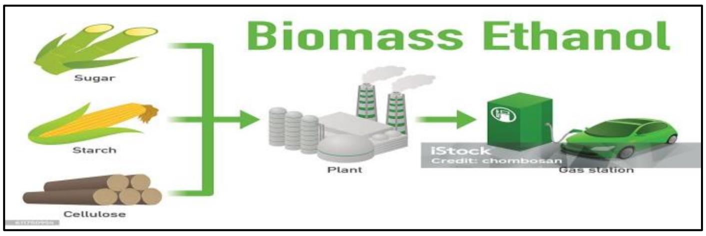
ETHANOL PRODUCTION IN INDIA: STATISTICAL STUDY

A Project report submitted in partial fulfilment of requirements for the

Degree of M.Sc. (Statistics)

With specialization in Industrial Statistics



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CERTIFICATE

This is to certify that **Mr. Nikum Deven Dnyaneshwar, Mr. Tambat Saurabh Sunil, Ms. Bagul Priyanka Dhanraj** students of M.Sc.(Statistics) with specialization in Industrial Statistics, at Kavayitri Bahinabai Chaudhari North Maharashtra University (KBCNMU), Jalgaon have successfully completed their project work entitled **"Ethanol Production in India: Statistical Study"** based on the data collected from online sources and their industrial visit as a part of M.Sc. (Statistics) program under my guidance and supervision during the academic year 2023-2024

(Prof. R. L. Shinde)
Project Guide

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Chapter 1: Introduction

Ethanol is produced from any fodder crop which contains simple sugar in polymers. The polymers like starch and cellulose are broken down into simple sugars through chemical hydrolysis or enzymatic hydrolysis, and then converted by fermentation process to ethanol and carbon dioxide, in saccharification process starch is converted into simple sugar(monosaccharide) using microorganism or enzymes such as glucoamylase and α-amylase.

Barley is first germinated, dried and crushed for the whole process. The resulting sugars are then by help of yeast converted into ethanol. Generally, the yeast attack on hexose sugars, but carbohydrates containing pentose subunits could also be digested by specific yeast into ethanol.

Ethanol is also used as fuel in gasoline engine and as preservative for biological specimens. Ethanol is very old chemical and has been made since old times due to the sugar fermentation. Majority of the beverage industry produce ethanol by fermentation process.

1.1 Motivation:

The pursuit of sustainable and eco-friendly energy sources has become an imperative in our contemporary world. In this context, the production of ethanol, a renewable biofuel, holds significant promise for reducing dependency on non-renewable energy resources. India, as a rapidly developing nation with a high rate of increase in population, faces a critical challenge in meeting its large scale of energy demands while simultaneously addressing environmental issues such as air pollution and climate change.

The motivation behind this project "Ethanol Production in India: Statistical Study" is to conduct a comprehensive analysis of the current state of ethanol production in India, aiming to provide some valuable insights and data-driven solutions. By dividing into statistical aspects, this project find out to clear up trends, challenges and opportunities within the ethanol production sector.

Key Motivators:

- **Environmental Sustainability**: Ethanol derived from renewable sources such as sugarcane, corn or other biomass, is considered a green alternative to conventional fossil fuels. The project aims to contribute to India's commitment to reducing carbon emissions and climate change by promoting the sustainable production of ethanol.
- **Energy Security**: As a nation heavily depend on imported fossil fuels, India faces challenges in ensuring energy security. Ethanol production can serve as a domestic alternative, reducing dependency on external sources and stabilizing energy prices.
- **Agricultural Diversification**: The cultivation of crops for ethanol production can provide an additional revenue stream for farmers. By analysing the statistical data

related to agricultural practices and ethanol production, the project aims to identify opportunities for rural development and agricultural diversification.

- **Government Initiatives**: The Indian government has been actively promoting ethanol production through policy measures and incentives. This project seeks to evaluate the effectiveness of these initiatives by analysing statistical data, providing insights that can inform future policy decisions.

1.2 Objectives:

Evaluation of Feedstock Sources:

- Examine the diverse feedstock sources used for ethanol production in India, including sugarcane, corn, and other biomass.
- Assess the sustainability, availability, and economic viability of different feedstock options.
- Analysis of production of sugarcane and molasses in India and forecasting

Assessment of Current Production Levels:

- Determine the current volume of ethanol production in India by analysing statistical data from relevant sources.
- Identify the major contributors and regions with the highest production levels.
- The number of ethanol plant in India and its state wise production.

