PWP is calculated using total consumptive water use (TCWU) and total production of crop. It is expressed as the ratio of agricultural output to amount of water used. The global average PWP for sugarcane was estimated to be 5.8 kg per cubic metre (Sharma et.al 2018). This means that 5.8 kg of sugarcane requires 1 cubic metre of water. In India, PWP is 5.2 kg per cubic metre. Rice alone consumes about one-third of total water required in Indian agriculture (Sharma 2018). In India, average PWP for rice is estimated to be 0.36. Although there are geographical areas that perform well when seen through the lens of PWP, PWP for rice is high in several regions where there is assured irrigation, but the region itself is water scarce—for instance, parts of Punjab (Sharma 2018).

IMPACT ON VEHICULAR EMISSIONS AND OVERALL ENVIRONMENT

With E20, emissions are likely to fall as blended fuel is expected to produce lower GHG emissions (EESI 2016, NITI Aayog 2021, Reed 2022). Compared to fossil fuels (unblended), vehicular emissions (carbon monoxide (CO), hydrocarbons (HC), and oxides of nitrogen (NO)) are lower in blended fuels. Under E20, CO and HC emissions can potentially fall by 50 percent and 20 percent respectively for two-wheelers, and by 30 percent and 20 percent respectively for four-wheelers (NITI Aayog 2021). GOI states that from 2014-15, there was a reduction of 2.7 MMTs of GHG emissions due to ethanol blending (PIB 2022). However, these estimates only reflect emissions from vehicles when they run on blended fuel. There are reports that consider the life-cycle analysis[15] (LCA) and overall environmental impact of ethanol. LCA allows the consideration of the impact on carbon emissions at each stage of production and use (EPA).

For instance, the sugar industry has been one of the biggest polluters of fresh water. The sugar industry produces about 1000 litres of wastewater for every kilogram of crushed sugarcane (Sahu and Chaudhuri 2015). Effluents discharged from sugar units have a high amount of biochemical oxygen demand (BOD) load, chemical oxygen demand (COD), total suspended solids (TSS), and sulphate (Ranjan et.al 2021). These pollutants can cause damage to water resources in the nearby areas, if not discharged properly. Uttar Pradesh is a major polluting state, as there have been cases of untreated pollutants being discharged in River Ganga. Several legal cases have also been brought against the sugar mills.

Reflecting on ethanol production mandates in Brazil, Lima et al. (2020) finds that Brazilian public policy threatens the Amazon rainforest. Findings are that converting rainforest to farmland, migration of livestock to forest areas, and increased pollution due to increased sugarcane processing can lead to a carbon balance debt that could take centuries to reverse. Moreira (2004) found that increase in the production of ethanol in Brazil led to the additional use of resources such as fertiliser, pesticides, and water. Besides, such large-scale sugarcane-based ethanol production activities caused increasing levels of water pollution in Brazil. Cavalett et al (2012), using a different life-cycle impact assessment model, finds that ethanol is, in fact, better than petrol in

15 LCA helps us assess the impact of fuels on carbon emissions while including each stage of production and use.

tackling global warming and ozone layer depletion threats. However, evidence suggests that the focus on ethanol leads to acidification, eutrophication[16], and increased use of agricultural land. WRI's study on land use and biofuels found that using land for biofuel production is inefficient.

On the other hand, a recent report from the Department of Energy, USA, finds that in terms of the life cycle assessment (LCA) emissions, ethanol from maize fared better than petrol. This was due to the fact that between 2005 and 2021, emission from maize decreased by 20 percent (ANL 2021) due to higher yield.

Overall, there appear to be gaps in understanding the life-cycle impact of increased ethanol blending in the Indian context. Based on our estimates, there will be a need to bring more land under cultivation—or achieve higher productivity—if the country is to achieve its E20 target. Increasing stress on agricultural resources to produce more crops for ethanol production has made it necessary to ascertain environmental impact of such activity. More research is required in this area.

