Impact assessment of interest subvention scheme under National Biofuel Programme (NBP) 2019 on farmers, distillery, local economy, and environment

By

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Abbreviations

EBP	Ethanol Blending Program
GDP	Gross Domestic Product
FRP	Fair and Remunerative Price
NFSA	National Food Security Act
NBP	New Business Profit
GOI	Government of India
MoP&NG	Ministry of Petroleum & Natural Gas
OMCs	Oil Marketing Companies
NBP	National Biofuels Policy
MSA	Maharashtra Sugar Association
KLPD	Kilograms Liters per Day
SAP	State Adjusted Price
UP	Uttar Pradesh
DAP	Di-ammonium Phosphate
PBT	Profit before tax
EBITDA	Earnings before interest tax depreciation
kWh	Kilowatt-hour
MWh.	Megawatt hour
PDM	Potash derived from molasses ash
CO_2	Carbon dioxide
DDGS	Distiller's dried grains with solubles (DDGS)
DWGS	Distillers Wet Grains Soluble
TRS	Total Reducible Sugar
FCI	Food Corporation of India
VGF	Viability Gap Funding
1 G	1st generation
2 G	2nd generation
CO2	Carbon dioxide

Unit

Emissions	t CO2	tonnes of carbon dioxide
	Gt CO2-eq	gigatonnes of carbon dioxide equivalent (using 100-year global warming potentials for different greenhouse gases)
	kg CO2-eq	kilogrammes of carbon-dioxide equivalent
	g CO2/km	grammes of carbon dioxide per kilometre
	g CO2/kWh	grammes of carbon dioxide per kilowatt-hour
	kg CO2/kWh	kilogrammes of carbon dioxide per kilowatt-hour
Energy	EJ	exajoule (1 joule x 1018)
	PJ	petajoule (1 joule x 1015)
	TJ	terajoule (1 joule x 1012)
	GJ	gigajoule (1 joule x 109)
	MJ	megajoule (1 joule x 106)
	Boe	barrel of oil equivalent
	kWh	kilowatt-hour
	MWh	megawatt-hour
	GWh	gigawatt-hour
	TWh	terawatt-hour
Mass	Kg	Kilogramme
	T	tonne (1 tonne = 1 000 kg)
	Kt	kilotonne (1 tonne x 10^3)
	Mt	million tonnes (1 tonne x 10^6)
	Gt	gigatonne (1 tonne x 10^9)
Power	W	watt (1 joule per second)
	kW	kilowatt (1 watt x 10^3)
	MW	megawatt (1 watt x 10^6)
	GW	gigawatt (1 watt x 10^9)
	TW	terawatt (1 watt x 10^{12})

Section I: Developments in the ethanol blending sector in India and motivation for the study

1. Introduction

The Ethanol Blending Program (EBP) in India, initiated by the central government, aims to promote home-grown ethanol as a substitute for traditional oil products to reduce dependence on imported oil, support the sugar industry (and, in turn, sugarcane farmers), mitigate greenhouse gas emissions, and enhance energy security. Ethanol is mainly produced from sugarcane but has recently been diversified to other food crops such as maise and rice. However, like in many countries promoting biofuels, the concerns of biofuel expansion on food security, land substitution between feedstock and non-feedstock crops, increase in prices of other agricultural commodities and accurate accountability of net CO_2 emission reduction remain contested. It is, therefore, important that when India has reached an ethanol blending of 10%, an impact analysis of the sector's economics and different stakeholders is carried out.

Therefore, this study assesses the impact on the sugar industry, sugarcane farmers, distilleries' profitability, local economy and environmental impact. The following section provides the background on India's sugarcane industry and why ethanol as fuel was promoted.

1.1. Background: sugarcane landscape in India

Sugarcane (Saccharum officinarum) family Gramineae (Poaceae) is a widely grown crop in India. Sugarcane production in India has been rising (Figure 1). The sector employs ~ 0.5 million workers people directly[1]. This sector is contributing 1.1% to the national gross domestic product (GDP)[2]. However, the production is concentrated in a few states like Uttar Pradesh, Karnataka, Maharashtra and Tamil Nadu (Figure 2). With the rise in sugarcane production, India's sugar production has also risen in the last few decades (Figure 3).

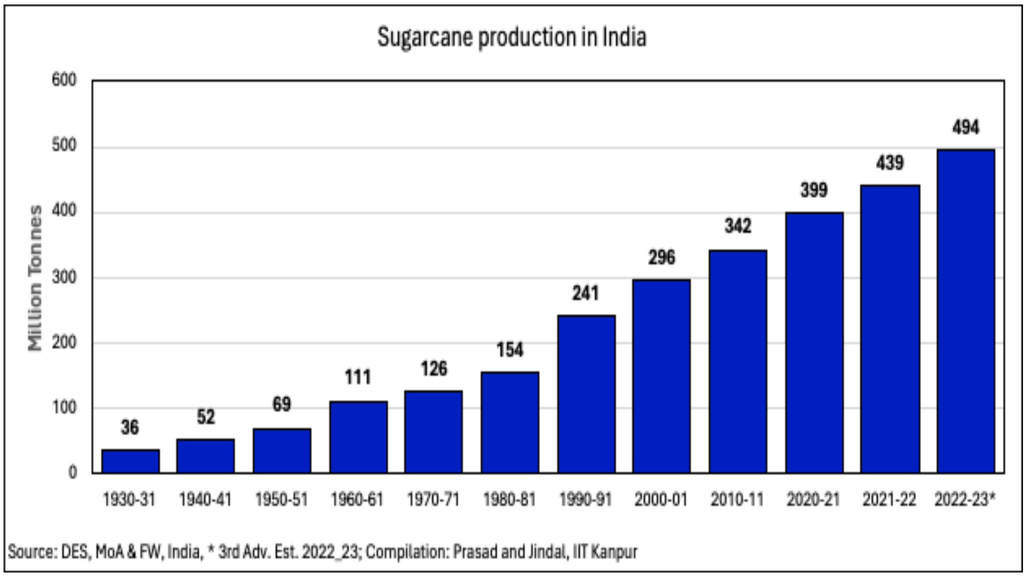

Figure 1: Sugarcane production in India over the time period1930-2023

[1]Report of task force on sugarcane and sugar industry. Niti Aayog, March 2020.

[2]https://www.researchgate.net/publication/310490712_Sugarcane_Production_and_Development_of_Sugar_Industry_in_India#:~:text=Sugarcane%20accounted%20for%20about%20648,area%20(Solomon%2C%202016)%20.

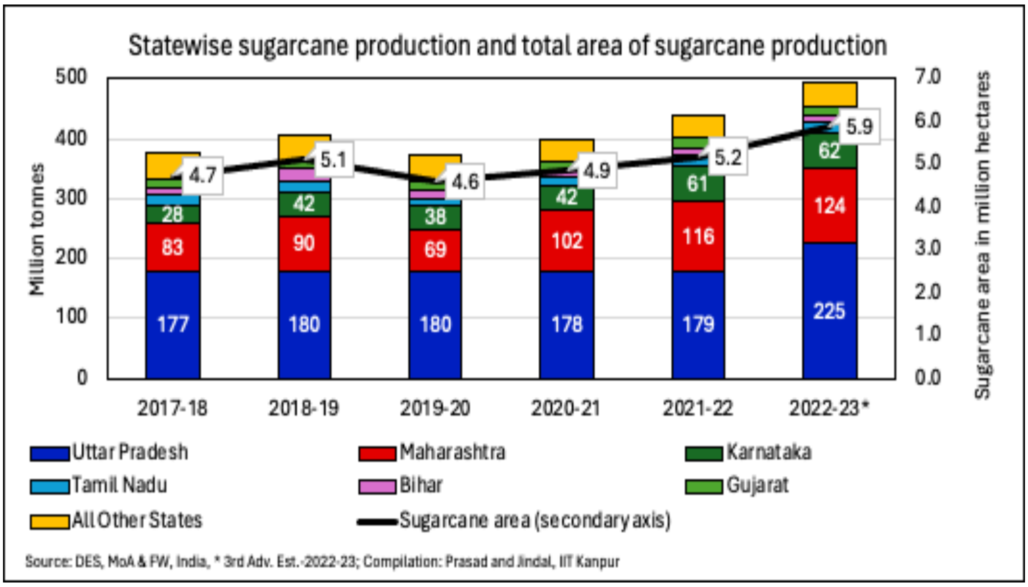

Figure 2: State-wise sugarcane production and cultivation area for 2018-2023

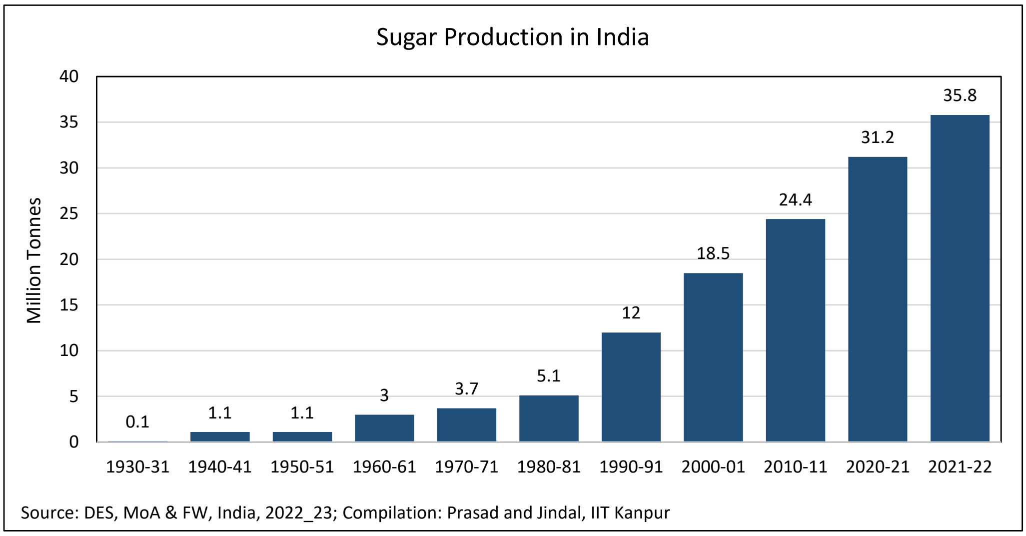

Figure 3: Sugar production in India over the years 1930-2022

This increase in sugar production led to India emerging as the world's largest producer and consumer of sugar. However, the domestic consumption of sugar has not increased at the same pace to match the rising production of sugar (Figure 4). This imbalance led to a situation where sugar production in India exceeded internal consumption; for example, during the years between 2002-03 and 2021-22, 15 years out of 20 years saw higher production growth compared to consumption, therefore building up in the carryover stocks as seen in Figure 4.

The increased production is despite exporting sugar and India being the 2nd largest sugar exporter after Brazil. However, surplus stock was still built up, which kept the final price of sugar low in the domestic market. On the other hand, the price of sugarcane[3] a crop supported under the Fair and Remunerative Price (FRP) model by the government has continuously increased, outpacing the almost constant price of sugar, as seen in Figure 5.

[3] https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1935899

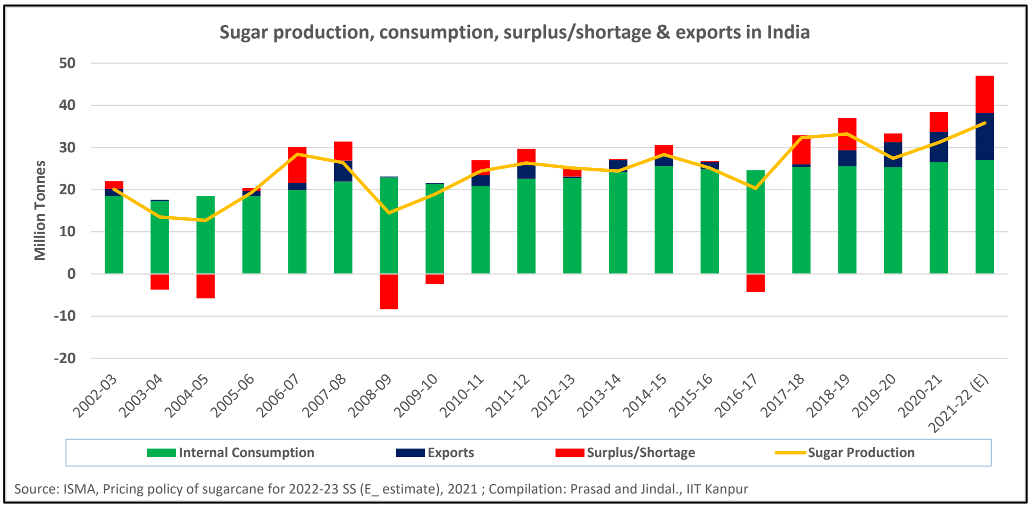

Figure 4: Sugar production, domestic consumption, exports and surplus/shortage

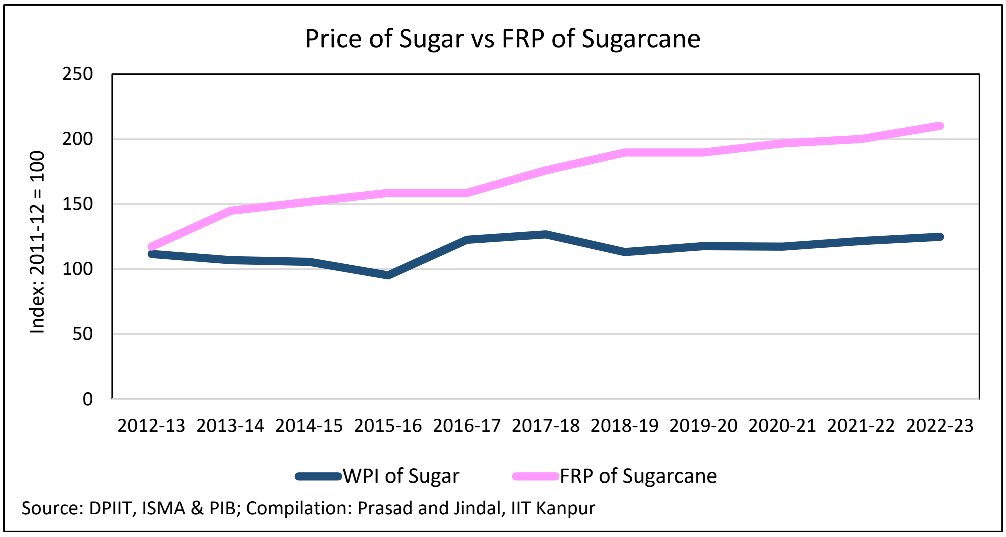

Figure 5: Relative change in sugarcane prices and sugar with 2012-13 as base

Excess sugar production and stagnant prices, combined with the rise in raw materials (sugarcane) cost, squeezed the sugar mills' margins and made them cash-strapped. As a result, the sugarcane farmers stopped receiving timely payments and which resulted in the accumulation of cane price arrears, which went as high as 42% in the year 2013-14 and consistently remained above 30% for the next three-year period until 2015-16 (Figure 6). As a result, the government intervened and provided liquidity to the sugar mills in the form of soft loans, direct subsidies to farmers as part of production linked subsidy, export incentives, increases in import duties, incentivising production of fuel-grade ethanol from sugar by-products and increasing the ethanol blending target from 5% to 10%[4]. This led to a decline in cane arrears in the years after 2015-16, as seen in Figure 6.

[4] https://pib.gov.in/newsite/PrintRelease.aspx?relid=134672 NFSA coverage in all the States by April 2016, 21 Jan 2016.

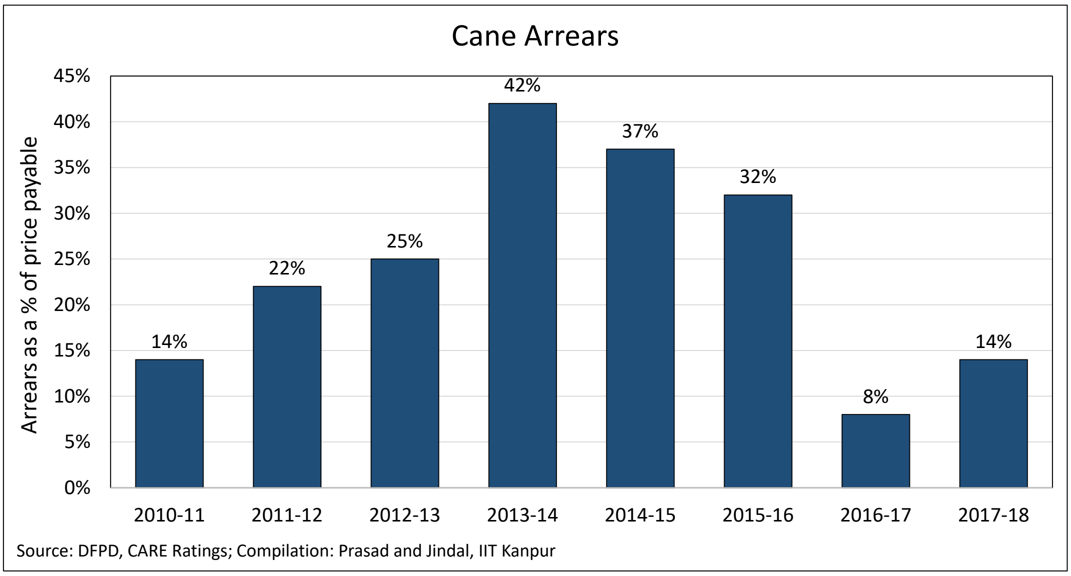

Figure 6: Cane arrears of farmers from 2010 to 2018

NBP 2018 envisaged that incentivising the production of fuel-grade ethanol can also help India meet other objectives like energy security and climate change. India needs a considerable amount of fuel in its transport sector, so any additional fuel source aligns with energy needs as it can help meet the country's growing demands. Currently, 18% of petroleum is consumed by the transport sector, making it the primary fuel source for the sector. Further, India depends on imports for this fuel. India's net import of petroleum was 185 Mt at the cost of US $55 billion in 2020-21[5]. As Figure 7 shows, petroleum consumption in the country and the transport sector are rising.