Trend Analysis and Forecasting:

- Conduct a comprehensive statistical analysis of historical ethanol production trends.
- Develop forecasts for future production based on current trends, considering factors such as crop yields, technological advancements, and policy changes.

Impact on Agricultural Practises:

- Investigate the impact of ethanol production on existing agricultural practices.
- Analyse the correlation between ethanol production demands and agricultural diversification, evaluating its potential benefits for farmers.

Assessment of Government Policies and Incentives:

- Evaluate the effectiveness of current government policies and incentives promoting ethanol production.
- Provide recommendations for policy improvements or modifications based on statistical findings.

Environmental Impact Analysis:

- Assess the environmental impact of ethanol production, including greenhouse gas emissions reduction and land-use implications.
- Analyse the overall carbon footprint of ethanol as a biofuel compared to traditional fossil fuels.

Economic Benefits:

- Quantify the economic benefits associated with ethanol production, considering factors such as revenue generation, and industrial growth.

- Identify opportunities for further economic development within the ethanol production sector.

Technological Innovations and Research Opportunities:

- Explore existing and emerging technologies in ethanol production.
- Observation of ethanol production process

Comparative Analysis with Global Practices:

- Compare India's ethanol production statistics with global trends and practices.
- Identify best practices and learnings from other countries to enhance India's ethanol production strategies.

Dissemination of Findings:

- Compile comprehensive reports and publications summarizing the statistical findings.
- Disseminate information to policymakers, researchers, and industry stakeholders through presentations, workshops, and publications.

1.3 What is Ethanol?

Ethanol is an alternative energy source. It is an alcohol made by fermenting sugarcane, corn or other similar biomass material. There are three primary ways that ethanol can be used as a transportation fuel:

1. As a blend of 10 percent ethanol with 90 percent unleaded gasoline called "E-10 Unleaded".

2.As a component of reformulated gasoline, both directly and/or as ethyl tertiary butyl ether (ETBE).

3.As a primary fuel with 85 parts of ethanol blended with 15 parts of unleaded gasoline called "E-85." When mixed with unleaded gasoline, ethanol increases octane levels, decreases exhaust emissions, and extends the Supply of gasoline. Ethanol in its liquid form, called ethyl alcohol, can be used as a fuel when blended with gasoline or in its original state. It can also be used as a raw material in various industrial processes. Ethanol is made by fermenting almost any material that contains starch or sugar. Grains such as corn and sorghum are good sources; but potatoes, sugar cane, Jerusalem artichokes, and other farm plants and plant wastes are also suitable. In India ethanol mainly produce from molasses. Molasses is wastage part of sugarcane crop.

1.4 Why is ethanol considered necessary in today's world?

Ethanol use and production has increased considerably during the 1980s and 1990s. Growth in use of "E-10 Unleaded" gasoline has taken place because the fuel performs well in automotive engines and is competitively priced with "conventional" gasoline. Other reasons for increased production and use of ethanol, especially in the Midwest include:

- Ethanol reduces the country's dependence on imported oil, lowering the trade deficit and ensuring a dependable source of fuel should foreign supplies be interrupted.
- Farmers see an increased demand for grain which helps to stabilize prices.

- The quality of the environment improves. Carbon monoxide emissions are reduced, and lead and other carcinogens (cancer causing agents) are removed from gasoline.
- Car owners benefit from increased octane in gasoline, which reduces engine "knock" or "pinging." Ethanol-blended fuels also absorb moisture and clean the fuel system.
- Ethanol burning with a blue flame and is less pollutable.

Fig1: Ethanol Flame

1.5 Advantages & disadvantages of Ethanol Production:

Ethanol production particularly from biomass sources like corn, sugarcane, or cellulosic materials has both advantages and disadvantages. Here's a breakdown:

Advantages of Ethanol

1. Renewable Energy

Ethanol and biofuels come from biomass, a renewable energy source. The crops grown to produce biomass feedstocks harness energy from the sun and grow relatively quickly. During photosynthesis, the plants sequester carbon dioxide, which is eventually released during combustion. This cycle makes the process carbon neutral.

2. Fewer Greenhouse Gas Emissions – Ethanol vs Gasoline

One of the main benefits of all biofuels is that they are significantly less carbon-intensive than traditional fossil fuels. Because ethanol fuel is carbon neutral, the feedstock absorbs carbon to grow, then releases the same amount when burned, and new feedstock is quickly grown to continue to cycle. The only true emissions come from energy inputs from farming practices and transport.

