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Does India have enough feedstock to meet its E20 fuel-blending targets by 2025?[§]

Shweta Saini[1]* and Siraj Hussain[2]

[1]Arcus Policy Research, New Delhi
[2]formerly Ministry of Agriculture (Government of India)

*Corresponding author: ssaini@arcusresearch.in

Abstract The Indian Government has set the target of achieving 20 per cent blending of ethanol (E20) in petrol by 2025-26. This is projected to achieve savings of about $4 billion in country's annual oil import bill. The NITI Aayog projects country's annual ethanol requirement at 10.16 billion litres to achieve the E20 mandate and an additional 3.34 billion litres to meet the demand from other industries. This paper estimates the requirement and availability of feedstock (sugarcane, rice, and maize) to meet these E20 mandates. The study reveals that India is not likely to have enough feedstocks to meet the E20 blending target by 2025-26. Besides, with climate change and growing pressures on land coupled with the country's growing nutritional requirements, the government may do well to rethink its land-use policy, water-use policy and even its climate-related plans. It should define a medium to long-run roadmap of providing enough crops for fuel blending targets.

Keywords E-20 mandate, ethanol, feedstock availability, sugarcane, rice, maize, energy security, atmanirbharta, food security, fuel blending, India

JEL codes Q1, Q4, C6, O44, O53

India depends on imports to meet roughly 86 per cent of its domestic demand for petroleum products (Saini et al. 2023). Such overwhelming dependence on imported crude oil has an adverse impact on India's energy security and makes the country vulnerable to volatility in globalcrude oil prices (Sati et al. 2022, Rogoff 2022). In 2021-22, India's imports of crude oil were worth USD 120 billion. One of the measures taken by the Indian Government to reduce dependence on imported petroleum is the promotion of bio fuels, mainly ethanol-blended petrol. According to the National Institution of Transforming India (NITI Aayog), an annual saving of US $4 billion could be achieved by ethanol blending of petrol. The measure is also expected to reduce greenhouse gas emissions (Kumar 2021 and PIB 2024).

Since 2018, when the National Policy on Biofuels (NPB) was introduced, considerable progress has been made in achieving the Government's fuel blending target. Between the ethanol supply year (ESY)[1] 2019-20 and 2021-22, the availability of ethanol for blending rose from less than 2 billion litres to 4.1 billion litres, increasing the average blending rate in the country from 5 per cent to 9.5 per cent. Having originally set itself the target of achieving a blending rate of 20 per cent

[§]This paper is an updated and abridged version of the Report "Ethanol Blending of Petrol in India: An assessment of raw material availability" authored by Shweta Saini, Pulkit Khatri and Siraj Hussain. The Report can be read here: https://arcusresearch.in/wp-content/uploads/2023/05/Ethanol-blending-of-petrol-in-India-APR-.pdf

[1]The ethanol supply year (ESY) was recently changed from the earlier 12-month period of December 1 to November 30 to a 11-month period from December 1 to October 31.

by 2029-30, the Government has now advanced the target year to 2025-26.

There are three major challenges to achieving the target: first is a realistic assessment of surpluses of Indian crops which can provide the required feed stock for ethanol production from 2025-26 onwards. When ethanol blending policy was promoted in 2018, the country was surplus in its major crops; however, the recent impact of climate change on rains and temperatures has affected these crop surpluses adversely. In the two years of 2022 and 2023, the surpluses in India's staple crops of rice and wheat dwindled, pushing the Government to undertake multiple steps to restrict their trade so as to address the high rates of food inflation. The second is the increase in demand for ethanol from the competing and fast-growing industries like the alcoholic beverages. There is also increasing competition from the feed industry for ethanol feedstock crops like maize. Third is the trade-off between using crops or even resources like land for producing crops for food vs fuel. The country may need to strategically plan how much of its food crops can be diverted towards fuel production. Concerns over undernutrition (one in every third undernourished person in the world is in India) and affordability of balanced diets (FAO's "The State of Food Security and Nutrition in the World" 2023) remain the mainstay in debate.

This paper attempts to answer these questions.

Indian ethanol production and policies

Biofuels are produced from any plant material which can be converted into fuels (e.g., charcoal) or electricity and/or heat. Biofuels used as transport fuels include ethanol, biodiesel, renewable diesel, and bio-jet. The global production of biofuels used in transportation has increased over the years and was about 157.4 billion litres in the triennium ending (TE) 2020 (IEA 2021), with ethanol accounting for about 69 per cent, followed by biodiesel (27%) and renewable diesel (4%). In India, coal is the biggest energy source accounting for 43 per cent, followed by oil (24%) and biofuels (22%) (IEA 2021).