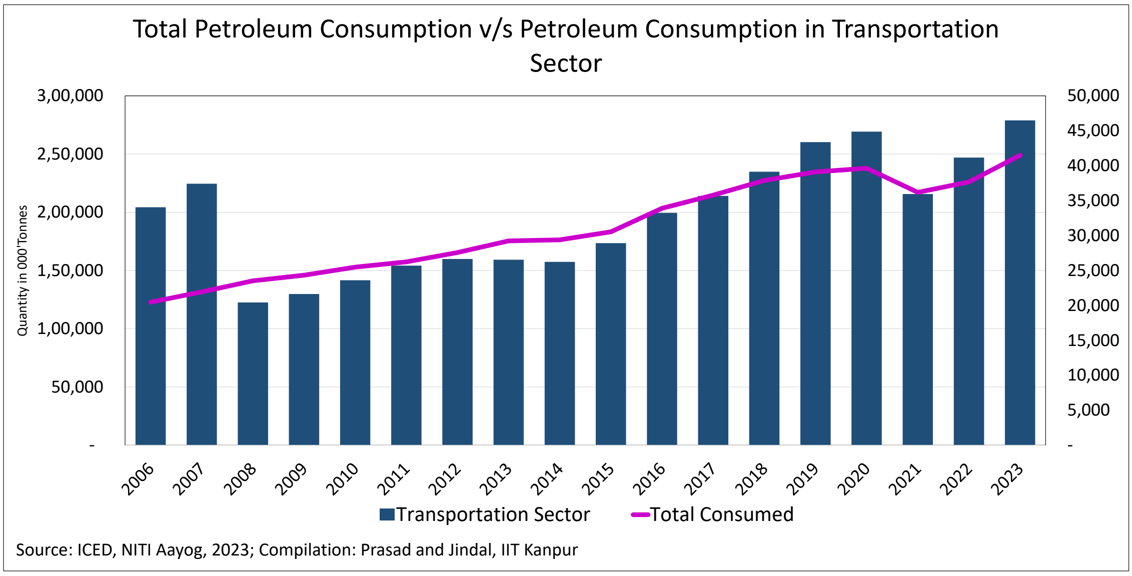

Figure 7: India's overall petroleum consumption and petroleum consumption in the transport sector over the years 2006-2023

[5] Roadmap for Ethanol Blending in India 2020-2025. Niti Aayog | Ministry of Petroleum and Natural Gas, June 2021.

1.2. Intervention by the government to incentivise fuel-grade ethanol production and blending

In 2001, the Government of India (GoI) introduced pilot projects on ethanol-blended petrol at three locations in Uttar Pradesh. Later, in January 2003, the Ethanol Blended Petrol (EBP) Programme was launched, which set a target for 5% ethanol-blended petrol. In September 2006, the Ministry of Petroleum & Natural Gas (MoP&NG) directed the Oil Marketing Companies (OMCs) to sell 5% ethanol blended petrol subject to commercial viability in 20 States and four union territories. However, the project did not make any real impact.

In 2009, another attempt was made through the National Policy on Biofuels (NBP 2009) to promote indigenous biomass feedstocks as an alternative to fossil fuels, especially non-food feedstock like non-edible oil seeds. This time, the target was increased to 20% blending for bioethanol by 2017. However, the target was just indicative and not binding with a proposal on minimum prices for supporting non-edible oil seeds and the purchase of biofuels. NBP 2009, unlike the EBP Programme – 2003, covered various biofuels, including bioethanol, biodiesel, biomethanol, biosynthetic fuels, etc. Support was provided to research and development for efficiency improvement, cost reduction, and exploration of other biofuel sources. Capacity building was incentivised through a proposal to set up the regulatory framework for ethanol blending and develop the infrastructure for ethanol blending, such as ethanol production plants, storage facilities, blending units, and distribution networks. Despite these initiatives, the program could only achieve 4.22% blending compared to the 20% blending target by ESY 2017-18. Primary reasons for the shortfalls were identified as

- Lack of clear implementation plan and delays in setting up the necessary infrastructure for biofuel production and distribution.
- Not sufficient incentives to promote the production and use of biofuels.
- Limited feedstock availability for biofuel production, such as sugarcane and oilseeds.
- Technical challenges for biofuel production and distribution, such as the need for specialised equipment and infrastructure and concerns around fuel quality and compatibility with existing engines.
- Lack of awareness amongst consumers and stakeholders on the benefits of biofuels.
- Some states-imposed taxes on non-consumable/non-portable ethanol.

In 2018 this policy was revamped as the revised National Biofuels Policy (NBP) 2018. Although the NBP 2018 has the indicative target of 20% blending of bioethanol, the period to achieve the target was extended until 2030. NBP 2018 was a targeted policy with direct financial incentives by subsidising the interest payments of up to 50% on the loans taken to expand the ethanol capacity on the production side. On the demand side, the oil marketing companies were mandated to procure a certain percentage of the ethanol for blending, providing an assured market. Clear price signals in the market of the various grades of ethanol supported the creation of this market. The timeline of the initiatives taken to promote biofuels in the country are given in Figure 8, and the milestones achieved in ethanol blending are shown in Figure 9. We have provided detailed provisions of the NBP 2018 in Annexure 1.

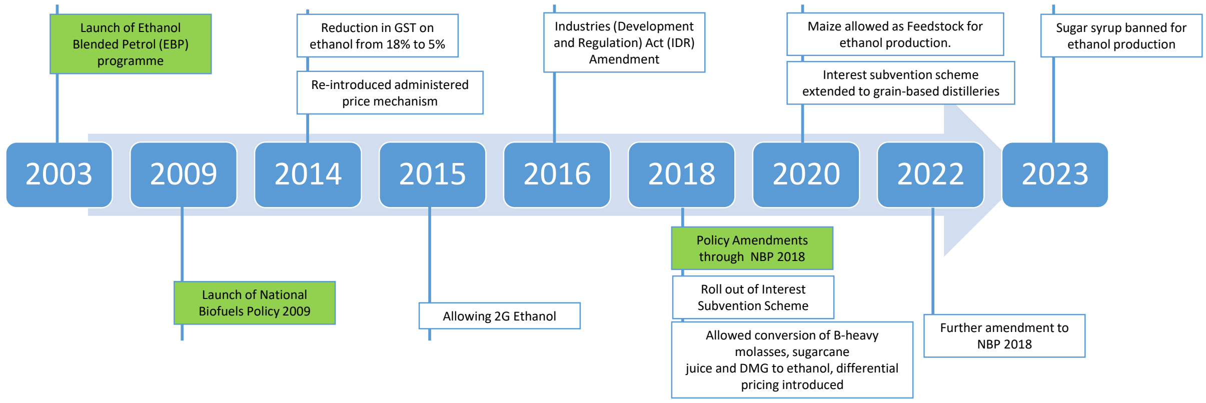

Figure 8: Policy Announcements & amendments announced over the years

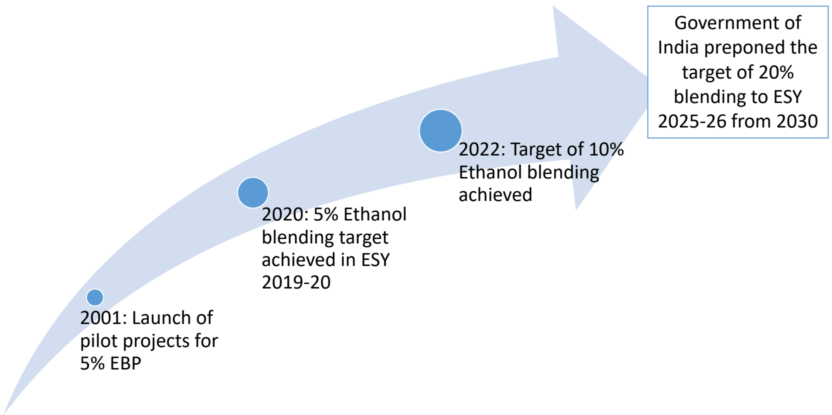

Figure 9: Major milestones of the ethanol-blending program

1.3. Ethanol sector in India post NBP 2018

NBP 2018 significantly influenced the ethanol production industry for blending in India. The ethanol production capacity, which was constant at around 4 billion litres (per year) for four years, from 2013-14 to 2016-17, increased to 14.4 billion litres by 2023-24 (Figure 10). Thus, there was an addition of 9.8 bn litres from 2016-17 to 2023-24, an increase of 214%. Of this increase of 9.8 bn litres, 32% or 3.1 bn litres was in grain-based ethanol capacity and 68% in molasses-based capacity. The share of molasses-based ethanol capacity is 62% in 2023, up from 50% in 2013-14, and the rest is grain-based.

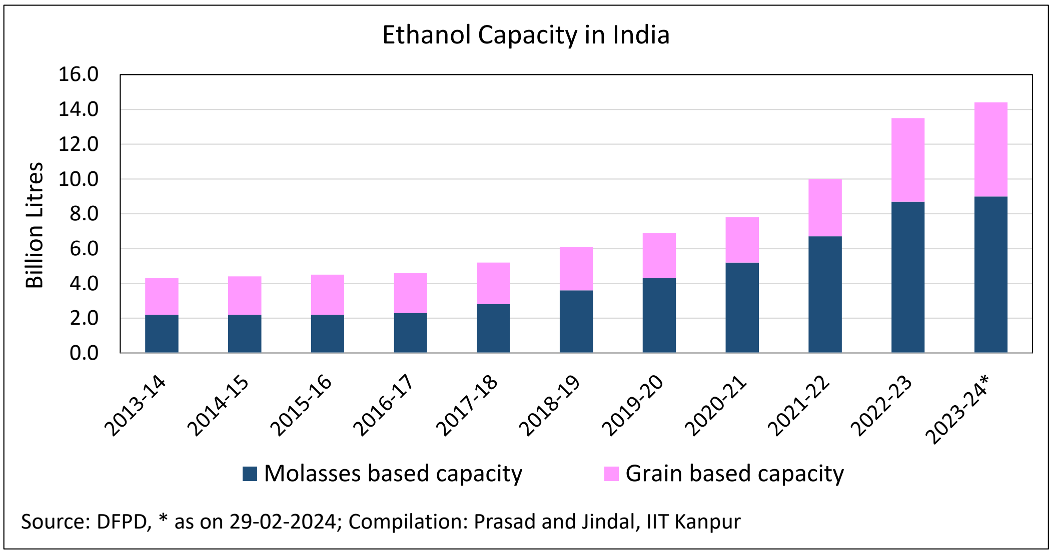

Figure 10: Molasses-based and grain-based ethanol manufacturing capacity in India from 2013-14 to 2023-24

Following the increase in ethanol capacity, the total ethanol production rose from 4.2 bn litres in 2019-20 to 7.8 bn litres in 2022-23[5,6], a rise of 86% in four years (Figure 11). This increase has led to a structural change in the sector as more ethanol is now used for blending. The share of ethanol for blending in total ethanol increased from 41% to 64% during the same period. The share of ethanol for other uses like country liquor, chemical and industrial applications fell from 59% to 36%. The variety of feedstocks for ethanol also increased to include maize and rice.

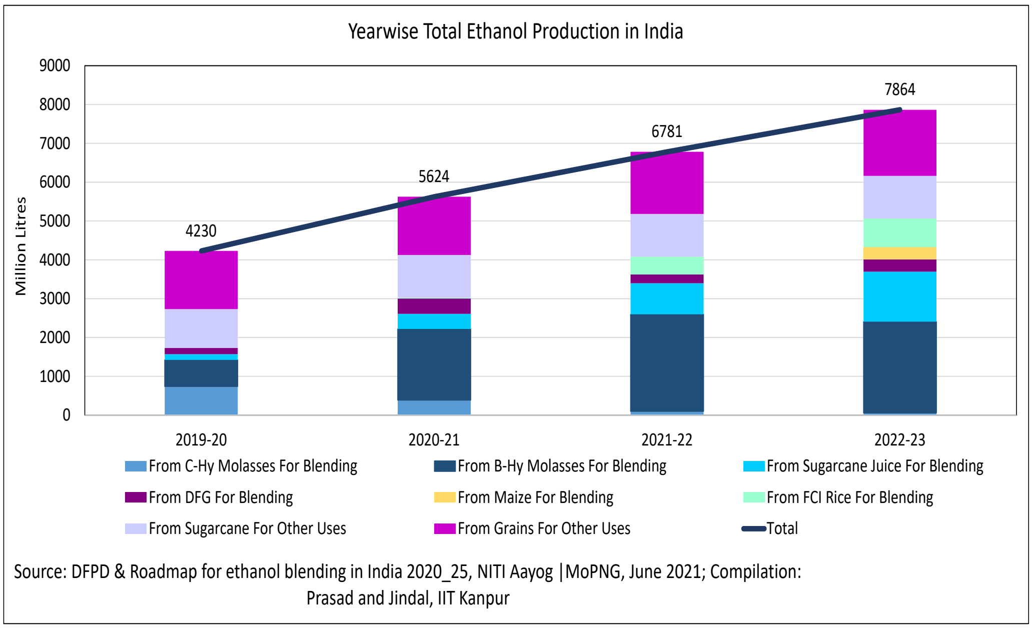

Figure 11: Ethanol production in India from 2019-20 to 2022-23 categorise by the type of feedstock

The most considerable increase in percentage terms was in ethanol production from sugarcane juice, which increased from 148 million litres in 2019-20 to 1.3 bn litres in 2022-23. The biggest increase in absolute terms was in ethanol from B-heavy which rose from 681 million

[6] DFPD, Ministry of Consumer Affairs.

litres in 2019-20 to 2.3 bn litres in 2022-23, an increase of 1.7 bn litres. On the other hand, the most significant decline was seen in ethanol from C-heavy molasses, which fell from 741 mn litres to 56.1 mn litres over the same period. Figure 12 shows the changes in production and consumption from 2019-20 to 2022-23, including details of the types of feedstocks. The increase in production suggests that the price signal used by the central government has been picked up by the sugar mills (Figure 13), and the feedstock with the highest price has seen the biggest capacity gain. The price signal combined with additional ethanol feedstock sources resulted in many independent distilleries coming up, particularly in the grain-based ethanol segment.

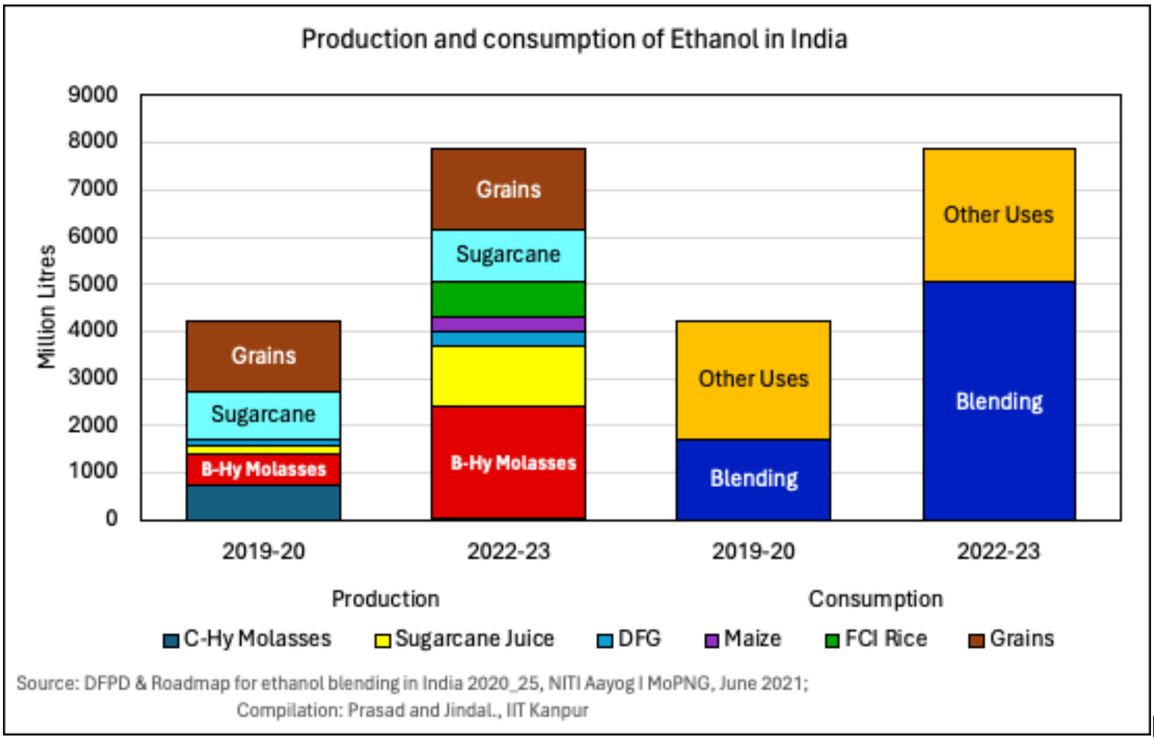

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Figure 12: Changes in production and consumption of ethanol categorised by feedstocks

The state-wise data for ethanol produced for blending[6] shows that ethanol production for blending is more widely distributed than sugarcane production (Figure 14). This spread indicates that non-sugarcane-producing states are also increasing ethanol production for blending, which could be grain-based or dependent on other states' molasses. While state-level economics could answer how some states are doing better than others regarding the Fratio of sugarcane production to ethanol production, we have not covered it in this study.

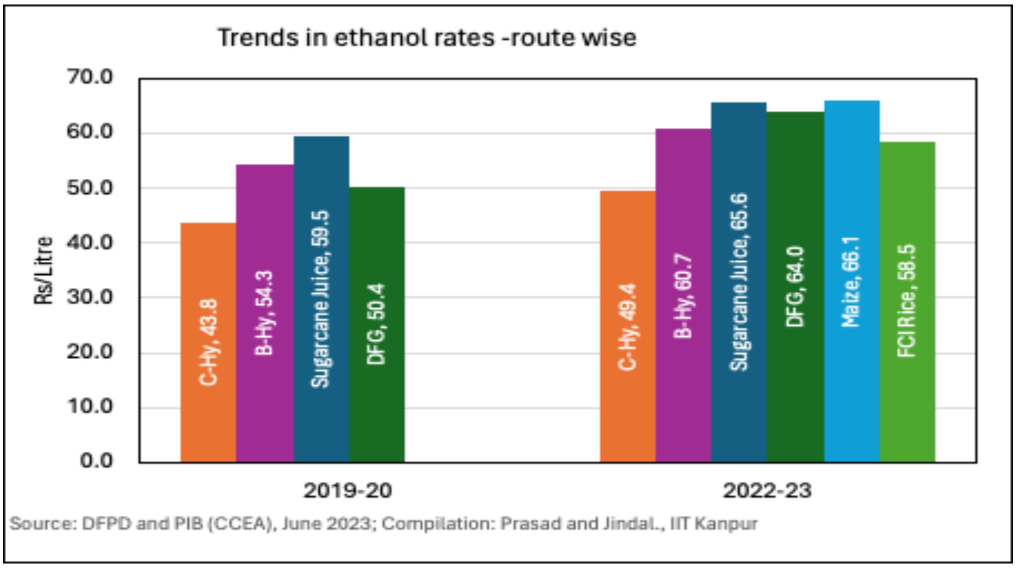


Figure 13: Prices of feedstocks for ethanol in the year 2019-20 and 2022-23

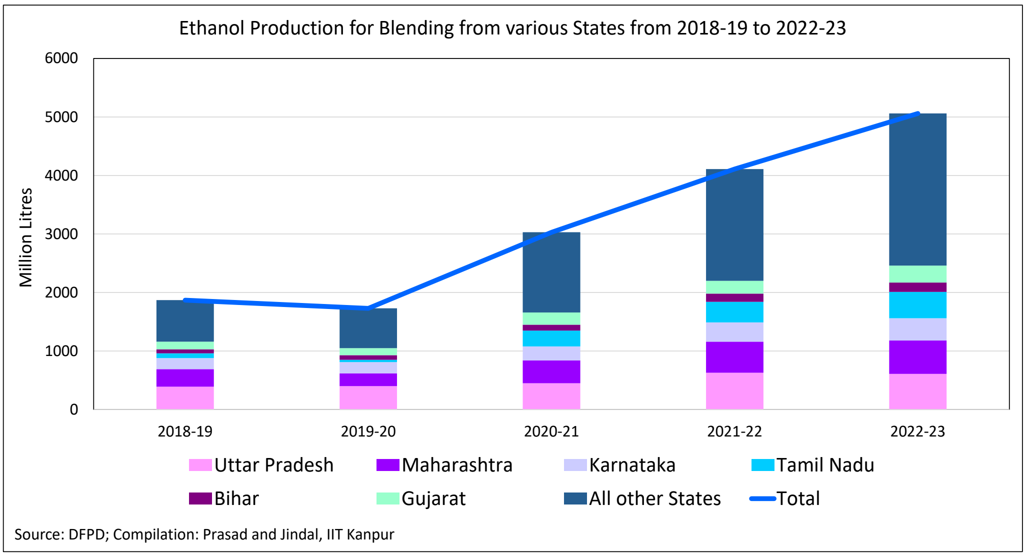


Figure 14: Growth of ethanol production in various states in recent years

Overall, we find that post-NBP 2018, there has been multifold expansion in ethanol capacity, increase in ethanol production, shift towards higher production of ethanol for blending, diversification of feedstock varieties, participation of more states in ethanol production as compared to only sugarcane producing states, the establishment of grain-based ethanol capacity, increased number of players in ethanol blending through standalone distilleries in addition to attached/integrated distilleries with sugar mills. These changes have increased ethanol blending from 5% in 2019-20 to 10% by 2022-23, suggesting the policy effectively met the headline targets. This also indicates that price signal as an instrument has mobilised investment in specific ethanol production routes. However, this has also necessitated understanding the details of the headline changes for different stakeholders. Such a bottoms-up analysis of NBP 2018 can provide evidence for the future direction of the policy targets and timelines. It will also identify possible trade-offs with food, water, environment, and energy security. We have therefore conducted a field-level study (Section 2) to assess the economic, social, and environmental implications of the NBP program and inform the policymakers of our findings.