3. Ethanol Production Supports Rural Economies

Ethanol fuel production is a major source of income for farmers, particularly in rural areas. This creates employment opportunities in communities that often lack a diversified job market.

4. Increased Energy Independence

Countries can reduce their dependence on foreign oil resources by relying on the domestic production of ethanol fuel. This allows nations to develop policies and take actions that make a positive impact.

5. Stable Prices

Fossil fuel prices are notoriously volatile because they are a limited resource controlled by a fraction of the world's countries. For example, 2022 saw record prices for natural gas in India due to the Russia-Ukraine war. Similar effects are occurring around the world, which is leading to global inflation and energy shortages.

Biofuels and other renewables are significantly stabler when it comes to price because they need minimal financial investment after initial construction. Additionally, there is an unlimited supply, and countries can produce them locally from domestically grown crops. This alone is a major pro against the cons of ethanol fuel use.

Disadvantages of Ethanol – Cons

1. Land Use Issues

The production of ethanol feedstock requires large quantities of arable land. Clearing land of native vegetation leads to habitat loss for native species and biodiversity loss. It can also reduce the overall health of surrounding intact ecosystems.

2. Water Use

Corn and sugar cane are water-intensive crops, and their use can strain local water supplies. This is particularly relevant to major agricultural areas in the US ,Brazil and India that already have drought issues.

As climate change continues, the world will face growing water stress concerns.

Source: https://energytracker.asia/pros-and-cons-of-ethanol/

Overall, while ethanol production offers several potential benefits, its widespread adoption requires careful consideration of its environmental, social, and economic implications to ensure sustainability and mitigate negative impacts.

1.6 Methodology:

Methodology, is the process which analyse the principal methods and rules used during the project. It explains the nature of study and methods of data collection and tools applying for analysing the data.

In our project, firstly we decide the topic of project and collect information related to it from different source. We choose the topic in such way that objectives of project are clear in our mind, and we also study before finding related to it. Then we move towards important part of our project which is data collection.

This learning is based on secondary data. The essential data was collected from the Government source as well as private sector of data were collected. The Forecasting of data was done by Time series analysis, Polynomial Regression, Graphical tools and by using descriptive statistics as well as some statistical concepts. Additionally, we are reading the research papers and other published materials such as websites, reports, articles, etc.

For this project conclusive researches are as:

- Using the data to create a descriptives, graphs, and study them.
- Using statistical tool and software to find associations and variances
- Plotting the interactive descriptives using table and analysing the data.

Chapter 2: Terms and concept related with Ethanol

In this chapter, we will explore several important terms and concepts related to ethanol production. Understanding these concepts is crucial for assessing and managing ethanol production. We will discuss the production measurement, the unit of measurement used, subindex, and the contribution of the Central government in monitoring and controlling ethanol production.

2.1 What is Molasses?

Molasses is a thick syrup that people use a sweeten. It is a byproduct of the sugar-making process and it comes from crushed sugar cane or sugar beets. First, manufacturers crush sugar cane or sugar beets to extract the juice. They then boil down the juice to form sugar crystals.

B-Molasses

This is the syrup that results from the first boiling. It has the lightest colour and the sweetest taste.

C-Molasses

This is the syrup that results from the second boiling. It is thicker, darker, and less sweet. People can use it in baking, but it lends foods a distinct colour and flavour.

2.2 Concepts related with ethanol Production

Ethanol production in India involves various terms and concepts related to the process, industry, and policies. Here are some key terms and concepts related to ethanol production in India:

- Ethanol: Ethanol, also known as ethyl alcohol or grain alcohol, is a renewable fuel produced through the fermentation of sugars found in crops such as sugarcane, corn, and wheat.
- Feedstock: The raw material used for ethanol production. In India, sugarcane, molasses, corn, and other agricultural crops serve as feedstock for ethanol production.

- Fermentation: The biochemical process in which microorganisms such as yeast convert sugars into ethanol and carbon dioxide in the absence of oxygen.
- Distillation: The process of separating ethanol from the fermentation mixture through heating and vaporization, followed by condensation and collection of the ethanol vapor.
- Rectification: The purification process used to increase the ethanol concentration by removing impurities and water from the ethanol-water mixture.
- Blending: The process of mixing ethanol with gasoline to produce blended fuels such as E5 (5% ethanol, 95% gasoline) or E10 (10% ethanol, 90% gasoline).
- Economic Viability: Refers to the feasibility and profitability of ethanol production, considering factors such as feedstock costs, production efficiency, market demand, and government incentives.