Ethanol can be produced from various sources, including sugarcane, foodgrains, and agricultural or industrial waste, utilizing either first generation (1G) or second generation (2G) technologies. The 1G technology involves the production of ethanol directly from the food crops. The 2G technology is more advanced, as it enables the production of ethanol from Agri- byproducts, non-food crops, industrial wastes, and lignocellulose feedstocks (Susmozas et al. 2020). The NITI Aayog (2021) has strongly advocated the use of 2G technology for producing bioethanol. However, despite some progress, the 2G technology is still commercially unviable (Zhou et al. 2021) in India or even globally. This implies that most of India's ethanol production today is directly from crops.

Blending petrol with ethanol serves two purposes: (i) it reduces the demand for oil without significantly affecting the fuel efficiency of vehicles, and (ii) reduces emissions since blended petrol burns more cleanly than petrol (Kumar 2021 and PIB 2022). The USA and Brazil are the largest global ethanol producers today. For TE 2020, the two countries accounted for 84 per cent of global ethanol production (IEA 2021). In Brazil, the rate of ethanol-blending in petrol in 2022 was 27 per cent (ET 2022).

Although India first permitted ethanol blending in 1948 with the passing of the Power Alcohol Act, it was not until 2003 that the Government launched its Ethanol Blending Programme (EBP), which made it mandatory to blend 5 per cent ethanol with petrol in nine states and four union territories. Subsequently, blending was made optional in 2004 and 2005 because of the shortage of ethanol. The mandate was reintroduced in 2006, when the Government directed oil marketing companies (OMCs) to sell 5 per cent ethanol-blended petrol in 20 states and four union territories; the following year, the mandate was extended all over the country, barring the north-eastern states, J&K and the islands (Ray, Miglani and Goldar 2011).

Ethanol blending received a fillip after the second National Policy on Bio Fuels (NPB) was introduced in 2018, under which 10 per cent blending was to be achieved by 2020-21 and 20 per cent blending (E20) by 2030. On the occasion of the World Environment Day in 2021, the Prime Minister announced the advancement of the E20 target from year 2030 to 2025-26, following which the NPB was amended in 2022 (PIB 2022). To help achieve the target, the Government introduced several measures to increase the production of ethanol, which included the *Pradhan Mantri Ji-Van Yojana* aimed at incentivising investment in integrated ethanol units and allowing the use of surplus rice available with the Food Corporation of India (FCI) for ethanol production. The use of imported denatured ethanol[2] for fuel blending has been restricted. However, the announcement by the Finance Minister of India in her budget speech in 2022-23to exempt imported denatured ethanol from basic excise duty indicates some relaxation of the restriction, at least for non-blending fuel purposes.

In ESY 2021-22 (December to November), India produced 3.76 billion litres of ethanol for blending (MOPNG). The data sourced from the Ministry of Petroleum and Natural Gas (MOPNG) and the Indian Sugar Mill Association (ISMA) indicates that 84 per cent of this ethanol was produced from sugarcane, about 10 per cent from surplus rice from FCI and the remaining 5 per cent from maize, damaged grains, and rice from the open market.

Estimating feedstock requirement for E20

In June 2021, the NITI Aayog in its policy guiding report titled *"Roadmap for Ethanol Blending in India 2020-25"* provided the estimates of the amount of ethanol that would be needed for achieving E20 blending target. It also provided the source of feedstock to produce it. The major feedstocks were sugarcane, rice and maize.

The NITI Aayog has estimated the total annual demand for ethanol in 2025 at 13.5 billion litres, of which 10.16 billion litres is for blending of petrol and 3.4 billion litres for other uses. Of the estimated demand for blending, it projected 5.5 billion litres to come from sugarcane and 4.66 billion litres from grains. As the report did not assign the contribution between grains, we have assumed that rice and maize are the two grains and each of them is to provide 2.33 billion litres of ethanol.

It has been found that different feedstocks provide different yields of ethanol. A tonne of sugarcane can produce 20 litres of ethanol, a tonne of rice around 435 litres and a tonne of maize 380 litres. The high conversion rate of rice makes it a preferred feedstock for ethanol production.

Based on this assumption and using the crop to ethanol conversion ratios, we estimated the total demand for sugarcane, rice, and maize crops to meet the E20 blending target. We found that to produce 10.16 billion litres of ethanol, India will need 275 million metric tonnes (MMT) of sugarcane, 6.1 MMT of maize, and 5.5 MMT of rice (Table 1). Unlike in the case of sugarcane processing, which yields ethanol as a by-product, the diversion of rice and maize to produce ethanol means the diversion of these crops from food to ethanol production.