Section II Present study: Objective, Methodology, Findings, and Implications on future growth

2.1 Objective and scope of the study

To assess the economic, social, and environmental implications of the NBP program to provide insights into its effectiveness and potential trade-offs. In doing so, the study also highlights the sector's possible challenges and future pathways. The impact is assessed for four stakeholders: farmers, distillery plants, the local economy, and the environment. The following points define the scope of the project:

- Impact on farmers' income who provided crops for ethanol production.
- Impact of the payment schedule to the farmers for feedstock offered under the EBP program.
- Impact on distilleries profitability.
- Implications for fossil fuel consumption.
- Impact on greenhouse gas emissions and other environment indicators like water use and soil pollution
- Impact on job creation in the ethanol blending value chain after the EBP program.
- Potential demand and market size of by-products of ethanol.

2.2 Study Design and Methodology

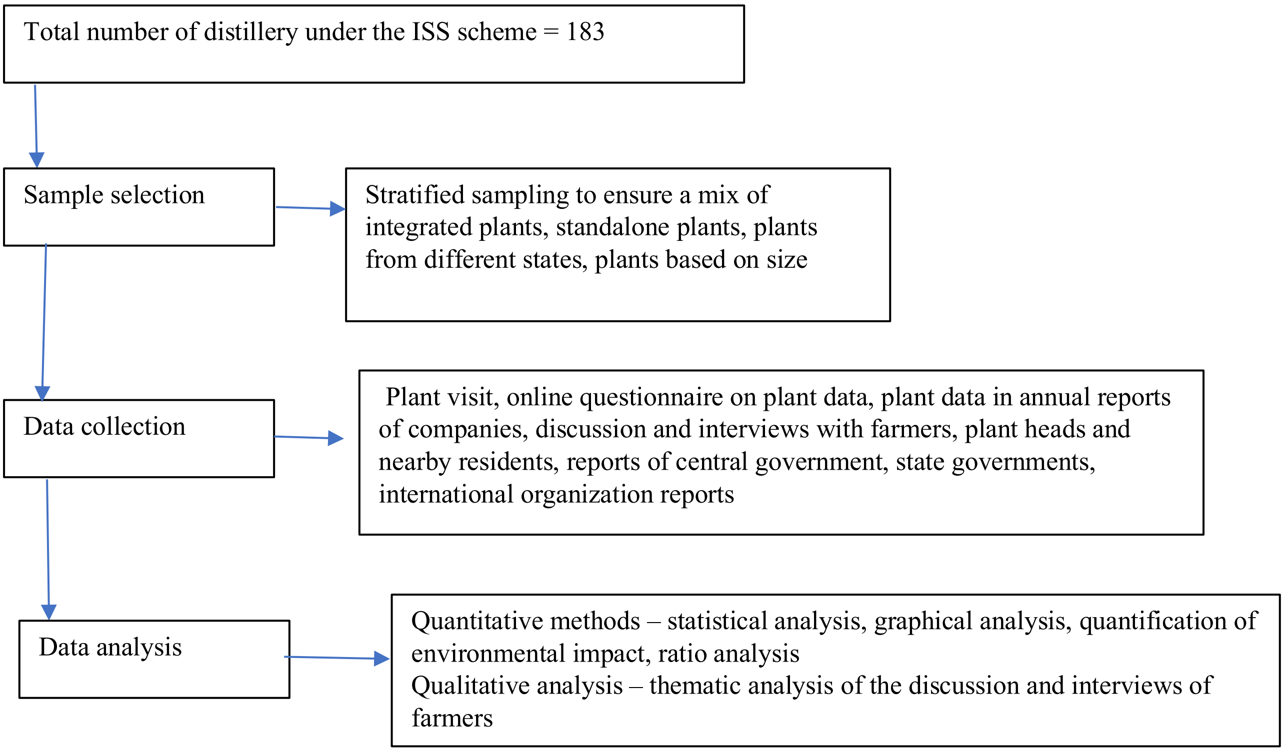
We used a case study approach of selected distilleries using (a) interviews with multiple stakeholders like plant heads, other experts in the distillery plant, farmers, and nearby residents; (b) observations of the plants; (c) analysis of reports and data.

For this, we first identified a set of indicators to capture the impact in the short, intermediate or medium, and long term and quantify it wherever possible. Table 1 presents the list of stakeholders, the corresponding indicators, and their source of data used for this study.

Table 1: List of stakeholders, indicators and data sources used for this study

Stakeholders	Indicators	Data source
Farmers	Payment of Sugarcane (value and time) Support from sugar mills Issues in sugarcane production Overall experience in dealing with mills	Field visits, primary data from surveys and discussions with farmers
Distilleries	Financial data like ethanol production (value and quantity), raw material (type, value, quantity), staff expenses (value), number of workers, interest expenses, profit before tax, depreciation, profit after tax, loan for ethanol machinery, cash and bank balance Non-financial data: CO_2 emissions, waste management, by-products and their management	Financial statements, data provided by plants using online questionnaires, plant visits, onsite discussions with plant head and workers
Economy	Sugarcane production, sugar production, ethanol as fuel (by sugarcane and grains), jobs created, economic activities in the nearby areas	Reports from Niti Ayog, Ministry of Consumer Affairs, companies' records, field visits
Environment	CO_2 equivalent emissions Soil Water	Calculated Economic Surveys of India, plant visits and discussions with residents near the plants

During the period of July 2018 up to August 2023, 183 distilleries availed financing under the interest subvention scheme, of which we shortlisted 28 distilleries using a stratified sampling technique. The criteria included plant location, capacity, nature, whether integrated (attached to sugar mills) or standalone, and the feedstock used. The list of the distilleries was shared with the Ministry of Consumer Affairs, which forwarded our request to the selected distilleries to share the data and our intent to visit them in person. The distilleries were informed that the data collection is for research and shall remain confidential.



ISS: Interest Subvention Scheme
Figure 15: Research methodology

To capture the financial details, we prepared a basic template for economic data and shared it with the ministry. This was done because the annual reports of the companies that owned these distilleries did not always give the details of ethanol production and costs incurred by the distillery unit. We also sent a request for a visit, for which we received an invite from 22 distilleries, which we visited from December 2023 to February 2024. Although we included five distilleries from Maharashtra in our first sample list, we visited eight distilleries, as these were arranged by the Maharashtra Sugar Association (MSA). The December to February 2024 period was selected to coincide with the sugarcane harvest season. Twenty distilleries shared financial data on production and cost over email. The process of sample selection is given in Figure 15. The details of the economic data sought from the distilleries are given in Annexure II. The final list of distilleries visited in person and the list of distilleries that shared the data online are provided in Annexure III. For the data analysis, we used both primary and secondary data.

(a) Primary data was collected through interaction with plant heads, farmers, and other plant personnel and our observations.

(a.1) Semi-structured interviews:

During the visits, we interacted with the distillery personnel to understand their perception of the scheme, its impact and the challenges. We conducted the interviews of the plant heads in person using a semi-structured questionnaire which inlcuded the financial aspect of ethanol production, the impact of the incentive scheme, the cost of the raw materials, the treatment of the by-products among others. The detailed questionnaire is given in Annexure IV.

(a.2) Discussions and observations:

We conducted focused group discussions and one on one interaction with various stakeholders, including farmers, plant heads, and managers. These conversations provided valuable qualitative insights into the perspectives and experiences of those directly and indirectly involved with the distilleries and, in turn, ethanol production. Apart from this, we walked through the plants with distillery personnel, understanding the procedures, production processes, and environmental practices that are being followed, which were crucial in understanding the operational aspects of ethanol production

(b) Secondary Data: The secondary data was collected from the companies' published financial reports, data shared by the plants, reports on India's sugar industry by Indian and international think tanks, and reports from central and state governments.

We employed qualitative and quantitative techniques for the analysis. The quantitative methods used in this study include financial ratio analysis, statistical analysis, graphical representation of data, and quantification of environmental impacts. These methods help understand the distilleries' margins, efficiencies, and the sector's environmental footprint. We used discourse analysis to interpret the discussions and interviews in the qualitative analysis. This approach was instrumental in understanding the perspectives of farmers and the distillery personnel.

2.3 Results and Findings

2.3.1 Descriptive statistics of the visited distilleries and the distilleries that shared the financial data

Table 2 presents the descriptive statistics of the study sample. Our initial sample included 34 distilleries to whom requests for visits were sent. Of this 22 distilliers responded with confirmation and we visited. Two other distilleries whom we did not visit shared their financial data on ethanol over the mail.

Table 2: Summary statistics of the plants in the study sample

Items	Total Sample	Visited	Visited and data shared	Not visited but data shared
Number	34	22	18	2
Capacity (KLPD)	5,720	4,640	3,865	400
Integrated/Attached	29	19	16	2
Standalone	5	3	2	0
Size				
Small (30-100 KLPD)	15	6	3	0
Medium (100-300 KLPD)	11	8	8	2
Large (300-700 KLPD)	8	8	7	0

2.3.2 Observed value chain (from plant visit)

We observed the ethanol blending process value chain during the plant visit. Based on that, we mapped the ethanol blending process using sugarcane molasses and grains. The ethanol blending value chain comprises molasses from sugarcane or slurry from grains that are fermented, distilled and evaporated to produce ethanol (Figure 16). The snapshot of the value chain is shown in Figure 16 (the detailed value chain can be seen in Annexure V).

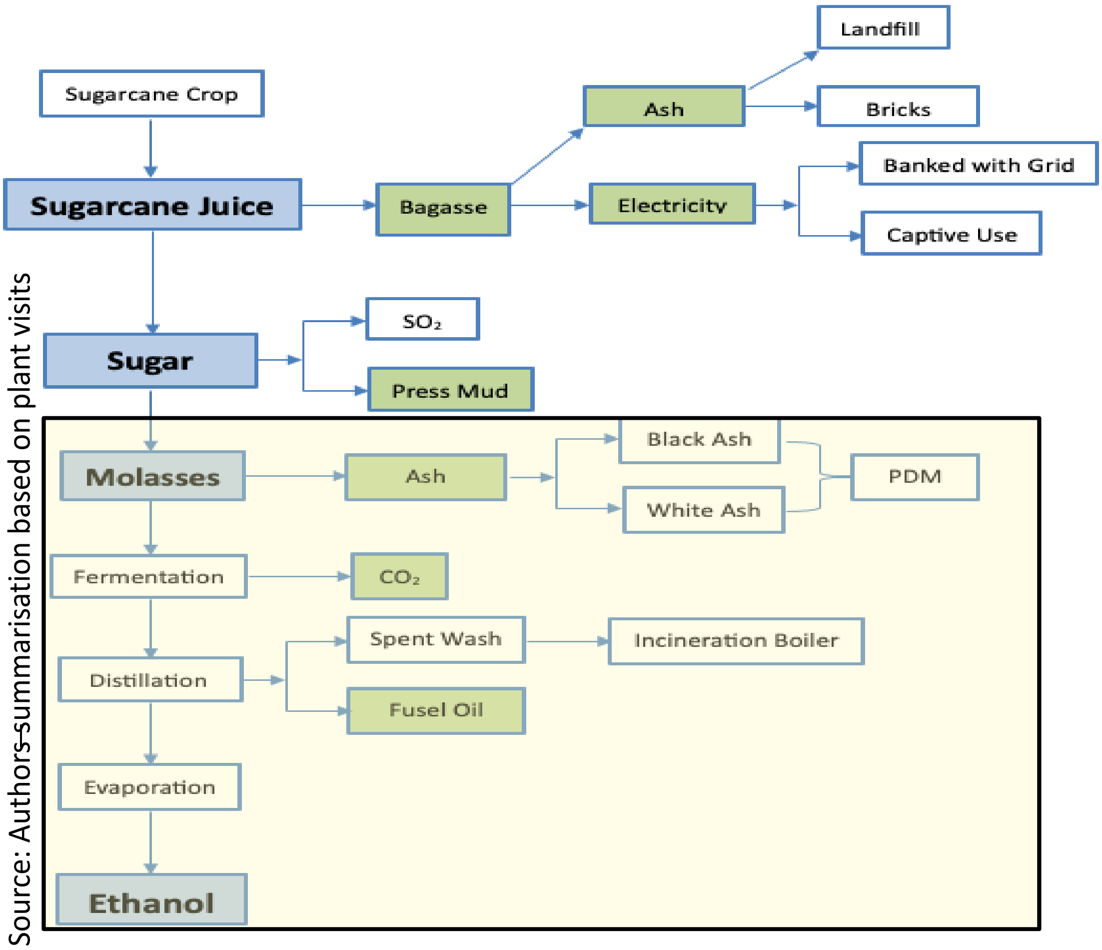


Figure 16: Sugarcane-based ethanol process (Blue blocks indicate products. Green blocks indicate by-products. The shaded part represents the process flow of a standalone distillery)

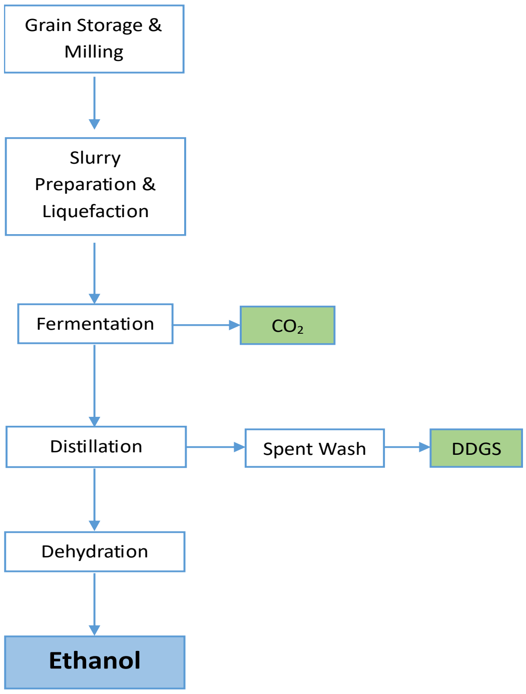


Figure 17: Grain-based ethanol process (Blue blocks indicate products. Green blocks indicate by-products).

2.3.3 Impact on farmers

Using discourse analysis, we identified the major themes shared by the farmers, which can be broadly categorised into two categories: (a) regarding payment duration and rate and (b) the other crop-related issues (Table 3 and pic 1,2,3). We further categorised the response by the size of the farm holding of the farmers, thus allowing capture their responses in case they differ across the states and the farms' size (Table 3).

(a) Payment for sugarcane (value and time)

The government controls and guarantees sugarcane selling prices through Fair and Remunerative Prices (FRP)[3]. The central government fixes this price, and some states provide top-ups over and above the FRP, known as the State Adjusted Price (SAP). Currently, FRP is worked out using a standard formula involving a fixed price and certain variations depending on the sugar recovery rate from sugarcane. While the price of sugarcane has been on the rise, as seen in Figure 5 in Section 1, there were severe delays in receiving the payment, as seen in high cane arrears in Figure 6 in Section 1. Our interaction was therefore, motivated by their earlier experiences from the published reports in which it was noted that the farmers did not receive money on time and at the rates of either FRP or SAP, whichever is higher.

During our visit, most of the farmers we met in the UP region shared that the payment of their sugarcane produce is on time and at the rate that the central government or the state government determines. They receive money in their bank account within 14 days of selling their produce. Sometimes, they even receive it earlier. They receive the notification for the same on their mobile. If one does not have a mobile, it can be easily checked using an unique number on any other mobile device. The timely payments has improved their lifestyle significantly. Previously, the payment was delayed by several years from the sugar mills, which meant they could not pay school fees on time, denying their kids an opportunity for a good education. But now, they are able to make invetsments such as purchase and building their own houses. Some of the videos of our interaction with the farmers in this region bring out the benefit of timely payment to their lives. On comparing the farmers views across selected states which we visited, we find that all of them receive money within two weeks in their bank accounts. The highest rate is offered to farmers in Karnataka followed by UP and Uttarakhand (Table 3). Improvement in payments to the sugarcane farmers is also evident in the declining proportion of arrears (Figure 18).