FOOD SECURITY AND IMPACT OF CLIMATE CHANGE ON FOOD SURPLUSES

The Global Hunger Index (GHI) ranks India 107 out of 121 countries and finds that India still has the highest child wasting rate in the world. India's National Family Health Survey 2019 finds that 18.7 percent of women and 16.2 percent men in India have below normal body mass index (BMI).[17] Besides, 35.5 percent of the total number of children below five were stunted and 19.3 percent were wasted. Can or should India use its scarce resources to produce food or fuel?

On the other hand, as per the Rise of Indian Middle-Class report 2022, India's middle class more than doubled from 14 percent to 31 percent between 2004-05 and 2021-22 (PRICE 2022). This increase in incomes for households will have an impact on dietary patterns leading to increased consumption of high value and nutritional products such as pulses, fruits, vegetables, dairy and meat. The use of rice, maize, and sugarcane for ethanol production will create competition for resources and go against the country's nutritional security initiatives that support diversification to crops like pulses.

Climate change also threatens to severely affect food availability in future. As per FAO, crop diversion to biofuels and climate change are the most potent threats to long-term food security.

TRANSFER OF BENEFITS TO CONSUMERS

For owners of two- and four-wheelers, E20 petrol is predicted to reduce vehicle fuel efficiency by 5 to 7 percent (NITI Aayog 2021). This will increase the overall fuel requirement for running a vehicle, affecting household budgets. In addition, there are concerns regarding the price paid by the consumers for fuel in case the procurement price of ethanol rises, leading to an increase in fuel prices. Besides, engines currently being produced are not E20 compatible.

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16 Eutrophication sets off a chain reaction in the ecosystem, starting with an overabundance of algae and plants. The excess algae and plant matter eventually decompose, producing large amounts of carbon dioxide (NOAA).

17 Normal range of BMI is between 18.5 kg/m^2 to 25kg/m^2

Conclusion

IN India, there appears to be both political and industry optimism around ethanol blending. The buoyancy around the likely impact of ethanol-blended fuel on crude import bills, emissions, and mounting sugar surpluses is not unfounded. However, assuming that enough crop surpluses will continue in the future may be rather bullish, as has been estimated and presented in this paper.

Some interesting trends emerge in the case of the three crops/commodities studied in this report:

A. Sugarcane will be the most critical supplier of ethanol for fuel blending in the country. However, threat from climate change, challenges from water-use efficiency and global prices of sugar are some factors that could dampen cane's role in meeting E20 targets.

B. There is a deficit of maize in the country even without the additional demand of ethanol. High demand pressure from the alcoholic beverage industry and the poultry and starch sectors is likely to create competition for maize with OMCs demanding it for ethanol production. Besides, price parity between crops and volatile yields and returns to maize farmers will throw up intense challenges for retaining and growing acreages under the crop.

C. Rice for food or for fuel: In 2022, about 1 MMTs of FCI rice (fit for human consumption) was sold to distillers at subsidized rates for production of ethanol. The availability of this FCI rice is not guaranteed in the longer run. In which case, distillers will have to purchase rice from the open market where they will have to compete with the alcohol beverage industry that relies heavily on open market purchases. Besides, threats from erratic rains, droughts, and rising temperatures are real in the case of paddy. However, irrespective of rice availability, its diversion for fuel manufacturing seems misplaced in a country that is still home to the largest percentage of wasted children in the world and has high rates of malnutrition.

D. Explore alternate feedstocks: There is no doubt that the country may struggle to meet its ethanol demand of 13.5 billion litres by 2025-26. From the viewpoint of resource-use efficiency and sustainability, the country would do well to research alternate feedstocks for increasing ethanol production in the country. Besides, considering the competition for ethanol among OMCs, beverage manufacturers and other industries, there is need to consider the viability of imported ethanol, at least for purposes other than fuel-blending.

E. Invest in improving crop yields: Irrespective of the ethanol needs, the country will do well by investing in yield improvements of its crops. This need cannot be over emphasized.

Indian consumers are increasingly demanding a more diversified food basket (including more plant and animal-based proteins). To address the problems of malnutrition, the country has rightly decided to focus on nutritional security for all. If one combines this scenario with the fact that the country has been losing its agricultural land to, among other things, climate change and urbanisation, there appears to be a need to re-think the current aggressive policy focus encouraging ethanol production by diverting land for growing crops for fuel.