Table 2.1 Unit Measurement

Product	Unit	Conversion
Sugarcane Production	MT (Metric Ton)	1 MT =1000 kg
Molasses Production	MT (Metric Ton)	1MT =1000 kg
Ethanol Production	US Gallon (Million Gallons)	1 Gallon=3.785 liters
Gasoline	MMT (Million Metric Ton)	1MT =1323 liters

Chapter 3: Data and Data Representation

In this chapter, we're going to take a close look at the information we're using for our project. It's really important for us to know exactly what our data is made of, where it comes from . We'll talk about what kind of information it contains, where we got it from and how accurate and reliable it is. By understanding our data inside and out, we can make sure that our findings and conclusions are solid and meaningful. So, let's dive in and uncover all the important details about our data.

3.1 About Data source:

We collect diverse datasets from various sources.

- **Statista:** Statista is a statistics portal that provides data on various topics ranging from market reserch to consumer behaviour, industry trends and more. It's commonly used by business, reserchers and marketers for accessing reliable and up-to data statsitical information.
- **The Ministry of Consumer Affairs, Food and Public Distribution in India:** The Ministry of Consumer Affairs, Food and Public Distribution in India is responsible for the formulation and implementation of policies related to consumer affairs, food and public distribution. It aims to safeguard consumer rights, ensure the availability and accessibility of essential commodities and regulate food distribution systems. Implementing programs such as the Public Distribution System (PDS) and the National Food Security Act (NFSA) to ensure food availability and affordability for all sections of society. PDS managing the distribution of essential commodities such as rice, wheat, sugar and kerosene through a network of fair price shops to eligible beneficiaries.
- **NITI Aayog:** National Institution for Transforming India, is a policy think tank and advisory body of the Government of India. It was established in 2015 to replace the previous Planning Commission, with the aim of fostering cooperative federalism by involving the states in the economic policy-making process. Conducting research, analysis and evaluation of government programs and policies to identify areas for improvement and innovation. Engaging with international organizations, governments and experts to exchange knowledge, best practices and experience in various development-related areas.NITI Aayog consists of a governing council chaired by th Prime Minister of India, with chief ministers of all states and union territories, along with members from various sectors including academia, industry and civil society.
- **The Ministry of Petroleum and Natural Gas:** The Ministry of Petroleum and Natural Gas, Government of India, is responsible for the formulation and implementation of policies related to the exploration, production, refining, distribution and marketing of petroleum, natural gas and petroleum products in India. Facilitating exploration and production activities to enhance domestic production of crude oil and natural gas through exploration licensing, production sharing contracts and technology development. Overseeing the refining and petrochemicals sector, which involves refining crude oil into various petroleum products such as petrol, diesel, kerosene and

petrochemical feedstocks. It plays a cucial role in ensuring the availability, affordability and sustainability of petroleum and natural gas resources to meet the energy needs of India’s growing economy and population.

- **Indian Institute of Maize Research:** The Indian Institute of Maize Research (IIMR) is a premier research institute in India dedicated to maize research and development. It operates under the umbrella of the Indian Council of Agricultural Research (ICAR), which is the apex body for coordinating, guiding and managing agricultural research and education in the country. Providing training, education and extension services to farmers, agricultural professionals and stakholders to disseminate knowledge and best practices in maize cultivation and management. IIMR plays a vital role in advancing maize research and technology development to address the challenges faced by maize farmers in India and contribute to the country’s food security and agricultural sustainability.
- **Agriculture Department of India:** The Agriculture Department of India is a governmental body responsible for formulating and implementing policies, programs and initiatives related to agriculture, including crop cultivation, livestock management, irrigation, agricultural research and rural development. It plays a crucial role in promoting agricultural growth, sustainability and food security across the country.

3.2 Data Information:

The global ethanol production data collected from Renewable Fuels Association includes regional production from 2019 to 2023. The production percentages by region are as follows: 53% from the United States, 28% from Brazil, 5% from the European Union, 5% from India, 3% from China, 1% from Argentina, and the remaining 3% from other regions.The total ethanol production figures (in million liters) for each year are: 2019: 29,400, 2020: 26,480, 2021: 27,250, 2022: 28,220, 2023: 29,590.