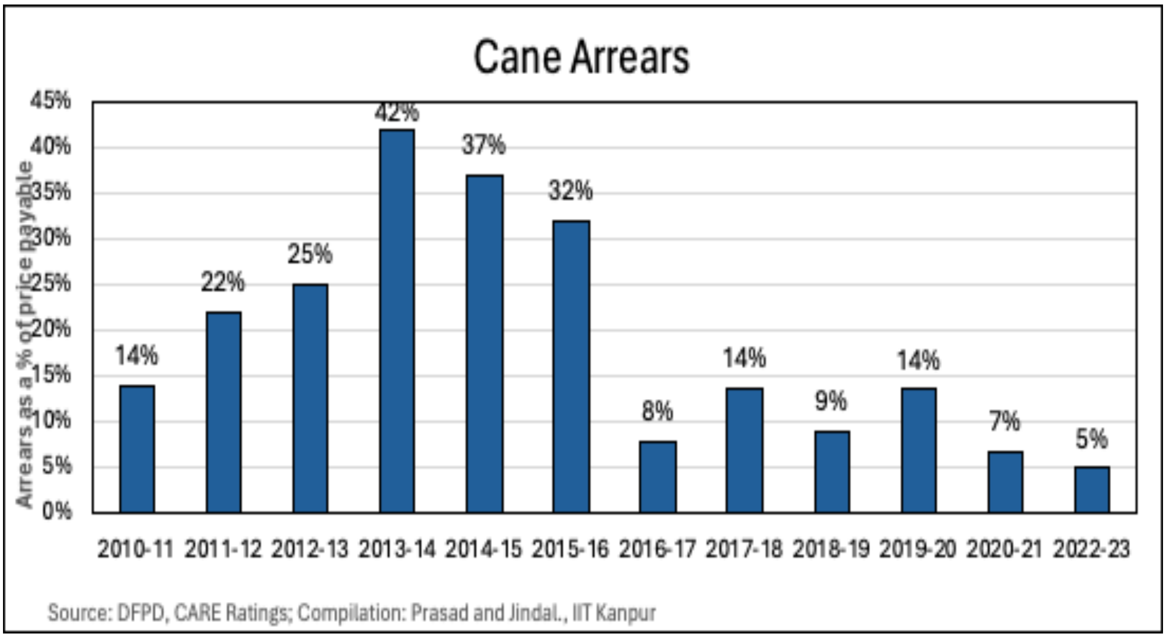


Figure 18: Cane arrears for Farmer’s: showing improvement in the last few years

(b) Other issues

In addition to the timely payments, farmers also shared the other kinds of support from sugar mills, like ensuring the crop yield through timely follow-ups and resolving issues of irrigation, harvesting, transportation and provision of fertiliser (Table 3). UP farmers near Meerut said, “*The sugar mills are part of their community”.* However, the same cannot be said about the grain side, where the farmer community’s integration with the mills was not apparent. A probable reason for this could be that the supply chain of grain-based ethanol is working through “Anaj Mandi”, which possibly involves some middlemen who do not share the same interests as sugarcane mills do with the sugarcane farmers.

Farmers shared some concerns about the increasing cost of seeds and fertilisers, which is impacting the cost of production. They believe higher payments should be made for the crop or the costs of other services (like seeds, fertiliser, etc.) should be subsidised.

Table 3: Summary of discussion with farmers on sugarcane prices, payment from the mills and other issues

States\Size	Small Farmer (1-2Acres)	Mid-size Farmer (4-10Acres)	Large Farmer (>10 Acres)
Uttar Pradesh	Rs. 340 - 350/- per quintal Payments are received within two weeks (in bank accounts), sometimes within 7-10 days.	Rs. 340 - 350/- per quintal Payments are received within two weeks (in bank accounts), sometimes within 7-10 days.	Rs. 340 - 350/- per quintal Payments are received within two weeks (in bank accounts) and sometimes within 7-10 days.
Karnataka	Rs.370/- per quintal Payments received within two weeks (in bank accounts)	Rs.370/- per quintal Payments received within two weeks (in bank accounts)	
Maharashtra	Rs. 250 - 310/- per quintal Payments received in 30 days (To bank accounts) The cane variety used is 86032, 265	Rs. 250 - 300/- per quintal Payments received within 15-25 days (To bank accounts) The cane variety used is 86032,265, 3102	Rs. 290 - 300/- per quintal Payments received in 30 days (To bank accounts) Cane variety used is 265
Uttarakhand	Rs. 335 - 350/- per quintal. Payments are received within two weeks (To bank accounts), sometimes earlier.	Rs. 335 - 350/- per quintal. Payments are received within two weeks (To bank accounts), sometimes earlier.	Rs. 335 - 350/- per quintal. Payments are received within two weeks (To bank accounts), sometimes earlier.
Tamil Nadu	Rs. 290-300/- per quintal. Payments are received within two weeks (To bank accounts), sometimes within 8-10 days. The most used cane variety is CO86032.		
Other issues			
Uttar Pradesh	A Rs. 5000 subsidy is given for trench, and a Rs. 1 lakh subsidy is given to farmers who buy tractors (deposited into bank accounts).	They were emphasising developing varieties with higher yields and increasing cane prices.	8-10 times watering per harvest.
Karnataka	25-30 times watering is required. They used to get a subsidy for drip irrigation, but now it is discontinued.	25-30 times watering is needed.They used to get a subsidy for drip irrigation, but now it is discontinued.	
Maharashtra	Fertiliser costs are Rs.15000 to 30000 per acre. Once in 7 to 30 days, watering is needed. Fertilisers used are Urea, DAP, and Pressmud.	Fertiliser costs are Rs. 6000 to 40000 per acre. Once in 15 to 30 days, watering is needed. Fertilisers used are DAP, Urea, Potash, and Single Phosphate.	Fertiliser costs are Rs. 15000 to 20000 per acre. Once in 15 to 30 days, watering is needed. Fertilisers used are Urea, 1026, 1846, and Press mud.
Uttarakhand	Unavailability of labour due to which labour costs have increased. Fertiliser costs are increased. Daily expenses and all input costs for sugarcane production are increasing, but sugarcane prices have not been revised in the past few years.		
Tamil Nadu	20-25 times watering is required. Fertilisers used are Urea and DAP. Fertiliser costs have increased.		

*DAP: Di-ammonium Phosphate
Source: Authors summarisation based on interaction with farmers during the field visit

Pic 1 **Pic 2**

Pic 3

Pic 1,2,3: At the Nanglamal sugar complex, cane collection point, with farmers (Nanglamal village, Meerut, Uttar Pradesh). On 29/12/2023 (12:10 PM). P.C., Dushyanth Kumar Reddy G

Pic 4: At Munoli village (Karnataka, Belgavi) in the sugarcane field with farmers near Shree Renuka Sugars Ltd. On 29/01/2024 (11:25AM). P.C., Farmer

Pic 5: At Munoli village (Karnataka, Belgavi) with farmers, nearby Shree Renuka Sugars Ltd. On 29/01/2024 (11:45AM). P.C., Farmer

2.3.4 Impact on distilleries

Our analysis of the data shared by the distilleries suggests that the ethanol blending programme has had two effects on the distillery units:

- On the profitability of distillery units
- On the potential market for the different by-products from the ethanol value chain.

(a) Ethanol production for blending – medium size plants with 100-300 KLPD capacity are driving the production increase.

We have conducted a two-dimension analysis based on size and period. While we requested financial data from our sample distilleries for ten years, we received data for 8 out of 10 years from 20 distilleries. Many distilleries shared consistent data for only last five years. In some cases where the distillery is completely new, the data has been shared for one or two years, depending upon availability. To get a better understanding of the movement in the production and profitability of ethanol, we divided the total period of 8 years into three categories:

- Sample data period: from 2015-16 to 2022-23, as the sample data period, the distilleries shared data for this period.
- Medium/intermediate period: from 2018-19 to 2022-23 as the intermediate or medium term.
- Short term: the period immediately following the NBP 2018 from 2018-19 to 2020-21

The distilleries in the study sample are classified in terms of size: large, medium and small. We have seven large distilleries with sizes more than 300 KLPD up to 700 KLPD, ten medium distilleries with sizes more than 100 KLPD but less than 300 KLPD, three small distilleries with sizes upto 100 KLPD (Table 4)

Table 4 Sample plants in the study categorised by capacity/size

Capacity (KLPD)	Name of the plants*
Small (0-100)	E.I.D. Parry (India) Ltd, Kothari Sugars & Chemicals Ltd, Karmayogi Sudhakarpant Praicharak Pandurang SSKL
Medium (100-300)	Buttar Biofuels Private Ltd (Standalone), Shreenath Mhaskoba Sakhar Karkhana Ltd, Rajarambapu Patil SSKL, Uttam Sugar Mills Ltd, Shree Datta Shetkari Sahakari Sakhar Karkhana Ltd, Sahakar Maharshi Shankarrao Kolhe SSKL, DCM Shriram Industries Ltd, Nanglamal Sugar Complex, BCL Industries Ltd, Balrampur Chini Mills Ltd
Large (300-700)	TruAlt Bioenergy Ltd, Shree Renuka Sugars Ltd, Oasis Ethanol Industries Pvt Ltd, Vitthalrao Shinde Sahakari Sakhar Karkhana Ltd, Avadh Sugar & Energy Ltd, Dhampur Sugar Mills Ltd, Triveni Engineering & Industries Limited (Standalone)

*The lists include the 18 plants that we visited and two plants that we did not visit, but they shared financial data

In the sample period, ethanol production increased by 218% from 192 million litres in 2015-16 to 609 million litres in 2022-23. In the short period, ethanol production for blending increased by 179 million litres or 51% from 2019 to 528 Mn litres in 2023. Figure 19 shows the ethanol production. A large part of this change was led by the medium-sized plants (capacity: 100-300 KLPD) followed by large-sized plants (capacity: 300-700 KLPD).

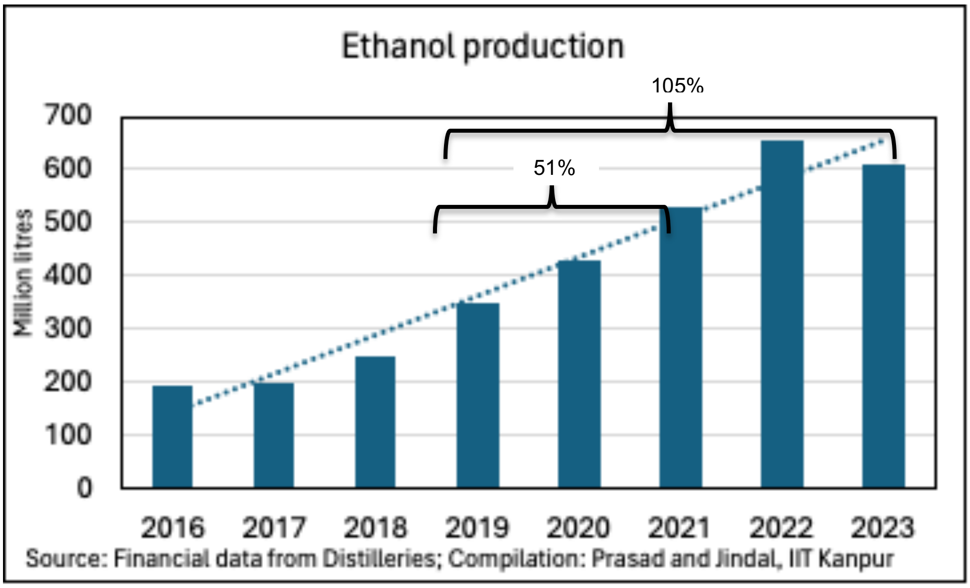


Figure 19: Ethanol production by the plants in the study sample from 2015-16 to 2022-23

Half of the increase in the ethanol production for the sample period (2015-16 to 2022-23) was driven by the medium-sized plants (100-300 KLPD) (Figure 20), where the production rose from 41 mn litres to 246 mn litres, an increase of 205 mn litres.

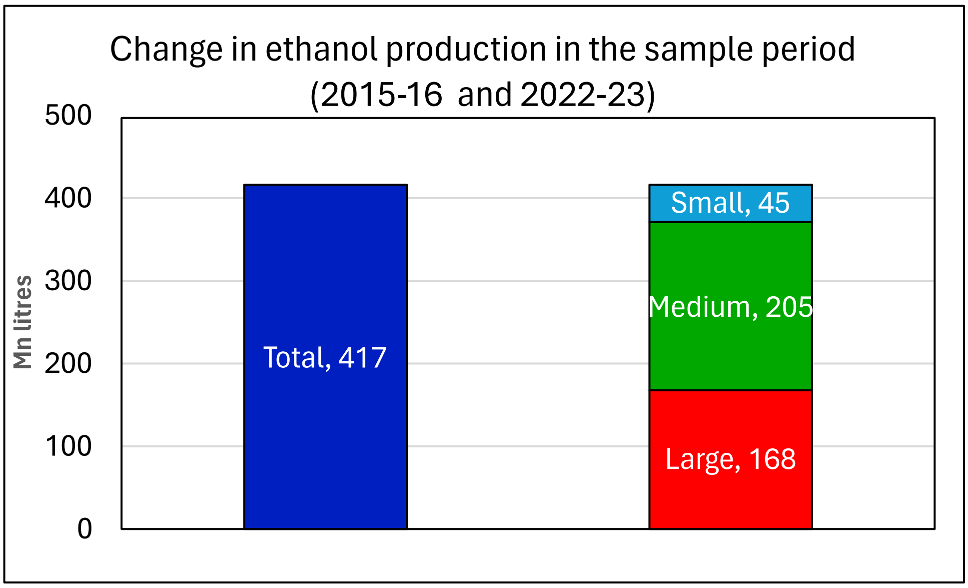


Figure 20: Change in ethanol production in the sample period categorised by the size of the plants

In the intermediate term (2018-19 to 2022-23), ethanol production increased by 260 million litres, of which 55% came from the medium size plants (100-300 KLPD) (Figure 21). Small-size plants (0-100 KLPD) contributed 13% to the increase (Figure 21).

Further, our discussion with the plant heads and the farmers suggest the ethanol production for blending will likely continue to rise, but they are concerned about policy uncertainty. The plants expect the policy uncertainty to continue for another two years. This uncertainty in policy direction is affecting them in two ways. First, many plants we visited had built their capacity on B molasses but due to the recent policy changes (such as higher prices for C-heavy compared to B-heavy, sugarcane juice not being allowed to be made into ethanol) the plants had stalled their further investment decisions for expansion. Second, the plants in the UP region are experiencing pressure from the state authorities to divert more and more molasses for country liquor. On the other hand, grain-based ethanol plants are experiencing difficulty in the availability and affordability of raw materials. As a result, their average capacity utilisation for the last four years is much lower (57%) than sugarcane molasses (64%), even though the molasses-based plants have also seen a decline in capacity utilisation (67% to 55% comparing the last two years).

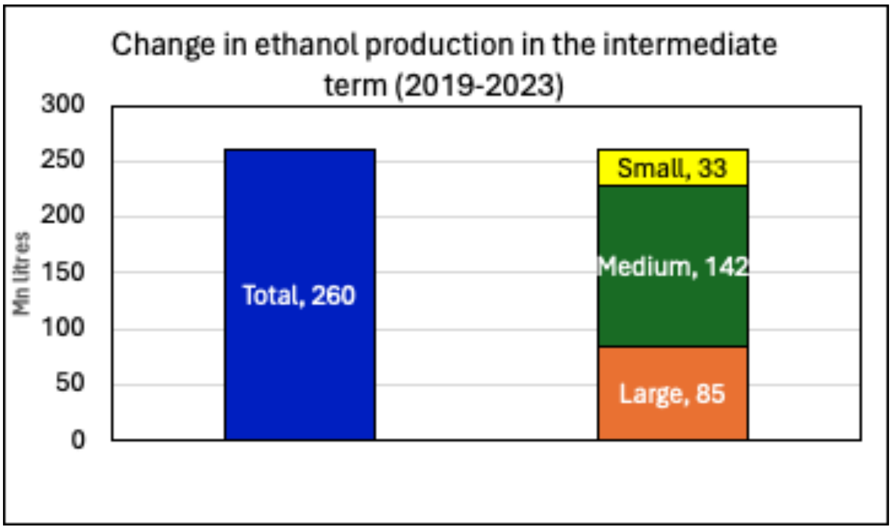


Figure 21: Change in ethanol production in the medium term categorised by size of the plants

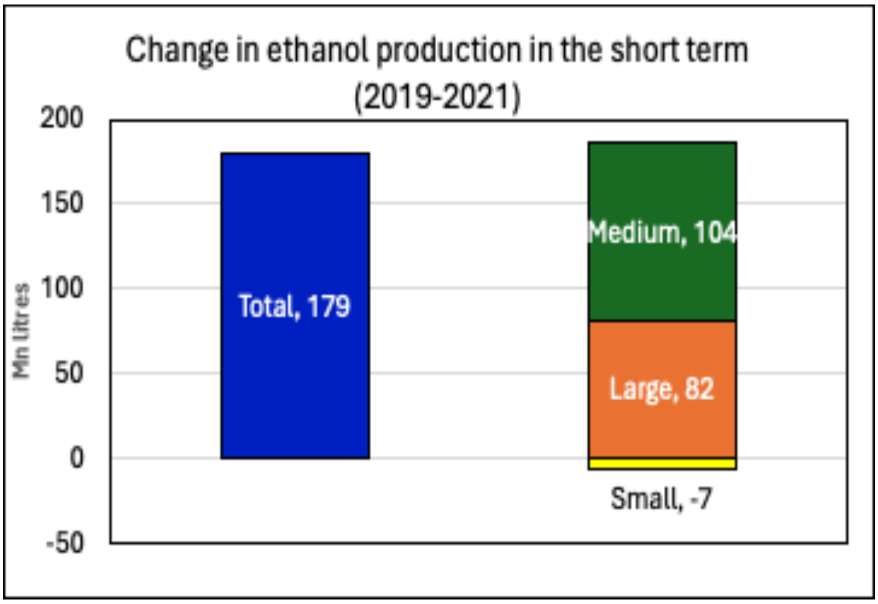


Figure 22: Change in ethanol production in the short term categorised by size of the plants

(b) Profitability of the distilleries

Profit margin, measured as profit before tax (PBT) divided by revenues from ethanol sales, is around 17% for all the sample distilleries in 2022-23, with large plants' (300-700 KLPD) PBT margin at 17%, medium size (100-300 KLPD) plants' margin at 19% and small plants' (0-100

KLPD) margin at 7% in the year 2022-23. We also analysed another another indicator of profitability: earnings before interest tax depreciation (EBITDA) margin calculated as EBIDTA divided by revenues from ethanol sales to understand the plant's operational business margin. We find that EBIDTA margin is 21% for all the sample firms in 2022-23; large plants' (300-700 KLPD) EBIDTA margin is 21%, medium size plants (100-300 KLPD) margin is 23% and small plants (0-100 KLPD) margin is 13% in 2022-23. A comparison of the difference between the PBT margin and EBITDA margin across different plant sizes suggests that smaller distilleries provide for higher depreciation of the plants in the short term.

We find that distilleries attached to sugar mills have their raw material prices (sugarcane) and final output price (ethanol) fixed by the central government, giving them an administered margin, highly dependent upon government decisions. If the central government wants to incentivise (curtail) ethanol production in the country, it can set a higher (lower) price signal on the output side. As a result, margins depend entirely on policymakers' intentions; hence, when the interest payments were subsidised, the plants benefited by expanding their capacity. Such a capacity build-up would have been tough without this financial incentive, especially when the investment amount runs into several crores of rupees. Also, because the margins from the sugar business were already squeezed, the incentive on ethanol production has provided them with an additional source of revenue.