It is creditable that the target of E10 was almost achieved in ESY 2021-22, and it can be sustained in the future too. However, policy makers may have to rethink the aggressive E20 mandate that is to be achieved in less than 3 years.

POLICY RECOMMENDATIONS

The global geopolitical crisis and ongoing climate change are two of the most compelling factors driving policy decisions world over. The dual threats have highlighted the urgent need for countries to become food and energy secure. India, as per the IMF, is likely to remain the fastest growing major economy in the world in 2024. In 2023, India surpassed China to become the world's most populous country (Sundaram 2023). By producing enough surpluses of its staple crops of rice and wheat, the country appears to have achieved food security at the macro level, although widespread malnutrition and deprivation continues to haunt the country's micro level (GHI 2022). The country has been meeting about 86 percent of its energy needs via imported fuels (PPAC). With pressures from climate change and risks from growing geopolitical tensions, every country, including India, is looking for ways to improve both food and energy security. Ethanol sits at the cusp of both: it impacts both and is, in turn, impacted by both.

Crop surpluses, when generated in the system, can be diverted to produce ethanol. This improves avenues of sale for farmers, pulling up their value realisation and augmenting their incomes. By substituting fuel, ethanol reduces a country's dependence on imported fuel.

But as land and water are scarce, crops for fuel directly compete for resources with crops produced for food (WRI 2015). Besides, with the palpable effects of climate change on crop yields, surpluses of a country's staple crops are already dwindling (Gupta and Pathak 2016). Will diversion of food crops like rice and maize affect their availability for food? In the last two years, both of India's staple crops of wheat and rice have suffered due to high temperatures and volatile rainfall patterns. This affected crop yields and shrunk the overall crop surpluses in the system, leading to double-digit inflation in the two cereals at the retail level (data from MOSPI suggests that in January 2023, wheat and rice reported 25.5 percent and 10.4 percent inflation respectively). With uncertainties looming large due to the effects of climate change, and evidence from countries like Brazil, there are lessons that India can build on while making aggressive strides on its ethanol fuel blending targets. We present below some recommendations based on the analytics presented in this work.

1. **Land planning and reviving fallow land:** For its agriculture sector, India needs strategic land planning. This is because India has been losing its arable land while fallow lands have been expanding. In 40 years between 1978-79 and 2018-19, the country lost about 5 million hectares of arable land (LUS, DES). During the same time, the country's fallow land (land that has been away from cultivation for more than 1 year but less than 5 years) increased by about 4.3 million hectares. Unless land planning is proactively undertaken by the governments, unhindered diversion of arable land towards crops for fuel would grow, further crowding out land for food crops. Can the government revive fallow lands and use them for sowing crops for fuel?

2. **Diversion of water for fuel:** Rice and sugarcane are two of the most important feedstocks for ethanol production and both are water-intensive crops. About 2500 litres of water are needed for producing one kilogram of rice (IRRI), and about

about 2,100 litres are required for producing a kilogram of sugar (TNAU). With close to half (about 48 percent) of India's gross cropped area unirrigated and rain-dependant, diverting scarce water to produce crops for fuels may not be the most optimal and desired outcome. Besides, sugarcane is also a large consumer of fertilisers (DES), with huge environmental cost (Chami et al. 2020). Three things, inter alia, are recommended in this regard:

a. The government would do well to outline a threshold crop area and/or crop size that will be allowed for biofuel production.

b. Invest in making both rice and sugarcane cultivation more resource-use efficient. Encouraging use of micro-irrigation techniques like drip irrigation and sprinklers will help, not just by improving crop yields but also by rationalising water usage in the cultivation process.

c. Millets like sorghum, barley, etc., can be used to produce ethanol. These are already being utilised to produce spirits for potable alcohol.