Using the existing levels of average crop yields, we found that the country will need to earmark 7.1 Mha or roughly 3 per cent of India's gross cropped area to produce the feedstock needed for E20 by 2025-26.

Table 1 Crop area requirement for meeting E20 targets in 2025-26

Feedstock	Supply target (billion litres)	Ethanol yield per tonne feedstock (litres)	Feedstock required (MMT)	Land requirement (Mha.)^
Sugar cane*	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
Notes * Ethanol is assumed to be produced through the B-Heavy molasses route. Ethanol yields have been taken from NITI Aayog's ethanol roadmap, except for sugarcane.
**As per NITI Aayog, ethanol yield from FCI rice and (broken) rice sourced from the open market is 450 litres/tonne and 400 litres/t respectively. Here, we have assumed an average yield of 425 litres/t of rice.
^crop yields have beentaken for year 2021-22 as 8.4 t/ha for sugarcane, 3.4 t/ha for maize and 2.8 t/ha for rice.

[2]Ethanol is of two types – denatured and un-denatured. Denatured ethanol is used as a fuel, or as inputs for medical and industrial purposes while un-denatured ethanol is mainly used to produce alcoholic beverages.

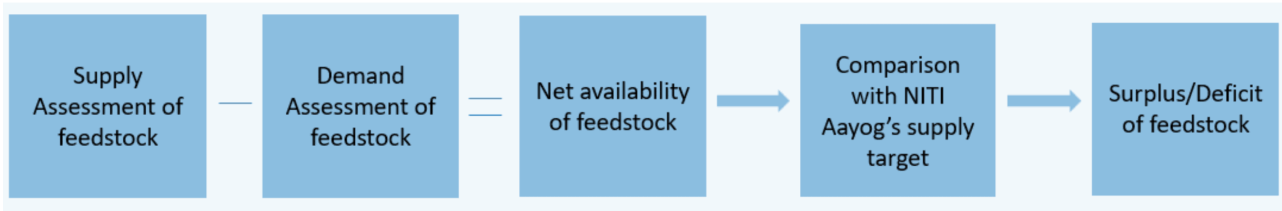

Figure 1 Concept of a crop balance sheet

So, the next question is: can the country spare the required quantities of these crops and resources? To estimate this, we have drawn up the crop-wise annual balance sheets for sugarcane, rice and maize crops for the year 2025-26.

The balance sheet concept involves estimating the residual supply of each crop available for ethanol production after domestic and industrial consumption demand, export demand, stocking requirements if any, and seed and feed requirements are met (Figure 1). The wastage along the crop's value-chain has also been accounted for, which reduces the system's availability. Using income elasticities of demand and supply, each crop's supply and demand are projected for the year 2025-26. To account for several possibilities in future, scenario-wise projections have been made for both demand and supply. Some of the production-side scenarios include, a 5 per cent jump in yields owing to a technology upgrade, a 5 per cent fall in yields because of adverse climate change effects, and a business-as-usual (BAU) scenario that builds on the past performance of the crop. On the demand side, the projections include growth in competing industries such as demand of maize for poultry. The projected demand has been mapped with supplies under different scenarios, and the residuals so estimated have been compared to the demand for feedstock from Table 1.

The crop-wise results have been summarized in the following sections.

Sugarcane: Projected to be the biggest feedstock for E20

The production of ethanol in the country in ESY 2021-22 was 4.1 billion litres. About 84 per cent of this was produced from sugarcane- derived products[3]. As per NITI Aayog's roadmap, in 2025-26 too, out of the 10.16 billion litres required for E20, at least 5.5 billion litres or about 55 per cent would come from sugarcane-based products.[4] As presented in Table 1, India will need at least about 275 MMT of sugarcane every year by 2025-26 to produce 5.5 billion litres of ethanol annually for meeting E20 target.

Using the assumptions listed in Table 2, we have projected 20 possible scenarios of the sugarcane balance sheet.

The sugarcane availability forecast has been done for three scenarios. The first (P1) is the BAU scenario, based on historical data analysis and forecasts of sugarcane area and yield. The projections of area have been made based on data from 2001-02 to 2021-22, using the Auto-regressive Integrated Moving Average (ARIMA) model. Sugarcane yields have been forecast employing the exponential smoothening forecast

[3]After the Government allowed the use of B-Heavy molasses and sugarcane juice/syrup to produce ethanol in 2018-19, there has been an increasing diversion of sugarcane for ethanol production (3.5 MMT equivalent of sugar in 2021-22; expected to rise to around 4 to 4.5 MMT in 2022-23) (ISMA).