A wide range of variability exists in the profit margins of large, medium, and small-scale distilleries. Table 5 shows the average PBT margins of the plants categorised by capacity and period. As seen in the Table 5 the PBT margin for plants ranges from 12-33% in the short term (2018-19 to 2020-21), with the highest margins for large-scale (300-700 KLPD) distilleries. In the medium term (2018-19 to 2022-23), the PBT margin varies from 14-27%, with the highest margins for medium-sized (100-300 KLPD) distilleries. Medium size (100-300 KLPD) distilleries also have the highest average PBT margins for the entire period under study (2015-16 to 2022-23) at 41%. This possibly explains why most ethanol capacity expansion was seen from the medium-sized plants.

Table 5: Average PBT margins* of plants in the sample time-period, short time-period and medium time-period

	Capacity (KLPD)	Sample period (2015-16 to 2022-23)	Short-term (2018-19 to 2020-21)	Medium-term (2018-19 to 2022-23)
All sample	0-700	28%	26%	23%
Large size plants	300-700	26%	33%	27%
Medium size plants	100-300	41%	18%	19%
Small size plants	0-100	10%	12%	14%

*Profit before tax divided by revenues from the sale of ethanol
Source: Authors calculations based on data shared by distilleries

Table 6 gives average EBITDA margins off the distilleries classified by capacity and for the periods classified into short-term and medium-term. Average EBIDTA margins, indicating operational profitability ranges from 23-49%, with large-size plants having the highest margins in both the short (2018-19 to 2020-21) and medium periods (2018-19 to 2022-23).

Table 6: Average EBIDTA margins* of plants in the sample time-period, short time-period and medium time-period

	Capacity (KLPD)	Sample period (2015-16 to 2022-23)	Short-term (2018-19 to 2020-21)	Medium-term (2018-19 to 2022-23)
All sample	0-700	35%	31%	28%
Large size plants	300-700	32%	38%	31%
Medium size plants	100-300	49%	25%	25%
Small size plants	0-100	23%	16%	21%

* Earnings before interest, tax and depreciation divided by revenue from the sale of ethanol.
Source: Authors' calculations based on data shared by distilleries.

Overall, 50% profitability margins seen from 2015-16 to 2018-19 seem to be stabilising at 20–25% (Figure 23), which is expected with the economies of scale in the sector and more plants entering the market. However, given that small plants (0-100 KLPD) operate on much lower margins as compared to large and medium plants, it is likely that any increase in raw material price or decrease in ethanol prices can adversely affect future growth and financial viability in the plants. Figures 24-26 show the trend in year-on-year profitability for different plant sizes.

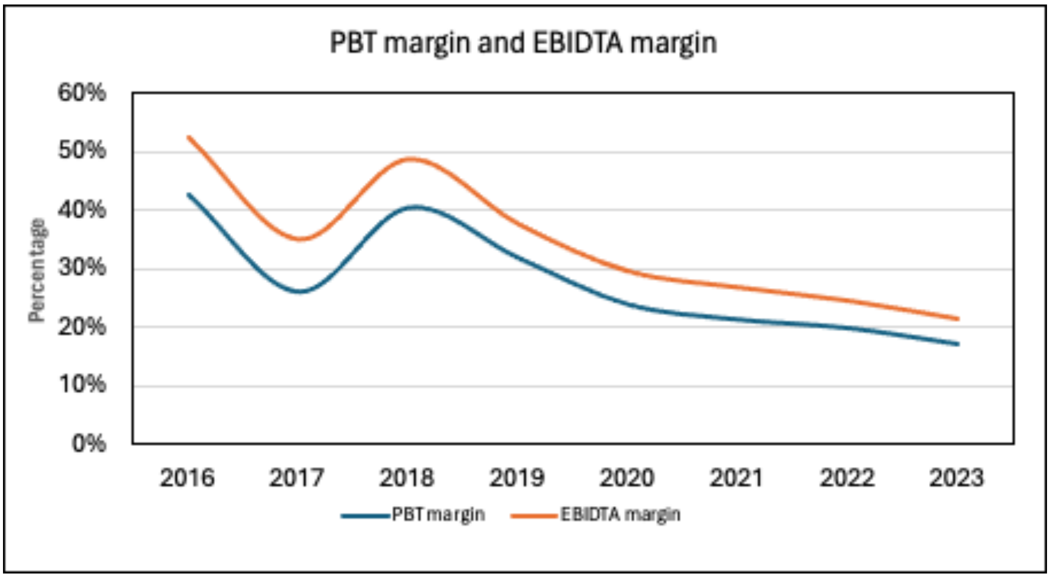


Figure 23: Profitability margins of all plants (0-700 KLPD) in the study sample from 2015-16 to 2022-23

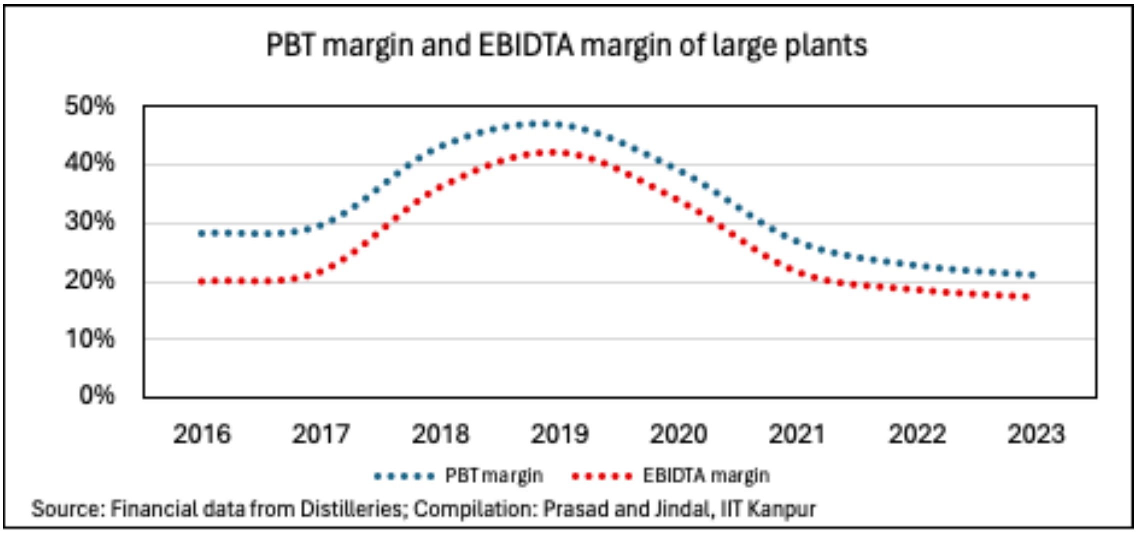


Figure 24: Profitability margins of large plants (300-700 KLPD) over 2015-16 to 2022-23

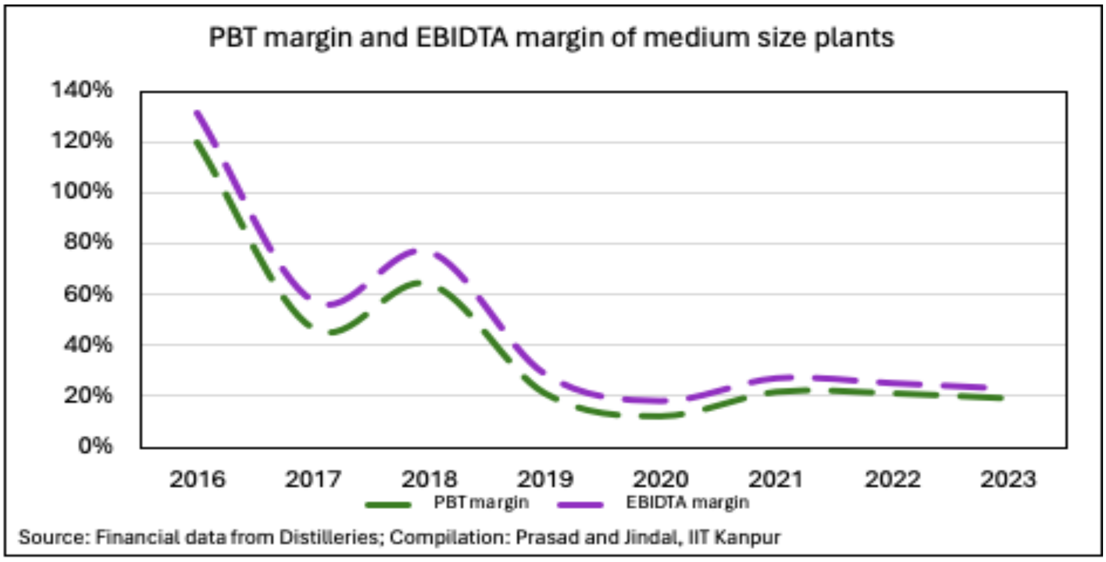


Figure 25: Profitability margins of medium size plants (100-300 KLPD) over 2015-16 to 2022-23

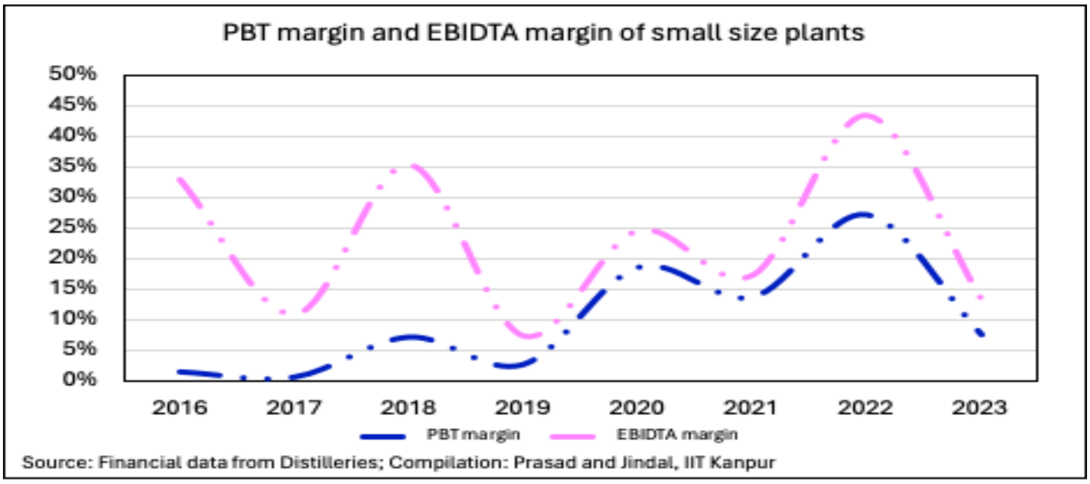


Figure 26: Profitability margins of small-size plants (0-100 KLPD) over 2015-16 to 2022-23

(c) Investment in ethanol blending plant and machinery

Investment in machinery related to ethanol production has increased from Rs 4.4 bn in 2015-16 to Rs 23.2 bn in 2022-23, an increase of 423% (Figure 27). In absolute terms, investments in large plants (300-700 KLPD) increased by Rs 7.5 bn, medium plants (100-300 KLPD) by 10.4 bn, and small plants (0-100 KLPD) by 864 million over the same period. Figure 28 shows the increase in the investments in machinery by plant size, which, as seen, is highest for medium-sized plants (100-300 KLPD). In percentage terms, the medium plants (100-300 KLPD) investments increased by 822%, large plants (300-700 KLPD) by 271% and small plants (0-100 KLPD) by 213% over the same period.

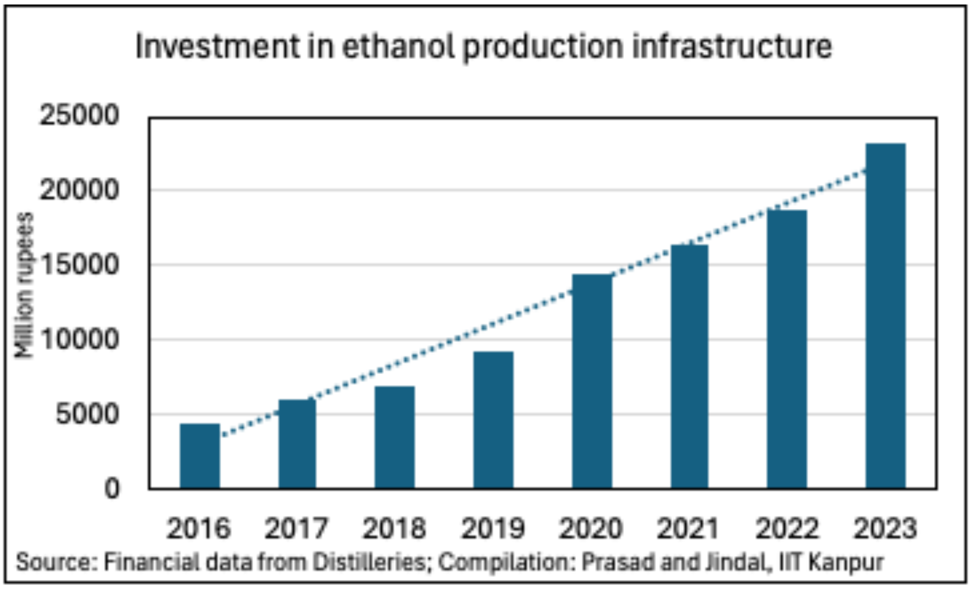


Figure 27: Investment in machinery for ethanol production over the years 2015-16 to 2022-23

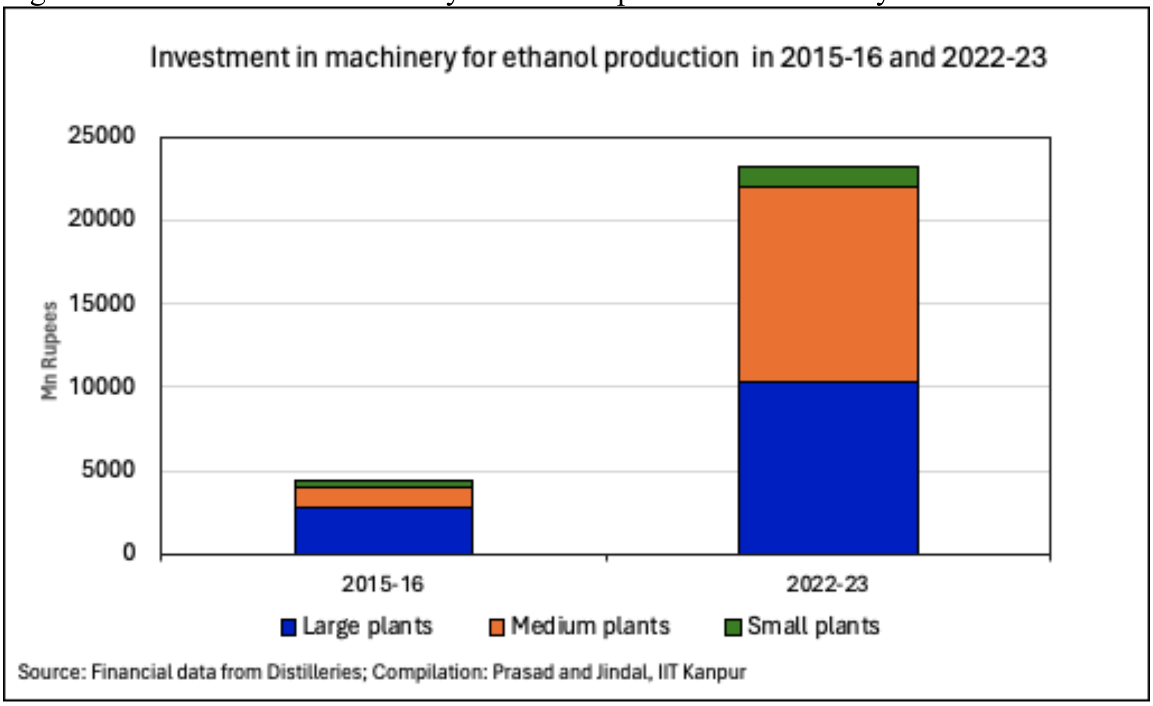


Figure 28: Investment in machinery for ethanol production over the years 2015-16 to 2022-23 by plant size

The increase in investment in ethanol machinery is more than the increase in ethanol production, suggesting that the industry has created capacity for larger blending targets. The company's perception of strong political will behind ethanol blending targets drove the confidence to expand in the sector. We also found that the plants are willing to develop and create further capacity provided the sector has policy certainty. However, the recent frequent changes in policy may not argue well for the continued buoyant growth of the industry. Hence, if the demand for ethanol were to be reduced, there would be a risk of stranded assets in the sector. Further, as per our interactions with the plant head, if the margins go below 10%, it would be difficult for them to continue their operations.

(d) Electricity consumption

Results show that the energy efficiency in the sector has improved with a reduction in electricity consumption per unit of product. In 2015-16, 16 kWh of electricity produced 1 litre of ethanol, which was reduced to 8 kWh/l in 2022-23. As seen in Figure 29, the electricity consumption per litre of ethanol produced has reduced to nearly half over the last eight years. This suggests that the new capacity built after the scheme has advanced technology and is more efficient than the previous one. The industry is confident that newer machinery for ethanol production puts India in a competitive position compared to other countries, like Brazil.

The electricity used in the attached or integrated ethanol blending plants is generated using the bagasse in their captive plant with the extra electricity banked with the grid. This arrangement allows the companies to draw power when needed at much lower rates at Rs 3.5-4/kWh than the prevailing grid power rates. 11 out of 20 plants we visited had captive power generation with a size range of 3-73 MWh. However, with the increasing quantity of bagasse, the plants are considering alternate uses.

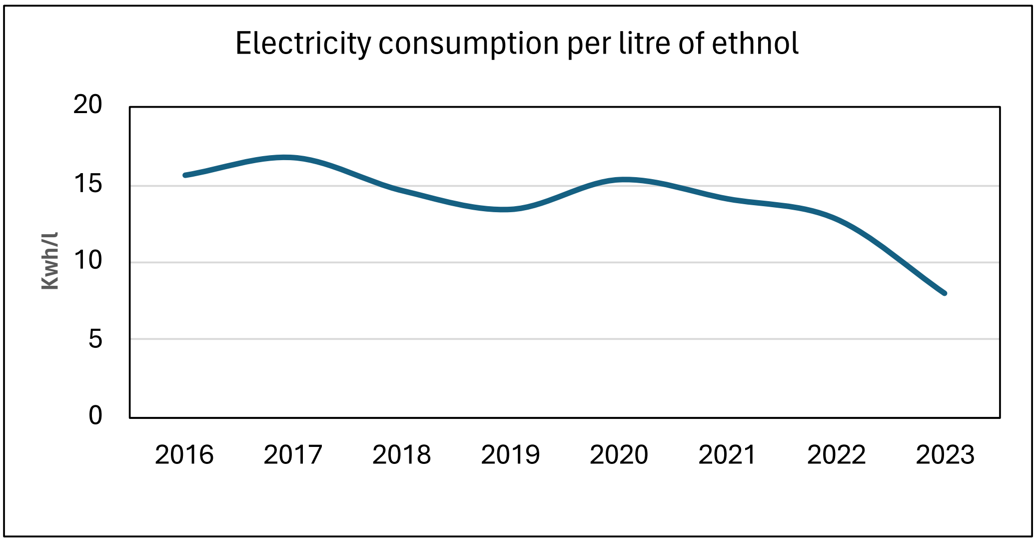


Figure 29: Electricity consumption per litre of ethanol produced

2.3.5 Potential market for by-products of ethanol

The sugar and ethanol production value chain also creates a possibility of different by-products like bagasse, press mud, molasses ash, carbon dioxide and fuel oil (shown in green boxes in Figure 16 and Figure 17), which has the potential to add additional revenue streams for the sector and probably improve margins for the overall industry. However, these are at nascent stages of extraction and market exploration.