Table 3.1: Global Ethanol Production

Region	2019	2020	2021	2022	2023	% of World Production
United States	15778	13941	15016	15361	15620	53.00%
Brazil	8860	8100	7320	7400	8260	28.00%
European Union	1380	1330	1410	1460	1440	5.00%
India	500	520	870	1230	1430	5.00%
China	1020	940	900	920	950	3.00%
Canada	497	429	434	447	460	2.00%
Thailand	430	390	350	370	370	1.00%
Argentina	290	210	270	310	300	1.00%
Rest of World	645	620	680	722	760	3.00%
Total	29400	26480	27250	28220	29590	

- The dataset containing yearwise and statewise data for sugarcane and molasses originates from the Ministry of Consumer Affairs, Food and Public Distribution. The yearwise data spans from 1930 to 2023 and includes several variables that impact production:

Table 3.2: Sugarcane, Sugar and Molasses Production in India

Year	Area under sugarcane ('000 hectare)	Production of sugarcane ('000 tonnes)	Yield of cane per hectare (tonnes)	No. of Factories in operation	Average duration days per year	Average capacity (tonnes per day)	Total cane crushed ('000 tonnes)	Total sugar produced ('000 tonnes)	Recovery of sugar (% cane)	Molasses production ('000 tonnes)	Molasses (% cane)
1930-31	1136	36354	32.1	29	-	-	1339	120	8.96	-	-
1931-32	1246	44011	35.3	31	-	-	1814	161	8.88	70	3.85
1932-33	1387	51950	37.5	56	138	-	3404	295	8.66	132	3.89
1933-34	1385	53297	38.5	111	103	481	5240	461	8.8	193	3.68
1934-35	1458	55218	37.8	128	104	500	6655	578	8.69	232	3.5
1935-36	1682	62185	37.1	135	126	545	10045	934	9.29	336	3.33
...	...	...	...	...	...	...	...	...	...	...	...
2014-15	5067	362333	71.5	538	133	4163	273073	28313	10.37	12479	4.57
2015-16	4927	348448	70.7	526	117	4192	236498	25125	10.62	10885	4.6
2016-17	4436	306070	69	489	100	4135	193434	20262	10.48	9002	4.65
2017-18	4732	376905	79.6	525	141	4439	301198	32328	10.73	13980	4.64
2018-19	5114	400157	78.3	531	130	4760	301179	33163	11.01	13885	4.61
2019-20	4603	370500	80.5	464	-	-	259043	27385	10.86	11916	4.6
2020-21	4857	399260	82.20	503	-	-		30000	11.03	14906	
2021-22	5175	439430	84.91	516	-	-		35740	10.95	18136	
2022-23	4910	490533	84.01	515	-	-		32820	11.02	16852	

1. Area under Sugarcane (‘000 hectare): This variable represents the total area of land used for cultivating sugarcane, measured in thousands of hectares.
2. Production of Sugarcane (‘000 tonnes): This variable indicates the total production of sugarcane, measured in thousands of metric tonnes.
3. Yield of cane per hectare (tonnes): This variable represents the average yield of sugarcane per hectare of land, measured in tonnes.
4. No. of factories in operation: This variable denotes the total number of sugarcane factories operational within a specified area or region.
5. Average duration days: This refers to the average duration, in days, of the sugarcane cultivation cycle from planting to harvesting.
6. Average capacity (tonnes per day): This variable represents the average processing capacity of sugarcane factories, measured in tonnes processed per day.

7. Total cane crushed ('000 tonnes): This indicates the total amount of sugarcane crushed in factories, measured in thousands of metric tonnes.
8. Recovery of sugar (% cane): This variable represents the percentage of sugar recovered from the total amount of sugarcane processed.
9. Molasses production ('000 tonnes): This variable indicates the total production of molasses, a by-product of sugarcane processing, measured in thousands of metric tonnes.
10. Molasses (% cane): This represents the percentage of molasses obtained from the total amount of sugarcane processed.

These variable provide comprehensive data on various aspects of sugarcane cultivation, processing and production of both sugarcane and its by-product, molasses over a specified time period and across different regions.