[4]Molasses-based ethanol production can be sourced from two main avenues: (i) molasses, could be A, B-heavy, and C-Heavy), and (ii) directly from sugarcane juice as the primary product. The efficiency of ethanol production is positively impacted by a higher sucrose content in the feedstock. For instance, when ethanol is derived directly from sugarcane juice, a mill can yield approximately 62 to 70 litres of ethanol per tonne of sugarcane. On the other hand, if ethanol is produced as a by-product, a tonne of sugarcane is expected to yield around 18 to 20 litres of ethanol.

Table 2 Assumptions made to estimate ethanol supply from sugarcane

Variable	Description
Recovery rates	The conversion rates for sugarcane to cane juice, ethanol, and sugar have been assumed to remain the same as in 2025-26.
Wastages	We have assumed that wastage will be the same as estimated in the latest NABCON 2022 report; it estimates post-harvest losses in the sugarcane value chain at about 7.3 per cent.
Diversion of sugarcane to uses other than sugar/ ethanol	Based on industry estimates (ISMA 2021), we have assumed that the diversion of sugarcane for *gur/khandsari* production would decrease from the current 25 per cent to around 17-18 per cent because ethanol production is more profitable.
Stocks of sugar	We have assumed that 6 MMT of carry-over stocks of sugar would be maintained at any time to meet the stocking requirements; this has been added as additional sugar demand.
Opening stocks of sugar	Opening stocks in a year have been assumed to be previous year's closing stocks.
Sugar Exports	Exports have not been taken into account while calculating the demand for sugar in the balance sheet calculation for sugarcane.
Distillation capacity	It has been assumed that there is adequate distillation capacity for ethanol production in the country.

technique. The mean absolute per centage error[5] (MAPE) has been used to estimate the efficiency of the predictions.

The other two scenarios of sugarcane production are:

i) **P2 scenario** — In this scenario production may fall 5 per cent due to lower crop yields attributed to climate change and/or a reduction in the area under the crop because of the relatively higher productivity/profitability of other crops.

ii) **P3 scenario** — For this, estimates have been taken from the OECD-FAO Commodity Outlook Report 2022-31.

The BAU has been assessed as the most likely scenario. Based on these three production scenarios in 2025-26, the sugarcane supply is estimated to be between 442 MMT and 469 MMT (Figure 2).

On the demand side, two scenarios have been considered. The first scenario (D1) uses an extra-polation of sugar demand based on sugar consumption data provided by the Indian Sugar Mills Association (ISMA). The second demand scenario (D2) is based on discussions with the sugar industry.

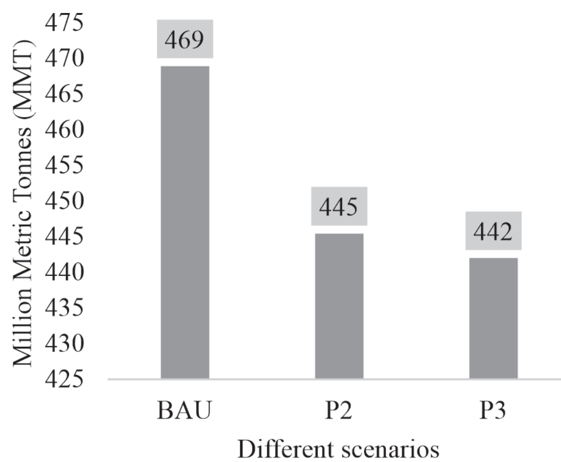

Figure 2 Sugarcane supply forecast for 2025-26
Source Estimated by authors

As per our assessments, the sugar demand in 2025-26 has been estimated to be between 28.8 MMT (D1 scenario) and 29.8 MMT (D2 scenario) and the country at any point in time is assumed to hold inter-year sugar stocks of at least 6 MMT. Based on the existing yields, the amount of sugarcane needed to fulfil this demand (consumption + stocks) would be between 315 MMT and 333 MMT.[6] Table 3 gives the estimates for excess

[5]The mean absolute percentage error (MAPE) is an indicator of the accuracy of a forecast and refers to the average difference between the actual (observed) and forecast values as a percentage of actual value. Percentage errors are summed without regard to the sign to compute MAPE.

[6]The two estimates are based on two possible recovery rates of sugar from sugarcane: 10.75 per cent and 11.04 per cent

Table 3 Estimate of excess sugarcane: After meeting domestic sugar and buffer demand

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

Source Estimated by authors

sugarcane after fulfilling the aggregate domestic sugar demand, assuming 11.04 per cent recovery rate.