(a) Bagasse: For integrated/attached sugar mills and distilleries, bagasse is one of the sugar-making process's by-products. Nearly 300 kg of bagasse is produced from 1 tonne of sugarcane. The bagasse is used as fuel in the distillery, to produce steam for the sugar and ethanol-making processes, and the extra bagasse is even sold off. Distilleries were encouraged to set-up turbines to produce electricity for their consumption and sell the surplus electricity to the grid. The price/unit for electricity sold to the grid has been reduced in 2023, due to which the initially installed excess capacity planned to be sold to the grid, which seemed profitable while installation, is not profitable at the low rates provided by the government recently. The ash that remains after the fuel is utilised is rich in potash and can be sold off for utilisation as fertilisers for farming.

(b) Press mud: It is produced during sugar production and is rich in organic matter. Currently, the mills are giving it to farmers at very subsidised rates.

(c) Potash derived from molasses ash (PDM): Molasses ash has a potash, making it an excellent agricultural fertiliser. However, the proportion of potash in molasses ash is 14 to 20%, which is low compared to the 60% potash in the imported fertiliser, Muriate of Potash. Currently, most ethanol plants sell the molasses to farmers at low rates, like a plant in UP, which sells it at Rs 500/ton. During our visit, we found that 3 out of 20 distilleries have invested directly or tied up with a third party to recover PDM.

(d) Carbon dioxide (CO_2): Another by-product that can have an economic advantage or cause environmental damage depending on how it is managed. If it is captured and processed, it can be used as dry ice or liquid CO_2. If it is not captured and emitted into the atmosphere, it can lead to global warming. We found that not all plants capture CO_2, and some do not even monitor the emissions (pic 6). 11 out of 20 plants reported capturing CO_2 and have collection and processing units.

Pic 6: Ethanol Fermentation Tank

At Avadh Sugar Mills, fermentation point, Sitapur, Uttar Pradesh). On 18/1/2024 (4:10 PM). P.C. Rajeev Jindal

(e) Distiller's dried grains with soluble (DDGS): DDGS are a co-product of grain-based ethanol production and are used as cattle feed. In the last few years, the price of DDGS has increased, leading to it being sold in the open market by the distilleries. This has added to the profit margins of the distilleries; in the absence of this, they would be working as a loss-making business. DDGS sales are currently aiding the distilleries in reaching a breakeven point rather than being at a loss.

(f) Distillers Wet Grains Soluble (DWGS): DWGS is a by-product of ethanol production. It does not have a market for itself. Hence, DWGS is converted into DDGS and then sold off.

The potential demand and market size for these by-products are subject to the efficiency of extraction methods, technological advancements, and overall market development. Increasing awareness of the environmental benefits of utilising by-products may further enhance market opportunities.

2.3.6 Impact on the local economy

Since NBP 2018, there has been a steady increase in sugarcane production (Figure 1), sugarcane crop area (Figure 2), sugar production (Figure 3) and ethanol production (Figure 11) . Section 1 provides a detailed account of the increased capacity production of ethanol and sugarcane and its implications on states. Sugarcane-growing states have increased sugarcane production (Figure 30), with states such as Maharashtra, Bihar and Karnataka growing faster than the national growth rate (Figure 31). Uttar Pradesh has grown consistently, matching the national growth rate. On the other hand, Tamil Nadu has seen reduced sugarcane production, but ethanol as fuel has increased, suggesting a structural change in the sector towards ethanol blending.

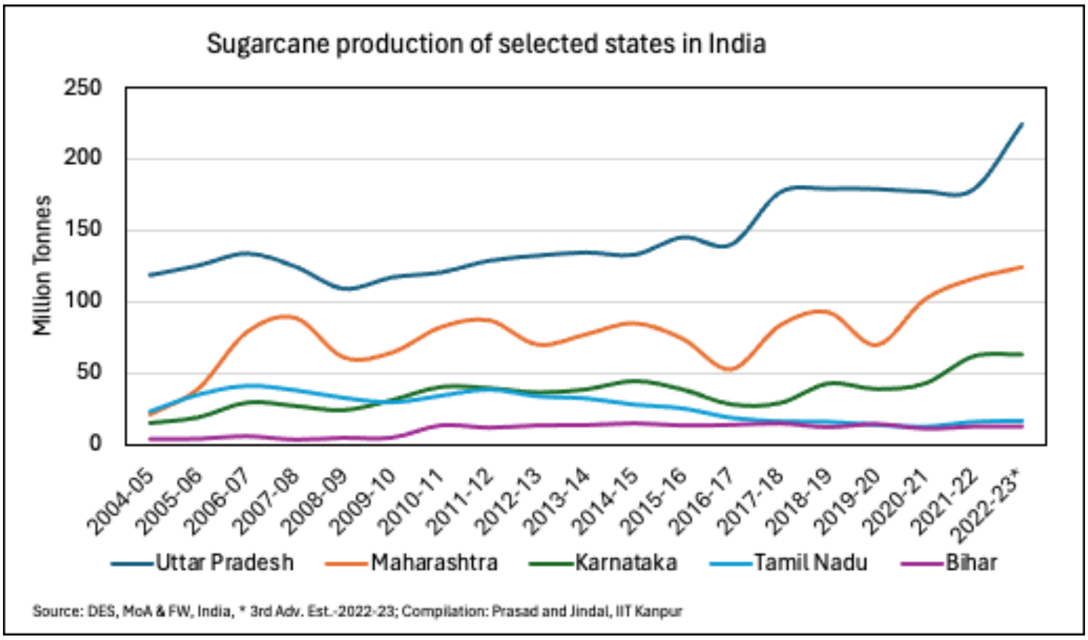
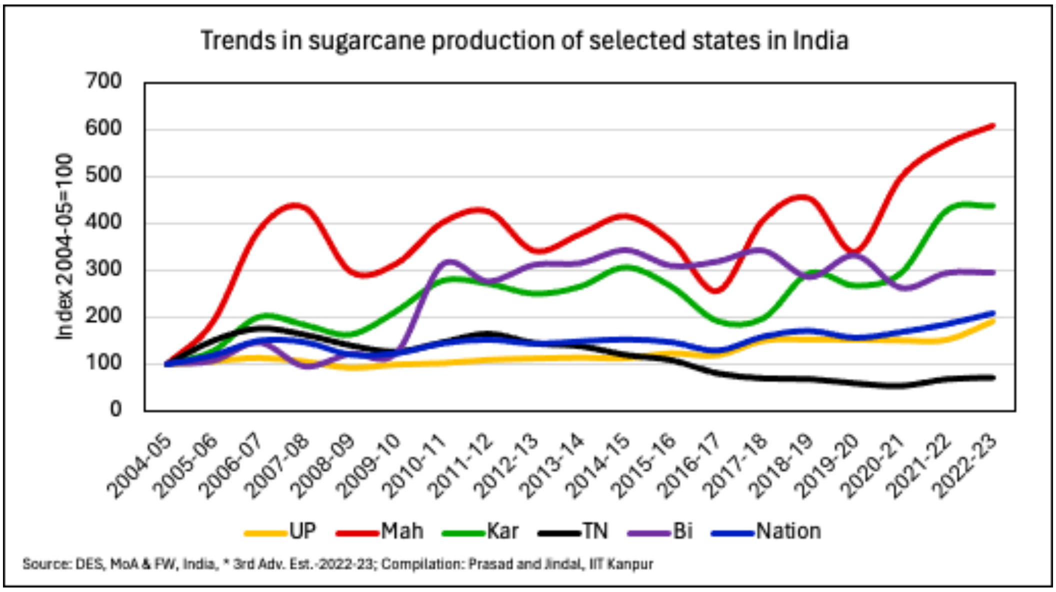


Figure 30: Sugarcane production of selected states in India from 2004-05 to 2022-23



UP: Uttar Pradesh; Mah: Maharashtra; Kar: Karnataka; TN: Tamil Nadu; Bi: Bihar
Figure 31: Trend in sugarcane production of selected states in India with 2004-05 as base

(a) Jobs created

The increase in ethanol capacity through the establishment of new distilleries and the expansion of existing ones has created new jobs and economic activities in the local area of the plants. The increased demand for feedstock boosted farmers' income and generated additional jobs in farming, harvesting, and transportation, contributing to rural employment.

As per the data from 20 distilleries, there are currently 3,636 direct employees in 2022-23, up from 1,411 employees, consistently rising since 2017. Large plants (300-700 KLPD) added 44 employees in the short term and 2,179 in the medium term. Against this, the medium size plants (100-300 KLPD) added 241 jobs in the short-term period and 356 in the medium-term. Small-scale plants (0-300 KLPD) added ten jobs in the short term and 101 in the medium term. The rising number of employees in distilleries is given in Figure 32.

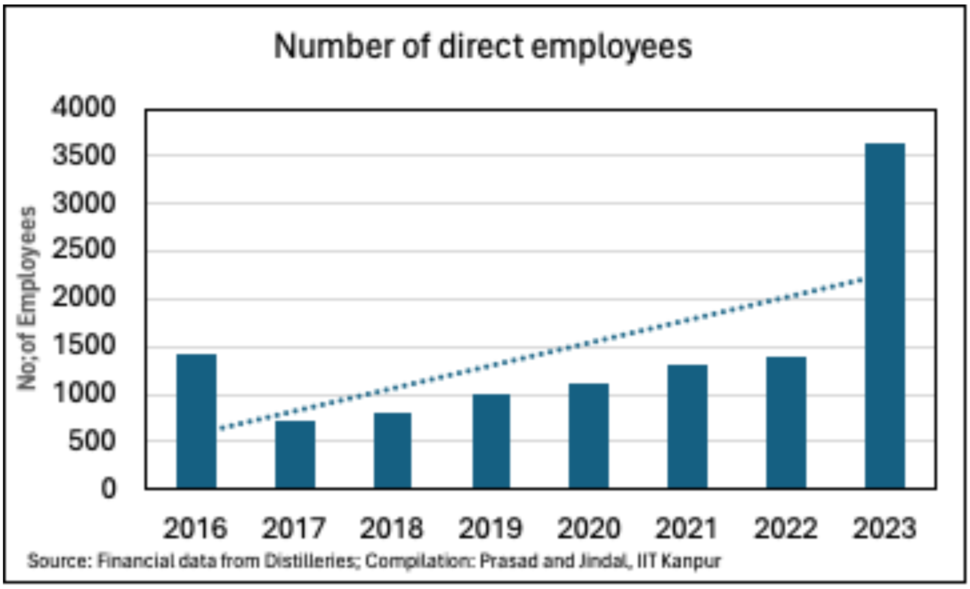


Figure 32 Number of direct workers from 2016 to 2023

2.3.7 Environment

2.3.7.1 Impact on greenhouse gas emissions:

Based on the reported emission values, our results on quantifying emissions from ethanol suggest that ethanol is a cleaner alternative to petrol, even after considering the emissions from production and combustion. We used the emission factor associated with ethanol production at 0.39 kgCO2eq/ litre and the emission factor associated with combustion at 1.45 kgCO2eq/ litre totals at 1.84 $kgCO_{2eq}$/ litre. If we compare these estimates with petrol, which emits 0.44 $kgCO_{2eq}$/ litre during refining and 2.27 $kgCO_{2eq}$/ litre during combustion, the total emissions are at 2.71 $kgCO_{2eq}$/ litre. As seen in Figure 33, the difference in emissions from ethanol as fuel vis a vis petrol is in the use stage or combustion. The production of ethanol and refining of petrol have similar emissions at 0.4$kgCO_{2eq}$/l. Thus, blending 1 litre of ethanol in 1 litre of petrol can reduce greenhouse gas emissions by 880 grams/l. Assuming 20% ethanol blending in petrol by volume means 800 ml of petrol and 200 ml of ethanol. The emission factor of blended petrol is 2.54 $kgCO_{2eq}$/ litre or a saving of 175 gCO_{2eq}/ litre.

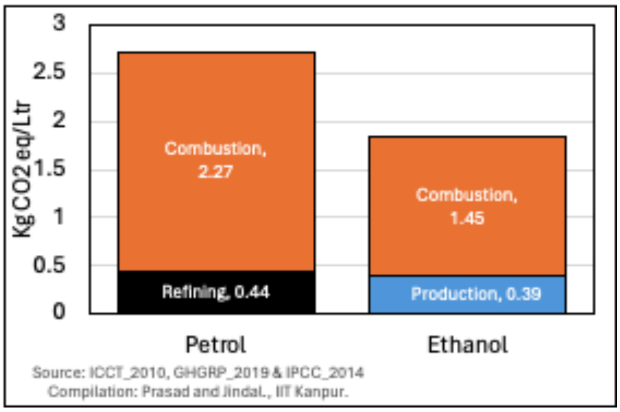


Figure 33: Comparative greenhouse gas emissions from petrol and ethanol as fuel

Therefore, the ethanol blending has saved 17.6 million tonnes of carbon dioxide equivalents from 2013-14 to 2022-23 (Figure 33). As the ethanol production for blending increased after NBP 2018, so did the savings in emissions. Our estimates of emissions saving of 17.6 mn tonnes are much lower than the emissions savings reported by the Minister of Oil and Natural Gas at 42.6 mn tonnes[7].

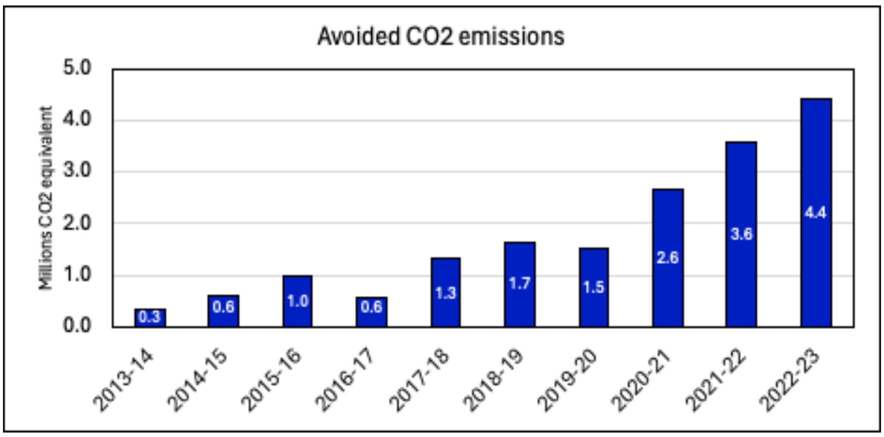


Fig 34 Annual CO_2 equivalent emissions avoided

[7] https://energy.economictimes.indiatimes.com/news/oil-and-gas/ethanol-programme-nets-78118-crore-savings-co2-emissions-cut-by-426-lakh-mt-hardeep-singh-puri/106531696

2.3.7.2 Impact on water usage

Figure 35 shows the relative water consumption of oil, solar and ethanol. To produce one GJ of energy from oil, about 1.1m^3 water is used, which is three times higher than the water needs of solar to generate the same amount of energy. Ethanol, on the other hand, is a highly water-intensive fuel. Ethanol[8] needs 135 m^3 to produce 1 GJ energy. Hence, there is a significant trade-off between energy and water security, especially for a country like India that requires both energy and water security.

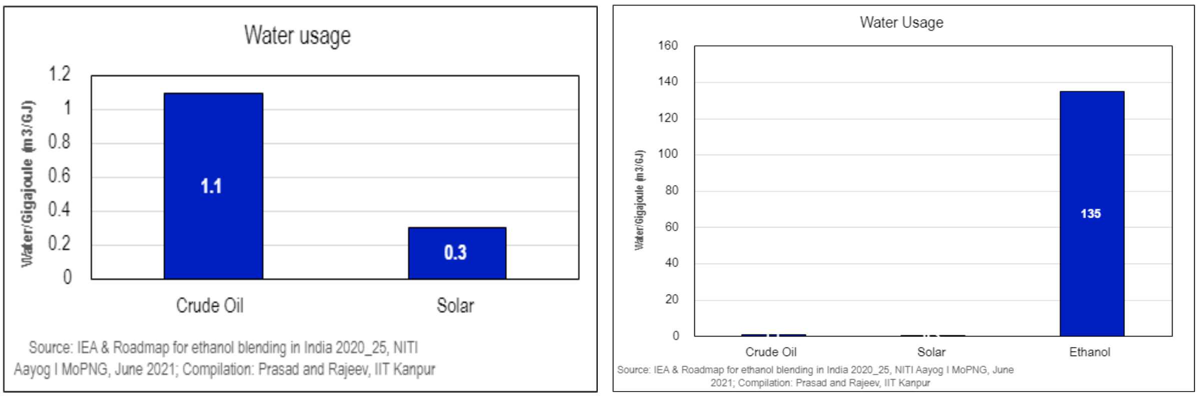


Figure 35: Water consumption of ethanol compared with selected fuels like oil and solar

However, as we understand that the industry is now recycling water extracted from sugarcane juice, a detailed process assessment and usage study are needed to understand the net impact on the water table using sugarcane in ethanol.

2.3.7.3 Impact on soil

We found that 15 out of 20 companies have installed an incineration boiler to treat the spent wash, one of the environmentally damaging by-products of the ethanol-making process. This makes the plants zero discharge plants. Earlier to the NBP 2018 policy, the spent wash was released directly into the ground, causing soil pollution.

[8] IEA-Technology Collaboration Program on Advanced Motor Fuels.

Section III Discussion, challenges, and implications for future blending targets

Our study finds that the interest subvention scheme under NBP 2018 has effectively increased the ethanol capacity and production for blending. Another instrument that has been influencing is the price signal managed by the central government in the form of ethanol prices. Mandated blending targets for oil marketing companies have provided an assured market for ethanol.

Much of the expansion was led by medium-sized plants with a capacity range of 100-300 KLPD, followed by large plants with a capacity exceeding 300 KLPD. The financial impact has been more favourable for the attached or integrated distillery units. Most of these plants primarily depended on the sale of sugar for their revenues. Since the amount of sugarcane produced and thus, in turn, sugar produced has increased in recent years in India [Figure 1 and Figure 2], it led to a condition of overproduction of sugar, and thus, in turn, these plants had to hold long inventories of sugar in their stock before they were able to liquidate the same. This situation led to two major issues – liquidity and dependence on one commodity for revenue, i.e. sugar. As the sugar was the only product and was overproduced, the cost vs price ratio was also not working in favour of these plants.