The dataset comprises statewise data from various regions in India, detailing variable such as year, area in thousand hectares, production in thousand tonnes, productivity in tonnes per hectare, cane crushed in thousand tonnes, sugar output in million tonnes, sugar recovery percentage and the number of sugar factories operating in each state for the respective years. The full dataset is available in following link:
https://drive.google.com/file/d/1pcTswH7Zq04N_ZJ_oF66O6y_1NViGqhM/view?usp=drivesdk

- The Maize production dataset sourced from Indian Institute of Maize Research spans from 2013 to 2023 in million metric tonnes.

Table 3.3:Maize Production in India

Year	Maize Production (in MMT)
2013-14	24.3
2014-15	24.2
2015-16	22.6
2016-17	25.9
2017-18	28.8
2018-19	27.7
2019-20	28.8
2020-21	31.5
2021-22	33.6
2022-23	34.6

- The Rice production dataset collected from Agriculture Department of India from 2012 to 2023 in million metric tonnes.

Table 3.4: Rice Production in India

Year	Rice Production (in MMT)
2012-13	105.2
2013-14	106.7
2014-15	105.5
2015-16	104.4
2016-17	109.7
2017-18	112.8
2018-19	116.5
2019-20	118.9
2020-21	124.4
2021-22	129.4
2022-23	130.8

- The ethanol blending dataset is obtained from the Ministry of Petroleum and Natural Gas. It includes the yearwise supply of ethanol from 2013 to 2023 in crore liters and the corresponding blending in percentage.

Table 3.5: Quantity Supplied (Ethanol) and %Blending Trends

Ethanol Supply Year	Qty supplied (Crore Lit)	Blending % age PSU OMCS
2013-14	38.0	1.53%
2014-15	67.4	2.33%
2015-16	111.4	3.51%
2016-17	66.5	2.07%
2017-18	150.5	4.22%
2018-19	188.6	5.00%
2019-20	173.0	5.00%
2020-21	332	8.50%
2021-22	437	10.00%
2022-23	542	10.50%

Source: Ministry of Petroleum & Natural Gas Office Memorandum Dated 13th January 2021 Accessed From http://mopng.gov.in/ files/article/articlefiles/OM-on-NBCC-decision-13012021.pdf

- Data set on Import, Export of Ethanol for India is obtained from the report named 'Biofuels Annual - 2023' of United States Department of Agriculture(USDA).

Table 3.6: Import, Export of Ethanol

Calendar Year	2014	2015	2016	2017	2018	2019	2020	2021	2022
Beginning Stocks	60	75	61	128	150	300	112	309	150
Production	2002	2292	2061	1671	2692	2552	2981	3280	5300
Imports	193	204	432	722	607	670	669	648	370
Exports	180	165	136	141	129	50	133	87	109
Consumption	2000	2345	2290	2230	3020	3360	3320	4000	5506
Fuel Consumption	350	425	450	675	1500	1890	2100	3695	5140
Ending Stocks	75	61	128	150	300	112	309	150	205
Production Capacity									
Number of Refineries	115	160	161	161	166	170	220	231	252
Nameplate Capacity	2000	2100	2210	2215	2300	3000	3500	4300	5700
Capacity Use (%)	17.8	20.5	20.4	31.8	65.2	64	60.6	87.1	87.7
Feedstock Use for Fuel (1000 MT)									
Sugarcane (syrup)	0	0	0	0	0	1951	5263	10000	14274
B-heavy Molasses	0	0	0	0	750	2271	3550	6667	9000
C-heavy Molasses	1600	2000	2125	3150	5500	4500	1200	900	800
Damaged Food Grains	0	0	0	0	350	603	1600	2000	2000
Rice	0	0	0	0	0	0	118	471	1610
Corn	0	0	0	0	0	0	0	0	0
Market Penetration (Million Lit)									
Fuel Ethanol	350	425	450	675	1500	1890	2100	3695	5140
Gasoline Pool 1/	26628	30823	32994	37098	40367	42496	40741	45453	50150
Blend Rate %	1.3	1.4	1.4	1.8	3.7	4.4	5.2	8.1	10.2

Chapter 4: Statistical Techniques

Introduction:

In this chapter, we will explore various techniques used to study Feedstock and Ethanol Production. We will cover statistical techniques that are commonly used for data analysis and visualization. These techniques help us to identify trends, patterns, and outliers in the data, which can provide valuable and outstanding performance. So, let's dive into the world of statistical techniques and learn how they can be applied to study Feedstock and Ethanol Production.