Ethanol production from molasses: Estimates for 2025-26

Since ethanol from sugarcane can be produced as a by-product of sugar manufacturing as well as directly from sugarcane without producing sugar, the total ethanol supply has been estimated as a sum of production through both sources. Using the conversion rates mentioned earlier, a recovery rate of 11.04 per cent and assuming demand scenario D2 (the most likely scenario), it is expected that in 2025-26, between 5.7 and 6.5 billion litres of ethanol as a by-product and between 0.4 and 0.9 billion litres as a direct product of sugarcane would be available. Thus, total production has been estimated between 6.2 to 8.4 billion litres (Figure 3).

This implies that there would be sufficient sugarcane available in 2025-26 to meet the NITI Aayog's projected requirement of 5.5 billion litres. This is be the likely availability of sugarcane even after domestic demand for sugar has been met.

However, if production is lower (P2 and P3 scenarios), the ethanol production from sugarcane is expected to fall short of the requirement of 5.5 billion litres by 0.4 -0.7 billion litres.

Maize: Competition between feed, starch and fuel needs

The third advance estimate (May 2023) of government shows that India produced about 35.9 MMT of maize in 2022-23. The annual domestic consumption of maize is between 28.7 and 30 MMT (OECD Outlook 2022-31). The cattle and poultry industry consumes about 55-60 per cent of this output, mainly for feed. Maize is

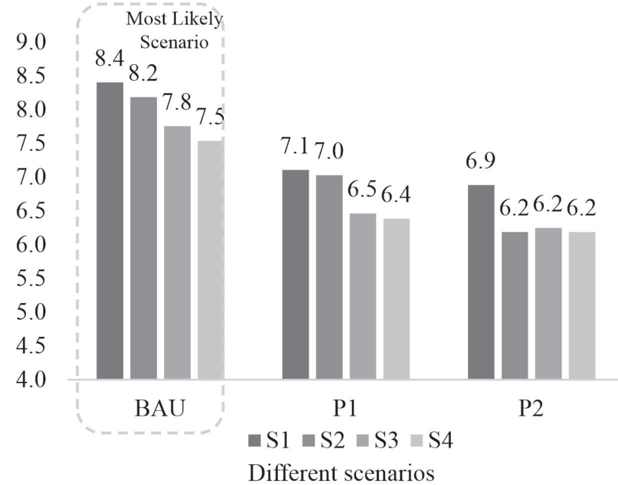

Figure 3 Estimated total ethanol supply from sugarcane in 2025-26

Source Estimated by authors

Notes S1, S2, S3 and S4 are scenarios for different conversion rates where 'S1' – 20 litre/t B-Heavy ethanol and 70 litre/t sugarcane from cane juice scenario. 'S2' – 20 litre/t B-Heavy ethanol and 62 litre/t sugarcane from cane juice, 'S3' – 18 litre/t B-Heavy ethanol and 70 litre/t sugarcane from cane juice and 'S4' – 18 litre/t B-Heavy ethanol and 62 litre/t sugarcane from cane juice.

also used by the starch, pharmaceutical, textile, and cosmetic industries. The consumption of maize as food is low and its exports are not consistent and are residual in nature, although India exported annually about 2.1 MMT of maize in the past three years (2019-20 to 2021-22).

As per our estimates (presented in Table 1), India would need about 6.1 MMT of maize annually to be able to produce about 2.33 billion litres of ethanol to meet the 2025-26 E20 mandate. Like sugarcane, ethanol production from maize has valuable by-products like dried distillers grain solids (DDGS), which can be utilised in animal feed as protein.

In poultry feed, maize is used as a source of energy due to its high starch levels. The DDGS can be used as a substitute for other oil meals like the ones from mustard, cotton seed, and soybean. Therefore, maize diverted for ethanol effectively is likely to compete with its use as poultry feed or in other starch-based industries.

As in the case of sugarcane, various production and consumption scenarios have been considered to assess the net availability of maize to produce 2.33 billion litres of ethanol for E20 in 2025-26 (Tables 4 and 5).

Table 4 Possible scenarios for estimating maize supply

Scenario	Rationale
BAU	Based on ARIMA forecasts
P1	BAU + 5% (likely growth of yields due to technology upgradation, increase in area)
P2	BAU – 5% (impact of climate change, or 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 5 Potential scenarios for estimating maize demand

Scenario	Rationale
D1	Based on OECD projections (Outlook 2022-2031)
D2	Extrapolated, with Food, Seed and Industrial (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 (using regression coefficients)
D4	Extrapolated, with FSI maintaining the same share in production and pegging feed-use to growth in the poultry feed sector (using regression coefficients)

Our estimates have indicated that the supply of maize in 2025-26 is expected to range between 33.7 MMT and 38.6 MMT, while demand is expected to range between 30.5 MMT and 41.3 MMT under different scenarios.