3. **Connecting farmer incomes:** Access to remunerative sale options is likely to pull up value realisation by farmers. While this is likely to be automatic in the case of crops like rice and maize, the case of sugarcane is likely to be different. Revenues generated by the sugar mills from sugar and its by-products, including ethanol, have soared in recent years. However, the increased gains are yet to percolate to the cane farmer, who still receives FRP or State Administered Price (SAP). Revenue sharing formula (RSF) was recommended by the Rangarajan Committee, which suggested that 70 percent of revenue from sugar and primary by-products should be paid as cane price to farmers. This is yet to be completely accepted by any Indian state (CACP 2021). Besides, sugarcane cultivation is the most profitable amongst all possible crop combinations in the country. Such assured and remunerative markets, via ethanol, can be pivotal in achieving PM Modi's dream of doubling farmer incomes.

4. **Alternate means to procure ethanol:** From this paper, it emerges that there will be a deficit of feedstock for meeting the 2025-26 ethanol targets. It is necessary to proactively look for alternate feedstock to ensure ethanol supply and to diversify into crops such as sorghum, bajra and ragi. NPB 2018 discouraged the import of ethanol for fuel blending and ethanol and was subsequently put under the restricted category (DGFT 2019). However, GOI needs to be open to the option of imports to meet demand for ethanol for purposes other than blending, mainly for potable alcohol and industrial purposes and also for fuel blending, if ethanol imports are cheaper than the costs of importing fuel.

5. **Millets for ethanol:** Following a proposal from India, the United Nations has declared the year 2023 as the International Year of Millets. Millets are not just more resilient to climate change impacts (ICRISAT); they also offer more nutrition than staple cereal crops like rice and wheat. Pearl millet, finger millet, and even sorghum can be used to produce ethanol. By promoting the use of millets in ethanol production, GOI can improve environmental sustainability, farmer incomes, and biodiversity simultaneously.

6. **Encourage 2G ethanol:** Instead of producing ethanol directly from crops, the country would do well to encourage faster technological breakthroughs in the production of

ethanol from agricultural waste, straws, stalks, etc. The country can bypass the food vs. fuel debate and yet achieve its blending targets. Given the delay globally in finding these solutions, India can also emerge as a front runner in technology if it finds a commercially viable solution to use 2G technology for ethanol production.

7. **Investments in yields and improving resilience:** Irrespective of the use of crops, policy makers must ensure higher investments in improving crop yields and ensuring the resilience of agriculture to climate change. Investment in crop technologies and yields is vital for India.

8. **Need for local data:** To outline the possible effects of blended fuel on emissions and vehicular efficiency, most data used comes from developed countries like the US, Germany and Brazil. As India's automobile industry differs from that in countries like the US, it is necessary to collect local evidence of the impact of blended fuel. Collection of data on the impact of blending on agricultural land, crop prices, food prices and availability, and the fuel efficiency of vehicles are critical factors to bring credibility and acceptance from consumers and other stakeholders, besides forming the basis for increasing the blending rate in future.

9. **Phased implementation of the mandates even after 2025-26:** Not every state is equally ready for blending, particularly states that are deficit in ethanol production. Similarly, not everyone in a state has a vehicle that will run efficiently on E20. Consumers and OMCs should be given adequate time and options to adjust.

10. **Rethink blending targets:** It will be necessary to rethink NITI Aayog's E20 targets, given the surge in the use of vehicles that run on electricity and other renewable sources of energy. Can the surge in sales of EV in India take some burden off the aggressive ethanol targets? EVs generate less emissions and reduce the country's dependence on imported fuels. The E20 target of requiring 10.16 billion litres of ethanol by 2025-26 may be revised downwards in case some of the emission reduction and exchange saving targets behind E20 are met via say EVs.

11. It is also necessary to ensure the following:

    a. **Educating consumers** on the need for blending and helping them choose the right blended fuel for their vehicle.

    b. **Ensuring appropriate disclosure of the blending level** of available fuel and its prominent display at gas stations.

    c. **Providing fuel options** since not all states will be ready with vehicles to shift to high blended fuel.

    d. **Providing incentives to consumers** to shift to blended fuel given the vehicle efficiency losses with E20.

12. Car manufacturing companies should **encourage production of flex-fuel cars** and spread awareness of their usefulness to consumers.

As per FAO, diversion of crops to ethanol production and climate change are the biggest threats to global food security. India can build on lessons from other countries and, with caution, leverage this unique opportunity to reduce its dependence on imports, while also increasing farmers' incomes.

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Notes

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