4.1 Analysis Using Data Visualization:

To better understand the data, we have used various graphical representation techniques including box plots, histograms, scatter plots, time series plots, heatmaps, bar graphs, line graphs, and pareto charts. These visualizations have helped us to identify trends and patterns in the data, such as the distribution of production of sugarcane and molasses in different states in India and the ethanol production. The relationship between sugarcane production and ethanol production.

We have used packages like Matplotlib and Seaborn in Python to create these graphs, which offer a wide range of customization options and allow us to tailor the visualizations to our specific needs. Additionally, we have used the PowerBI tool to create more interactive and dynamic visualizations for even better graphical representation of the data. Graphical representation has helped us to gain a deeper understanding of the data and communicate our findings more effectively.

- **Time Series Plot:** A time-series plot, also known as, is a type of a time plot graph that displays data points collected in a time sequence. In a time-series plot, the x-axis represents the time, and the y-axis represents the variable being measured. We use time plots in many fields, such as economics, finance, engineering, and meteorology, to visualize and analyse changes over time.

  Time-series plots allow you to see trends and patterns in data that might not be visible in other types of graphs. For instance, you can see how a particular variable changes over months, seasons, years, or even decades. This way, you can identify seasonal fluctuations, long-term trends, and cyclic patterns in data.

4.2 Correlation Analysis:

Correlation analysis is a statistical method used to determine the relationship between two variables. By quantifying the degree of correlation, we can evaluate the strength of the relationship between two variables. This analysis helps us understand how much one variable change when the other one does.

The correlation coefficient is used to assign a value to the relationship between two variables. It ranges from -1 to +1, where 0 indicates no relationship, -1 indicates a perfect negative correlation, and +1 indicates a perfect positive correlation. The most commonly used correlation coefficient is the Pearson Correlation Coefficient, which tests for linear relationships between data.

To determine if there is a positive, negative, or neutral relationship between the variables in the dataset, we calculate the Pearson Correlation Coefficient using the following formula:

$$r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2}\,\sqrt{\sum(y_i - \bar{y})^2}}$$

where,

r is the correlation coefficient,
x_i are the values of the x-variables in a sample,
$\bar{x}$ is the mean of the values of the x-variable,
y_i are the values of the y-variables in a sample, and
$\bar{y}$ is the mean of the values of the y-variable.

By conducting correlation analysis, we can determine the strength and direction of the relationship between variables in the dataset. This information can be used to make informed decisions and draw meaningful insights from the data.

4.3 Polynomial regression:

Polynomial regression is a form of regression analysis in which the relationship between the independent variable x and the dependent variable y is modeled as an n-th degree polynomial. In simpler terms, instead of fitting a straight line to the data points (as in linear regression), polynomial regression fits a curve.

The general equation for polynomial regression with one independent variable is:

$$y = \beta_0 + \beta_1 x + \beta_2 x^2 + \beta_3 x^3 + \cdots + \beta_n x^n + \varepsilon.$$

where,
y is the dependent variable,
x is the independent variable,
$\beta_0, \beta_1, \beta_2, \ldots, \beta_n$ are the coefficients representing the weights of each term in the polynomial,
n is the degree of the polynomial,
ε is the error term.

Polynomial regression allows for more flexible modelling of data that cannot be adequately described by a straight line. However, one needs to be cautious with higher degree polynomials as they can lead to overfitting, capturing noise in the data rather than the underlying relationship.

4.4 Time Series Analysis and Forecasting:

Time series analysis is a statistical technique used to analyse and interpret data that is collected and recorded over regular time intervals. It involves studying the patterns, trends, and dependencies within the data to make predictions or understand the underlying processes driving the observed behaviour.

In various fields such as economics, finance, meteorology, engineering, and social sciences, time series analysis is employed to gain insights, make forecasts, and support decision-making. By considering the temporal ordering of data points, time series analysis accounts for the fact that observations at different time points may be interrelated, allowing us to capture and model the dynamic nature of the data.

Performing time series analysis typically involves the following steps:

1. **Visualize Time Series Plot:** Time series plot is of great importance as it allows us to visually examine the patterns, trends, and seasonality present in the data. It provides an intuitive understanding of the temporal behaviour, helps identify outliers or irregularities, and guides the selection of appropriate time series analysis techniques.
2. **Decomposition:** Decompose the time series plot into its constituent components: trend, seasonality, and residuals. This step helps in understanding the individual contributions of these components and their impact on the overall behaviour of the series. Various decomposition methods, such as additive or multiplicative decomposition, can be applied.