These estimates were made using the following assumptions:

i. Wastage and losses along the maize value-chain were assumed to be the same as that given in NABCON 2022 study of post-harvest losses of 3.8 per cent.

ii. Import and export of maize were assumed to be zero.

The net availability of maize, calculated as the difference between production[7] and demand after adjusting for wastage is depicted in Table 6.

In 19 out of 20 scenarios for which the estimates were made, the availability of maize falls short of the target of 6.1 MMT, required to produce 2.33 billion litres of ethanol (needed to achieve the 2025-26 ethanol blending target). The only scenario where India is projected to generate the required surplus of 6.1 MMT is when the demand for maize does not grow as fast (say, because of slower growth in the poultry sector) and if the yield of maize improves.

Table 6 Net availability of maize for ethanol production in 2025-26 (MMT)

Scenarios	Demand scenarios			
	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.

Rice: A water guzzling food crop diverted to manufacture fuel

The high starch content of rice makes it the most efficient of the three feedstocks for ethanol production. One tonne of rice produces, on an average, about 425 litres of ethanol. This compares to 20 litres from one tonne of sugarcane (ethanol as a by-product) and 380 litres from one tonne of maize.

[7]Stocks of maize are assumed to have been exhausted and thus closing stock is taken to be 0.

Table 7 Assumptions made for estimating ethanol supply from rice

Variable	Description
Wastage	NABCON's 2022 report on post-harvest losses estimates a 4.77 per cent loss in paddy. The estimated production has been adjusted downwards to take this into account. (The conversion factor for paddy was taken as 0.67 on the basis of Food Corporation of India (FCI) reports.)
Stocks with FCI in central pool	Based on previous years' data, FCI's minimum stocks have been assumed to be 20.6 MMT (twice the required norm of 10.3 MMT)
Stocks with private trade	Private trade is expected to hold stocks equivalent to three months' domestic rice consumption.
Exports and imports	Export has been assumed between 20 and 21.4 MMT, based on current data, discussions with experts and OECD projections. Imports have been assumed to be 0 MMT.
Opening stock	Opening stock is previous year's closing stock.

Over the past ten years, India's production of rice has increased by about 23 per cent. As per the GOI's third advanced estimate, rice production in 2022-23 was 135.5 MMT (PIB 2023). The area under rice in TE 2020-21 was 44.29 Mha and average yield was 2.69 t/ha (Agriculture Statistics at a Glance 2021).

The availability of rice in 2025-26 has been estimated on the basis of the assumptions are given in Table 7.

Three scenarios were considered to estimate availability of rice. The first, referred to as the business-as-usual (BAU) scenario, is an ARIMA based forecast. Both area and yield of rice were separately modelled to estimate production. The second scenario is based on OECD's rice production projections (OECD-FAO Outlook 2022-31). The third scenario projects a 5 per cent yield loss on account of weather/climatic vulnerabilities. Based on these three scenarios, India's rice production in 2025-26 is projected to be between 131.9 MMT and 138.9 MMT.

The demand for rice has been projected under two scenarios. The first uses consumption projections from the OECD-FAO Outlook 2022-31 report. The second extrapolates NSSO data from 2011-12 household consumption expenditure survey, using IMF's estimate of per capita GDP growth rates, income elasticity of rice consumption (sourced from Kumar 2017) and population projection based on 2011 Census data. These two estimates peg the demand for rice in 2025-26 between 112.4 MMT and 116.6 MMT.

If India continues to export 20 MMT of rice (including 4.5 MMT of basmati) and there is no change in the stocks with the FCI and the private trade, rice output in India may fall short of even the domestic demand of rice in 2025-26. Our estimates have indicated a shortfall 1.2 MMT in 2025-26 against the requirement of about 5.5 MMT of rice (Table 1) for fuel blending in the most likely scenario (BAU-D2) (Table 8). However, if exports decline by 5 MMT, a net surplus of 3.8 MMT would be available to produce about 1.62 billion litres of ethanol.

Table 8 Net availability of 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

Putting together the estimates of crop availability for ethanol production for all the three crops, sugarcane, maize, and rice, it is estimated that the total supply of ethanol in 2025-26 would be anywhere between 7.5 and 10.02 billion litres.