With the current structure of assured buying of ethanol for blending in petrol by OMCs through long-term purchase orders, integrated plants have a new lease of life (with some underlying concerns covered in a separate section). The production volume for both is currently controlled by a government quota given to these plants through an allocation system. They now have two distinct revenue streams: sugar and ethanol as fuel. Video of a few interviews with distilleries management are attached.

3.1 Financial impact has been most favourable for medium size plants (100-300 KLPD) but not so much for standalone plants

Standalone plants, however, seem to be the left-out lot in the current arrangement of administered prices. While the government controls the input cost and selling price for integrated plants, ensuring a fixed margin, the same is not valid with standalone plants. During our study, we visited two types of standalone plants, the one dependent on only sugarcane molasses as input and the other dependent on both molasses and food grains as inputs (Figure 16 and Figure 17). The selling price for them is also fixed through long-term purchase orders given by OMCs for ethanol blending, and the government fixed the transfer price of country liquor. The input cost is only controlled for the molasses they get for the country liquor. The molasses and broken food grains used for ethanol as fuel depend on the purchases from the open market. This structure has led to a situation where they have little incentive to continue to invest further in ethanol capacity creation as they are not sure of the returns for their investment. Details of the same are shared in Section II.

3.2 Standalone plants face fixed output prices but market-determined input prices and need intervention

The input cost of raw material for sugarcane-based ethanol is controlled, and the output cost of the overall ethanol produced is controlled. There is no mechanism for controlling the prices at which standalone distilleries can buy molasses to produce ethanol for blending, and grain prices are not regulated. We suggest forming a national-level technical-policy-commercial-industry representation committee, which can create a price band based on informed assumptions on the cost of fertilisers, total recoverable sugar content (TRS), sugar price movement in the market and other similar inputs. The price band can then be used as a guiding mechanism to make significant policy decisions.

Standalone distilleries require the support from the government. They lack support and face challenges in securing feedstock. They depend on either open market or integrated plants for feedstock requirements for ethanol production. Providing enhanced support to standalone distilleries entails a reliable and cost-effective feedstock supply. This step might help to stabilise the market.

3.3 Risk of more food grains being diverted for ethanol blending

The trend in ethanol prices produced from different raw materials does not mirror sugarcane's Fair and Remunerative Price (FRP) trend. Figure 35 shows the relative growth in feedstock prices compared to sugarcane FRP in 2018-19, as the base. Figure 35 shows the price of ethanol derived from damaged food grains rising rapidly compared to sugarcane FRP. This suggests the government wants to promote grain-based ethanol. However, this could be a challenge in the future as more grains will be diverted to ethanol. Also, there are no standards specifying what counts as damaged grain, which puts food grains at risk of being diverted. The grain-based capacity is currently small; hence, any trade-offs with using grains for fuels are not apparent. However, this will change once the capacity increases. Currently, most ethanol production in India originates from B-heavy molasses and sugarcane syrup, and there is a minimal contribution from damaged food grains and C-heavy molasses[5,6] (Figure 11).

During our interactions with grain-based plants, we found that they are procuring grains from grain markets but do not have any certificates stating that they are indeed damaged. This can have a spiralling effect on food inflation. Compared to the base of 2018-19, the price for grain-based ethanol increased 36% in 2023-24 compared to a 15% increase in FRP (Figure 36). On the other hand, amongst sugarcane feedstocks like C-heavy, B-heavy and sugarcane juice, the price increase has been very different. While B-heavy was promoted immediately after NBP 2018, from 2018-19 until 2021-22, a shift favoured C-heavy in 2022-23 and 2023-24. This has surprised the industry, and their perception is that the government is very 'short-minded' and does not think through the effects of such quick changes. In section 2, we note that the industry can expand further but does not want policy uncertainty. Figure 37 shows the actual prices of ethanol feedstocks route-wise.

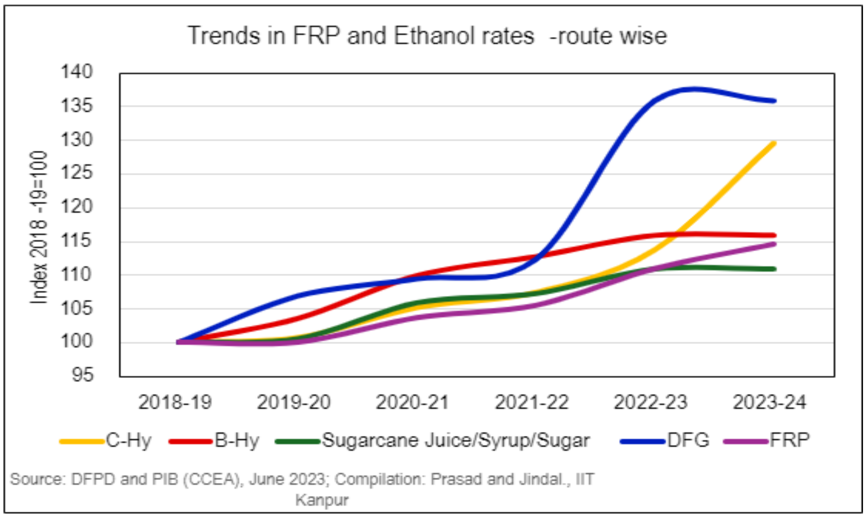


Figure 36: Price trend of sugarcane, B-heavy and C-heavy molasses, sugarcane juice, and damaged food grains (DFG) in the last few years.

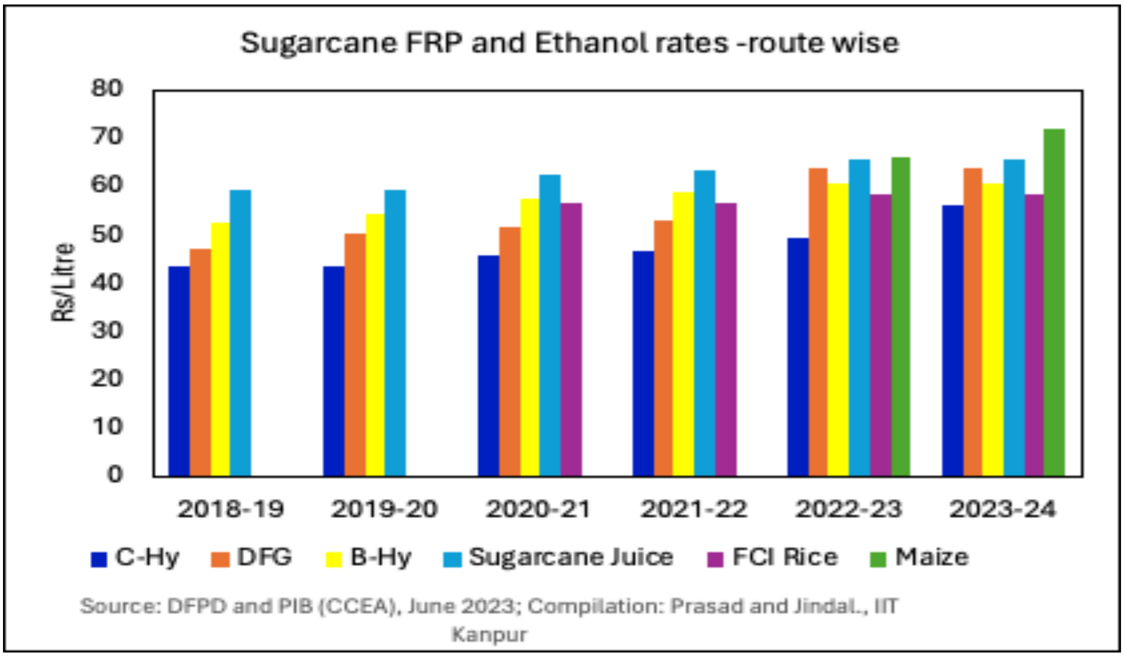


Figure 37: Prices of B-heavy and C-heavy molasses, sugarcane juice, and damaged food grains (DFG) in the last few years.

3.4 Home-grown ethanol is costly to produce as the raw material prices are fixed rather than freely determined

The cost of ethanol[6] produced in India is higher than that of leading world countries, and it is unlikely to match anytime soon. To understand this, consider the cost structure of ethanol production. The cost has two major components: (a) raw material cost and (b) conversion cost. While the cost of conversion of the Indian industry needs to be compared in detail with the international leading player's cost of conversion, which will be a separate study; we see some challenges in the cost of raw materials, such as:

(a) Sugarcane cost, the key raw material, is fixed by the central government and is known as Fair and Remunerative Price (FRP). It is not a free market. We find that the sugarcane prices increase yearly. As a result, the raw material cost is higher than that of other countries like Brazil. As the raw material prices are high, the output prices also tend to be high. While we understand that FRP is a separate subject of study, we have the following suggestions to make it more scientific within the given constraints:

(a.1) The quantity of ethanol produced from a specific feedstock depends on the sugarcane-based feedstock's total reduced sugar (TRS). The pricing of sugarcane should thus be based on the quality of feedstock. It, therefore, should not be uniform throughout the country, as the TRS content of the feedstocks varies from state to state and region to region, for which a testing mechanism should be formed on sucrose content, and pricing should be done accordingly.

(a.2) While we noticed that some distilleries are working with local farmers to increase agricultural productivity (per hectare yield) and TRS content, we suggest a nationwide effort to support the same. For this, more institutes like the National Sugar Institute (NSI) can be created in specific locations in India to address local issues.

(b) Food grain prices: There is no set mechanism for controlling food grain prices. As per our understanding of the market, the Food Corporation of India (FCI) was initially supposed to supply grains for ethanol production to distilleries, but that didn't happen. Due to this, distilleries acquire grains from the open market at high prices. As a result, even though the capacities have been built and established for ethanol production, the prices are becoming non-competitive. They may be one of the reasons for faster increase in grain-based ethanol prices. A clear mechanism will be needed to ensure grain availability at affordable costs to the distilleries. This may include encouraging varieties of grains other than food grades, but feasibility studies must be undertaken.

3.5 Consistent expansion in sugarcane crops means higher land under sugarcane cultivation but also poses a potential threat to water stress and soil erosion

Current rates of sugarcane FRP and timely payment to farmers have ensured that farmers consistently produce sugarcane crops. Theoretically, the fields should be used for diversified crops in between sugarcane production, and the crops should be less water-consuming to maintain the soil properties and restore the water table. However, our interactions with farmers and field visits showed that farmers consistently produce sugarcane without any break. Moreover, to ensure high yields, they have resorted to practices like using the sugarcane variety with maximum yield, fertiliser use multiple times, sometimes above the needed quantity and increased use of pesticides. The pressure to grow more and more sugarcane has meant that the area under cultivation has increased, as seen in Section 1, along with the use of fertiliser and pesticides.

3.5.1 Frequent policy changes have created an environment of policy uncertainty and perception of the government being 'short-sightedness' in the ethanol industry

Indian ethanol market is immature, and policy changes are too frequent, which is why this market/industry is not able to stabilise. For example, sugar juice/syrup and B-molasses were previously allowed to produce ethanol. Recently, ethanol production from sugar syrup was suddenly stopped, the volume of B-molasses for ethanol production was limited, and C-molasses-based ethanol prices were increased. These frequent policy changes bring disruption, and the industry's confidence is waivered, leading to a slowdown in capacity ramp-up. This might also affect the amount of ethanol supplied to oil marketing companies for blending. While periodic adjustments may be necessary, they should be implemented with a long-term vision, minimising abrupt changes that disrupt the market.

3.6 Ethanol production is associated with carbon dioxide emissions, which must be recorded, monitored and captured

The distilleries do not adequately measure how many tons of CO_2 are generated daily. The production of ethanol, encompassing the entire value chain from feedstock cultivation to fermentation and distillation, inherently leads to CO_2 emissions at multiple junctures. Few distilleries have the facility to collect and process the CO_2 released during the ethanol production process to convert it to dry ice or liquid CO_2. Given the CO_2 generation during critical stages such as fermentation, where sugars are converted into ethanol and carbon dioxide (which is not being captured as it can be seen in Pic 6), and indirect emissions from energy consumption, transportation, and feedstock production, a more detailed analysis in the form of comprehensive life cycle analysis (LCA) is needed for better estimates. This analysis is necessary to accurately quantify the carbon emissions attributable to each ethanol production phase.

Moreover, assessing the environmental benefits of using ethanol-blended fuels in vehicles is crucial, especially compared to traditional fossil fuels. Such an evaluation is essential for understanding the environmental benefits and challenges associated with ethanol use as a sustainable fuel alternative. We propose to continue working on this and submit a subsequent report.

As mentioned above, CO_2 emissions from the whole ethanol production value chain are highly uncertain. Thus, it requires a comprehensive understanding and diligent work with the industry at every step. For this, a larger team is needed in collaboration with industry & academia. Thus, establishing a collaborative platform involving industry and academia to study carbon emissions comprehensively, carbon capturing and processing strategies is necessary.

3.7 Creating potential markets from by-products needs standardisation, utilisation, and awareness:

There is potential value addition from by-products but for this, a proper structure needs to be formed by the government. Given the scope, it should be standardised by NSI or a government body. Currently, the standardisation and the facilities are lacking to make it a separate revenue stream, so the government can start a few research projects with the ethanol industry and academia to explore and leverage the potential of by-products as a separate revenue stream.

References:

1. Report of task force on sugarcane and sugar industry. Niti Aayog, March 2020
2. https://www.researchgate.net/publication/310490712_Sugarcane_Production_and_Development_of_Sugarf_Industry_in_India
3. https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1935899
4. https://pib.gov.in/newsite/PrintRelease.aspx?relid=134672 NFSA coverage in all the States by April 2016, 21 Jan 2016.
5. Roadmap for Ethanol Blending in India 2020-2025. Niti Aayog | Ministry of Petroleum and Natural Gas, June 2021.
6. DFPD, Ministry of Consumer Affairs.
7. https://energy.economictimes.indiatimes.com/news/oil-and-gas/ethanol-programme-nets-78118-crore-savings-co2-emissions-cut-by-426-lakh-mt-hardeep-singh-puri/106531696
8. IEA-Technology Collaboration Program on Advanced Motor Fuels.
9. https://www.nabard.org/content1.aspx?id=2790&catid=23&mid=23

Annexure I: Detailed provision of National Biofuel Policy 2018

1. To set up capacity and increase ethanol and biodiesel production by increasing domestic production.
2. Set up second-generation (2G) biorefineries.
3. To allow more raw materials like sugarcane juice, sugar-containing materials like sugar beet and sweet sorghum, starch-containing materials like corn and cassava, and damaged food grains like wheat, broken rice, and rotten potatoes to produce biofuels.
4. Focus on new technological developments to improve biofuel production.

The policy broadened the horizon of feedstock for ethanol production compared to the 2009 policy by categorising biofuels into 1G, 2G, and 3G based on the feedstock type. 1G: Ethanol production from food-based feedstocks ; 2G: Ethanol produced from various feedstocks, i.e., agricultural residues like rice straw, wheat straw, energy crops, etc.; 3G: Ethanol production from algae biomass, which is used for fermentation.

This policy opened doors for setting up different kinds of ethanol supply chains based on grain-based production and research and development projects for 2G and 3G ethanol-based production. The policy permits 100% Foreign Direct Investment (FDI) in the biofuel sector through automatic approval if biofuel is used for domestic consumption only. Some of the novelties that assisted to increase the country's blending capacity are:

- Ethanol production was allowed directly from B-heavy molasses and sugarcane juice. Also, utilisation of the fully developed first-generation technologies using damaged food grains like wheat, broken rice, etc., during surplus availability of food grains as per the decision of the National Biofuel Coordination Committee
- Ethanol Purchase Agreements were introduced between OMCs and 2G ethanol suppliers for 15 years to provide assured market to private stakeholders and support 2G ethanol initiatives.
- OMCs were primarily made responsible for maintaining and improving the storage, distribution, and marketing infrastructure to meet the requirements of biofuels.
- Administered and differential pricing of ethanol was introduced based on the type of feedstock utilised for production, controlled by the government based on market conditions, availability of biofuels in the domestic market, import substitution requirement, etc.
- Importing and exporting biofuels were prohibited to promote indigenous production and meet the domestic demand for biofuels.
- Interest Subvention Scheme was introduced to provide financial assistance[9] to
  - Enhance and augment the ethanol production capacity of sugar mills.
  - Convert molasses-based distilleries to dual feed, i.e., convert both food grains & molasses into ethanol.
  - Project proponents for enhancement of their ethanol distillation capacity or to set up distilleries for producing 1st Generation (1G) ethanol from feedstocks such as cereals (rice, wheat, barley, corn & sorghum), sugarcane, sugar beet, etc.
- Pradhan Mantri JI-VAN Yojana was introduced to provide Viability Gap Funding (VGF) to the 2nd Generation bioethanol manufacturing projects promoting 2G Biofuels Technology with feedstock comprising non-food crops, agricultural residues or waste.