Under the most optimistic scenario (ethanol supply of 10.02 billion litres), India may come close to meeting its fuel-blending requirement of 10.16 billion litres. However, it would still be not able to meet the remaining requirement of 3.5 billion litres (13.5 billion litres –10.16 billion litres) for other uses of ethanol.

Assessing the E20 mandate

A reduction in the country's oil import bill is one of the primary triggers for the policy thrust on ethanol

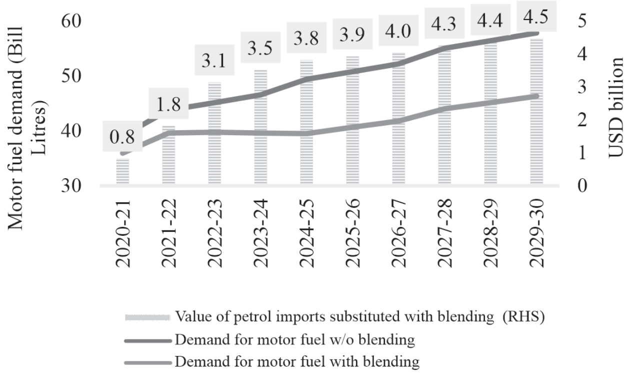

Figure 4 Demand for petrol (litres) and forex savings from blending (billion USD)

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

for fuel blending. Figure 4 shows that in 2025-26, India may annually save about US$4 billion to US$4.5 billion if the World Bank's crude oil price projections are considered[8]. The magnitude of savings estimated is close to NITI Aayog's estimated annual savings of US$4 billion.

Our analysis indicates that it may not be feasible for the country to meet the E20 target of blending under the business-as-usual (BAU) scenario.

Additionally, by creating competition for food crops, ethanol production is likely to squeeze their availability for food and feed related purposes. The Global Human Index (GHI 2022) ranked India 107 out of 121 countries, implying that the incidence of hunger and malnutrition in India remains high. The incidence of stunting and wasting among children under five is 35.5 per cent and 19.3 per cent respectively, with India holding the dubious distinction of having the highest wasting rate in the world. According to India's National Family Health Survey 2019-20, 18.7 per cent of women and 16.2 per cent men in India have a body mass index (BMI) below the normal.[9]

Another major challenge is the shrinking availability of land for cultivation which would have a direct impact on production of food crops. At the current level of productivity, the E20 mandate is understood to require about 7.1 Mha of land (Table 1). Since 1970-71, the operated area under agriculture has declined steadily from 162.3 Mha to about 157.8 Mha in 2015-16 – a decline of 4.5 Mha over a 45-year period. This is mainly due to pressures from urbanisation (Pandey and Seto 2015). According to Hoda (2018), the country is likely to lose at least 10 per cent of cultivated area by 2050. Can India afford to have 7.1 Mha of its land dedicated to producing crops for fuel?

Simultaneously, the per capita availability of water has decreased from 5177 cm^3 in 1955 to 1544 cm^3 in 2011 (CWC 2015). According to a reply in the Lok Sabha by the Minister of State for Jal Shakti, the Central Water Commission in its 2019 report, *"Reassessment of Water Availability in India using Space Inputs"*, had estimated that this would decline further to 1486 cm^3 in 2021 and 1367 cm^3 in 2031. The World Meteorological Organization (2021) ranks the terrestrial water loss in India, particularly in the northern parts of the country, the highest in the world.[10] Gulati and Mohan (2018) have pointed out that water-use for agriculture in India is inefficient. A comparison of water use efficiency for the sugarcane crop, expressed as physical water productivity (PWP),[11] shows that India's PWP was 5.2 kg/cm^3 against the global average PWP of 5.8 kg/cm^3 (Sharma et al. 2018). As per this study, the average PWP for rice was estimated at 0.36 kg/cm^3, with rice accounting for a third of the water used in agriculture. Although, there are geographical areas where there is efficient use of water, PWP for rice is low in several regions with assured irrigation but the region itself is water scarce " for instance, parts of Punjab (Sharma 2018).

Apart from the shrinking availability of land and inefficient resource use in agriculture, a major challenge in the past few years has emerged in the form of climate change impact. This has impacted yield of crops. For example, wheat crop was adversely affected in both 2021-22 and 2022-23 years.

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[8]The available data on oil prices is until 2023-24. Beyond this period, the per barrel price of oil is assumed to remain constant, equal to the last five-year average, which includes the projections for 2022-23 and 2023-24. Additionally, the blending rates for oil after 2025-26 are expected to be fixed at 20 percent levels

[9]Normal range of BMI is between 18.5 kg/m^2 to 25kg/m^2.

[10]WMO defines terrestrial water as the sum of surface and sub-surface water.

[11]Physical water productivity, expressed as the ratio of agricultural output to the amount of water used, is usually used to estimate the efficiency of water use.

The FAO (2015) also deems the diversion of crops to biofuels and climate change as the two major threats to long-term food security.

The estimates of this study have shown neither rice nor maize production is likely to be sufficient to yield the surpluses needed to produce ethanol for blending of petrol, even if one ignores the effects of climate change on crop yields.

Conclusions and inferences

The following conclusions are drawn from the analysis:

- A fall in sugarcane yield due to climatic changes is likely to have an adverse impact on its availability for production of ethanol. Given the centrality of cane as feedstock, this is critical for the government to assess.
- Maize production is not sufficient to allow it to emerge as a major feedstock in ethanol production. The alcoholic beverage industry, poultry, and other industries would compete for maize. Besides, lower returns on maize production as compared to other crops and volatile yields have been a major challenge to increasing the acreage under this crop.
- Rice is critical for country's food security and as per calculations, unless FCI stocks lower-than-normal and/or country's rice exports fall over time, rice availability may not be sufficient to meet its requirements under E20. Besides, its diversion towards fuel production appears marred with grave trade-offs in terms of subsidies used to produce rice, the amount of water used for its production and *inter alia*, the crowding-out that such diversion would do for the poorest and malnourished countrymen.
- Both rice and sugarcane are water-guzzling crops and their use in producing ethanol which in turn, would reduce overall emissions in the country, needs to be revisited with a life-cycle-of-the-crop approach. There is an urgent need to improve resource-use efficiency particularly by these two crops.
- Given the availability of feedstocks for ethanol is uncertain, the country would do well by exploring the use of alternate feedstock for ethanol production. Agricultural waste can be an important feedstock and six commercial Second Generation (2G) bio-ethanol projects with a total production capacity of 695 Kilo Litre Per Day (KLPD) in Punjab, Haryana, Odisha, Assam, and Karnataka have been sanctioned.
- At some point in future, the Government may revisit the policy on import of ethanol.
- One of the biggest challenges to the E20 plan is the possibility of a decline in crop yields as a result of climate change. Hence, investment in developing climate-resistant varieties and improving crop yields is imperative for food security itself, irrespective of the country's ethanol requirements.

Increasing incomes and growing urbanization have led to the demand for a more diversified food basket with the demand for plant and animal-based proteins rising. This has led, among other things, to the rapid growth of the poultry sector, which has registered a CAGR of 8 and 10 per cent (APEDA, 2023). Together with the challenges arising from climate change, and the reduction in operated area for cultivation due to increasing urbanization, there is a distinct probability that the outlook for the availability of feedstock for ethanol production, particularly maize, may be far less sanguine than the projections made by NITI Aayog in its roadmap. While E10 has been more or less achieved and is a sustainable level of blending, the E20 mandate may be overambitious.

Way forward

Based on the study, some critical aspects for of government consideration are summarized below:

- **Improvement in crop yields** — Yields of many crops like maize are exceptionally low in many parts of the country. The government needs to invest in technological development that could help raise crop productivity.
- **Development of climate resilient varieties** — 2023 was a El Nino year, from rice to sugarcane, yields of most crops fell. Many like maize are subjected to pest attacks. GOI has to invest in bringing climate resilience to its crops.

- **Strategic land planning** — A proper strategy has to be developed on land-use for arable purpose, both for a short-term as well as long-term, keeping in view the rising food demand and meeting E20 petrol blending targets. The government should adopt measures to revive fallows for sowing crops for fuel.
- **Irrigation water management** — The government to consider the efficiency of water-use in agriculture. Rice and sugarcane, which are the two most important feedstocks for ethanol production, are highly water-intensive. These two crops account for 60 per cent of the total irrigation water supplied to agriculture (NABARD, 2018). In the process several other crops are deprived of water. Therefore, the government should (i) outline a threshold crop area and/or crop size that would be allowed for biofuel production; and (ii) invest in making both rice and sugarcane cultivation more resource-use efficient. Incentivising investment in water conservation techniques like drip irrigation and sprinklers will help increase both cop yields and the productivity of water use.
- The government need to invest in developing 2G technologies that are commercially viable.
- The government should consider the involvement of different states to implement the E20 mandate.
- There is a need to encourage the use of electric vehicles and flexi-fuel vehicles which can take some of the burden off the aggressive ethanol blending target.

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