[9] https://www.nabard.org/content1.aspx?id=2790&catid=23&mid=23

Annexure II: List of financial indicators for which data was requested from distilleries

Name of the distillery										
S.No.	**Data items**	**Unit**	**Year**							
			2016	2017	2018	2019	2020	2021	2022	2023
1	Ethanol production	Qty								
2	Ethanol Revenues	INR								
3	Raw materials consumption in ethanol production									
3.1	Raw material 1	Name								
3.2	Raw material 1	Qty								
3.3	Raw material 1	INR								
3.4	Raw material 2	Name								
3.5	Raw material 2	Qty								
3.6	Raw material 2	INR								
4	Electricity consumed for ethanol production	Mwh								
4.1	Electricity consumed for ethanol production	INR								
4.2	Captive generation	Mwh								
4.3	Purchased electricity	Mwh								
5	Staff expenses/employee expenses/labour expenses	INR								
5.1	Workforce directly employed for ethanol production	Number								
6	Depreciation on ethanol production machinery	INR								
7	Interest/finance expenses	INR								
8	Profit Before Tax	INR								
8.1	Profit After Tax	INR								
9	Loan (Ethanol production related machinery)	INR								
10	Machinery related to ethanol production	INR								
11	Cash and bank balance	INR								

Annexure III: List of distilleries in the sample study

Name of the Distillery	Place	State	Capacity (KLPD)	Integrated/ Standalone	Molasses/ Grain/Dual
Buttar Biofuels Private Ltd (Standalone)	Buttar Seviyan, Amritsar Dist.	Punjab	300	Standalone	
Rana Sugars Ltd	Buttar Seviyan, Amritsar Dist.	Punjab	100	Integrated	Molasses
TruAlt Bioenergy Ltd	Mudhol	Karnataka	700	Integrated	Molasses
Shree Renuka Sugars Ltd	Munoli, Belagavi	Karnataka	380	Integrated	Molasses
E.I.D. Parry (India) Ltd	Nagaral Naianagali, Bagalkot	Karnataka	90	Integrated	Molasses
Kothari Sugars & Chemicals Ltd	Kattur, Trichy	Tamil Nadu	30	Integrated	Molasses
Oasis Ethanol Industries Pvt Ltd	Jatwar, Ambala Dist.	Haryana	320	Integrated	Grain
Shreenath Mhaskoba Sakhar Karkhana Ltd	Pune	Maharashtra	200	Integrated	Molasses
Vitthalrao Shinde Sahakari Sakhar Karkhana Ltd	Solapur	Maharashtra	300	Integrated	Molasses
Karmayogi Sudhakarpant Praicharak Pandurang SSKL	Solapur	Maharashtra	90	Integrated	Molasses
Rajarambapu Patil SSKL	Sangali	Maharashtra	150	Integrated	Molasses
Shree Datta Shetkari Sahakari Sakhar Karkhana Ltd	Shirol, Kolhapur	Maharashtra	130	Integrated	Molasses
Baramati Agro Ltd	Pune	Maharashtra	600	Integrated	Molasses
Sahakar Maharshi Shankarrao Kolhe SSKL	Ahmednagar	Maharashtra	120	Integrated	Molasses
Sahakar Maharshi Bhausaheb Thorat SSKL	Ahmednagar	Maharashtra	45	Integrated	Molasses
Uttam Sugar Mills Ltd	Libberheri	Uttarakhand	50	Integrated	Molasses
Avadh Sugar & Energy Ltd	Hargaon, Sitapur	Uttar Pradesh	160	Integrated	Molasses
DCM Shriram Industries Ltd	Daurala	Uttar Pradesh	215	Integrated	Molasses
Dhampur Sugar Mills Ltd	Dhampur	Uttar Pradesh	350	Integrated	Dual
Superior Industries Ltd (Standalone)	Bareilly	Uttar Pradesh	30	Standalone	Molasses
Triveni Engineering & Industries Limited (Standalone)	Muzaffarnagar	Uttar Pradesh	160	Standalone	Dual
Nanglamal Sugar Complex	Nanglamal, Meerut	Uttar Pradesh	120	Integrated	Molasses

Annexure IV: Questions for plant visits

Part I: Distillery

Profitability

1. What is the typical margin in ethanol production? Are these stable margins or fluctuate? Do you see the margins to remain at this level or change?
2. What is the share of revenue percentage by ethanol sales out of total revenue generated by the sugar & allied industry?
3. What is the typical cost structure of ethanol production? Main components and their contributions.
4. How are the price and volume of OMC purchases determined, and has this process changed recently? Does the distillery have a say in determining the price?
5. Have there been any significant shifts in the technologies or machinery used in the ethanol production industry in recent years?
6. Do you have any ethanol quality standards? If yes, how easy it is to meet these standards
7. Has there been an improvement in ethanol demand in the market?
8. Do you think the ethanol market, in general, is likely to become a big market?

Job creation

1. How many people have you employed in the distillery since its start?
2. What other jobs are created because of ethanol production: indirect jobs?

Farmer income

1. How are the prices for different feedstocks determined in your region? Is there a formal negotiation process with farmers, or are prices primarily driven by market forces?
2. How do you address situations where farmers experience lower yields due to climatic factors or other challenges? Do you have contingency plans or alternative sources of feedstock in place? Where do you typically turn for additional supplies?

Environment

1. What waste is generated in the distillery?
2. How do you manage the waste?
3. How much water is used in the distillery? How is wastewater treated?
4. Which processes release carbon dioxide? What is being done about the emissions
5. Do you measure, record and report on air, water, soil, and emissions?

By - products

1. What are the by-products generated? How are you utilising by-products generated during the ethanol production process?
2. Do you see the potential of potash as fertiliser from incinerated boiler ash produced from molasses/syrup-based distillery spent wash?
3. What are the by-products produced during ethanol production?
4. PDM, Bagasse, Press mud, Distillers Grains, Fusel Oil, Biogas, Vinasse/ Stillage?
5. Quantity of each by-product produced?
6. Are these by-products sold? If yes, at what price?
7. Are they utilised within the distillery? By reuse or recycle?
8. If not sold or utilised, how are they disposed of?

General

1. What are the biggest challenges in this sector?
2. What role can the government play?
3. Are the provisions in the current policy adequate, or do they need to be changed? If yes, what changes?
4. What has been your experience availing yourself of the benefits under the scheme?

Points:

1. Feedstock diversity: % of different feedstock, their efficiency, why?
2. Machinery: anything new? Lifespan? Depreciation? Advancements and effect on the workforce.

Part II: sugarcane Farmers

1. Do you produce sugarcane?
2. What is the size of your farm, and how much can you produce there? Do you own the farm? Yield per hectare?
3. Variety of sugarcane cultivated? Crop dependence on Environmental changes?
4. How much water and fertiliser are used?
5. Which fertiliser do you use? Did you change the fertiliser? Why/Why not
6. Were you always producing sugarcane?
7. How do you procure fertiliser, and the rate?
8. To whom do you sell your sugarcane? At what rate? Is there any difference in payments for the 1^{st}, 2^{nd} & 3^{rd} yield?
9. Is there any agreement, and for how many years? How much time does it take for your payment to be cleared?
10. How is sugarcane transported to the mills? By yourself or by the mills?
11. Have the rates for sugarcane improved in the last few years? If yes, by how much
12. Has the payment time been reduced in the last few years? If yes, by how much
13. Has sugarcane production changed your life in any other way?

Annexure V: Value-chain of an Ethanol Plant

(a)Value chain of an Integrated plant

a.1 Transportation to mill – Harvested sugarcane is transported to the mills through bullock carts, tractors, trucks, etc. and is unloaded directly to the milling assembly

Image: *Farmers bringing cane through various transport mediums to DCM Shriram Industries Ltd, Daurala Sugar Works.*

a.2 Weighing

Image: *Farmers getting the cane weighed at DCM Shriram Industries Ltd, Daurala Sugar Works.*

a.3 Cane Preparation –Sugarcane harvested and transported to the mill is cleaned to remove dirt leaves. Sugarcane is shredded into pieces using shredders or knives.

Image: *Cane preparation before shredding and crushing at Uttam Sugar Mills Ltd.*

a.4 Crushing & Juice Extraction*:* The cleaned and cut sugarcane is passed through crushing mills or rollers to extract the juice. The crushed cane goes through multiple milling stages to extract the maximum amount of juice-crushing

Image: *Cane crushing, and juice being extracted at Uttam Sugar Mills Ltd.*

a.5 Juice Clarification – Lime is added to the extracted sugarcane juice to raise its pH and facilitate the removal of impurities. The juice is heated to 75C to promote the coagulation of impurities, forming a scum that can be easily removed. The clarified juice is then transferred to clarification tanks where additional impurities settle, leaving a clearer juice. Sediments from the clarifier are sent to vacuum filters to obtain filter mud. The final recovered mud is called press mud.

a.6 Press Mud

Image: *Press mud collection point at DCM Shriram Industries Ltd, Daurala Sugar Works.*

a.7 Juice Evaporation – The clarified juice is concentrated by boiling in evaporators to remove excess water and to obtain concentrated syrup. Sugar juice goes through a series of evaporators to achieve the desired concentration.

Image: *Clear juice collection tower at Uttam Sugar Mills Ltd.*

a.8 Syrup Clarification – Sulphur dioxide is added to heated syrup for clarification.

Image: *Syrup collection tank after evaporation at Uttam Sugar Mills Ltd.*

a.9 Crystallisation - The syrup from the evaporator is passed to the vacuum pan to boil the thickened syrup (3-4 times) to get sugar crystals. The mixture is stirred to encourage the separation of sugar crystals.

Image: *Crystallisation process at Uttam Sugar Mills Ltd.*

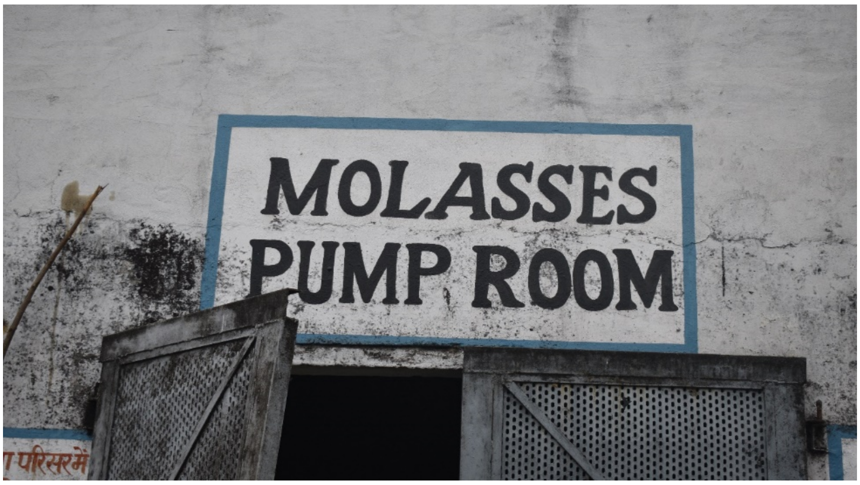
a.10 Centrifugation – The sugar crystals and liquid mixture are passed through high-speed centrifuges to separate the sugar crystals from the remaining liquid, known as mother liquor (molasses).

Image: *Centrifugation at DCM Shriram Industries Ltd, Daurala Sugar Works.*

a.11 Sugar Drying and Packaging – In the rotary drums, heated air is passed to dry sugar obtained from centrifuges to further control the drying effect. This dried sugar is then cooled, graded and packed into bags of various weights.

Image: *Various grades of sugar at sugar mills*

a.12 Molasses



Images: *Molasses pump room, storage tanks at Nanglamal Sugar Complex, Mawana Sugars.*

a.13 Fermentation*:* The molasses is first diluted from 45 to 15% fermentable sugars to produce ethanol. Yeast is introduced to the prepared solution to ferment the sugars into alcohol (ethanol) and carbon dioxide. This process typically takes place in fermentation tanks.

***Images:** Yeast culture, fermentation tanks at DCM Shriram Industries Ltd, Daurala Sugar Works and Nanglamal Sugar Complex, Mawana Sugars.*

a.14 Distillation*:* After completion, the yeast sludge is removed from the bottom, and the fermenter wash is pumped to the distillation unit. The fermented liquid, known as the "mash," contains alcohol, water, and other components. The mash is distilled to separate the alcohol from the water and other impurities. Distillation columns are used to achieve this separation. Fractional distillation is often employed to obtain high-purity ethanol. The distillation process separates the ethanol from the mixture.

***Image:** Distillation process plant at Nanglamal Sugar Complex, Mawana Sugars.*

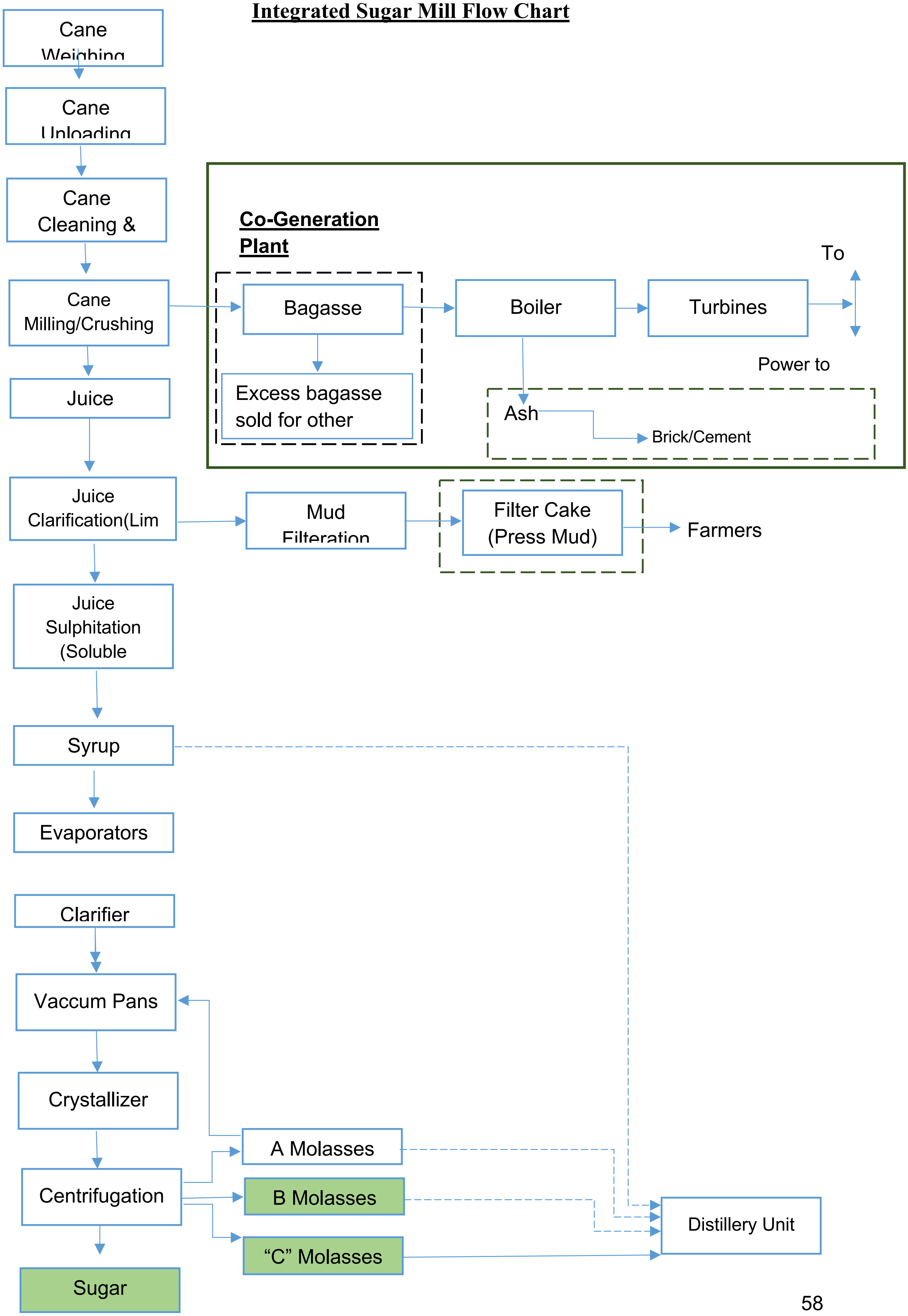
a.15 Dehydration*:* Even after distillation, the ethanol may still contain a certain amount of water. Dehydration processes are used to remove the remaining water and increase ethanol concentration. Alcohol with water is fed to the rectification column, wherein the rectified spirit is withdrawn. Biogas generated from the anaerobic digestion of wastewater and yeast sludge has about 50-75% methane and is used as a co-product for heat generation.

Image: *DCM Shriram Industries Ltd, Daurala Sugar Works*

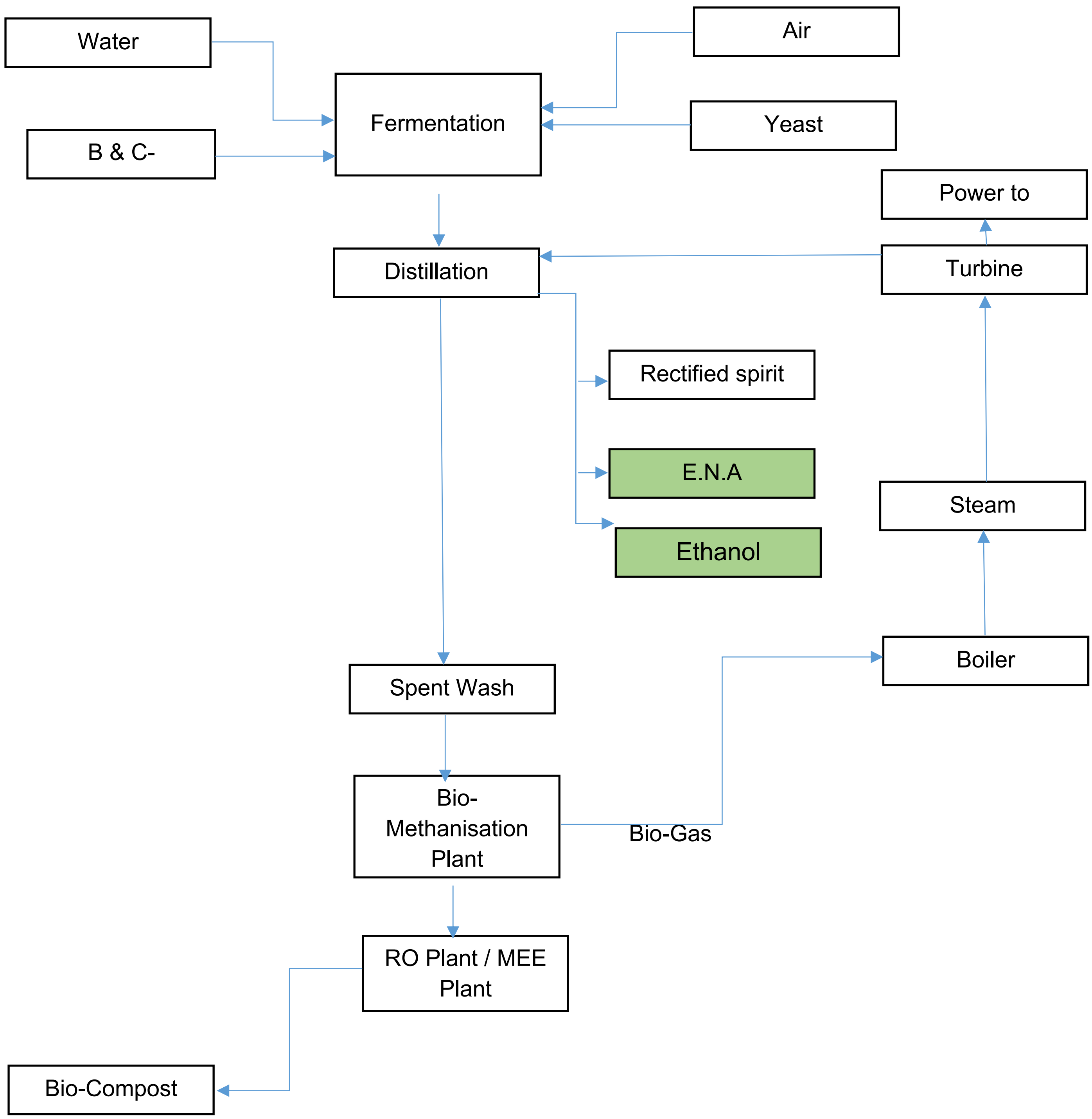
a.16 Crude Ethanol: The resulting product after dehydration is often called crude ethanol. It is a high-concentration ethanol product that can be used for various industrial purposes.

Image: *Ethanol storage tanks at Uttam Sugar Mills Ltd.*

Integrated Sugar Mill Flow Chart



A distillery with a Bio-Gas facility Process chart / ETP Flow Chart



Grain Based Flow