   The Classical Decomposition Model of Time Series Analysis is,

$$X_t = m_t + s_t + z_t$$

where, $X_t = Time\ Series$
$m_t = Trend\ Component$
$s_t = Seasonal\ Component$
$z_t = Noise\ Component$

3. **Stationarity Analysis:** Assess the stationarity of the time series. Stationarity is desirable for many time series analysis techniques. Conduct statistical tests (e.g., ADF test) or inspect plots (e.g., rolling mean and standard deviation) to determine if the series is stationary. If non-stationarity is observed, consider differencing to achieve stationarity.

   The time series$\{ X_t , t \in Z\}$ is Stationary (weakly stationary) if,

   1) $E|X_t| < \infty \quad \forall\ t \in Z$
   2) $E(X_t) = m \quad \forall\ t \in Z$
   3) $\gamma_x(r,s) = \gamma_x(r+t, s+t) \quad \forall\ r,s,t \in Z$

- **ACF (Autocorrelation Function) and PACF (Partial Autocorrelation Function)**

These plots are commonly used in time series analysis to determine the order of autoregressive (AR) and moving average (MA) terms in a time series model. Additionally, stationarity tests are employed to assess the stationarity of the time series. Here's a breakdown of the plots and tests in terms of AR and MA parameters, along with their hypotheses and interpretations:

- **ACF Plot:**

The ACF plot helps determine the order of the autoregressive parameter p.

Interpretation:

If the ACF values decay gradually and become insignificant after a certain lag, it suggests an AR(p) process, where p is the last significant lag.

If the ACF values cut off abruptly after a certain lag, it indicates an AR(p) process, where p is the lag at which the ACF cuts off.

- **PACF Plot:**

  The PACF plot helps determine the order of the moving average parameter q.

  Interpretation:

  If the PACF values cut off abruptly after a certain lag, it suggests an MA(q) process, where q is the last significant lag.

  If the PACF values gradually decrease and become insignificant after a certain lag, it indicates an MA(q) process, where q is the lag at which the PACF cuts off.

  If the time series is non-stationary, differencing can be applied to make it stationary. The order of differencing required can be determined by examining the ACF and PACF plots to see when the autocorrelation becomes insignificant or when the partial autocorrelation cuts off.

4. **Model Selection:** Choose an appropriate time series model based on the characteristics of the data and the analysis objectives. Common models include ARIMA (Autoregressive Integrated Moving Average), SARIMA (Seasonal ARIMA), exponential smoothing, or state-space models. The choice of model depends on the presence of trends, seasonality, and other patterns in the data.

- **ARIMA Model Fitting:**

  ARIMA is defined as Auto Regressive Integrating Moving Average. ARIMA model combines three different models: The Auto-Regressive model, integrated model, and moving average model. ARIMA model can be applied to data, which is of non-stationary type. Non-stationary information is the data that does not have continuous successive intervals in the series. ARIMA model are generally denoted with p, d, q which are nonnegative integers.

  Where,

  p is the number of time lags in the Auto-Regressive (AR) Model

  d is the degree of differencing of Model

  q is the order of the Moving Average (MA) Model

  For p, d, q ≥ 0, we say that a time series$\{X_t\}$ is an ARIMA (p, d, q) process if

  $$Y_t = \nabla^d X_t = (1 - B)^d X_t$$

  is ARMA (p, q). We can write

  $$\varphi(B)(1 - B)^d X_t = \theta(B) Z_t$$

Time-series analysis-ARIMA is used to forecast the AQI. ARIMA model is the combination of three different individual models known as the Auto Regressive (AR) model denoted by p, Differencing (I) model indicated by d, Moving Average (MA) model denoted by q. The coefficients AR model and MR model are calculated with the help of Partial Auto-Correlation Function (PACF) and Auto-Correlation Function (ACF).

The coefficient of the Differencing model depends on the number of times the data is differentiated. Differentiation relies on the stationarity of the data. The dickey-fuller test is performed to find whether the given data is stationary or not. The results of the dickey fuller test confirmed that the dataset is non-stationary. Hence, the data is differentiated by two times to make it stationary, and the coefficient of the differencing model (d) is calculated as 2. The p and q coefficients were obtained from PACF and ACF graphs. The flowchart for to check given model is ARIMA or not is given below.

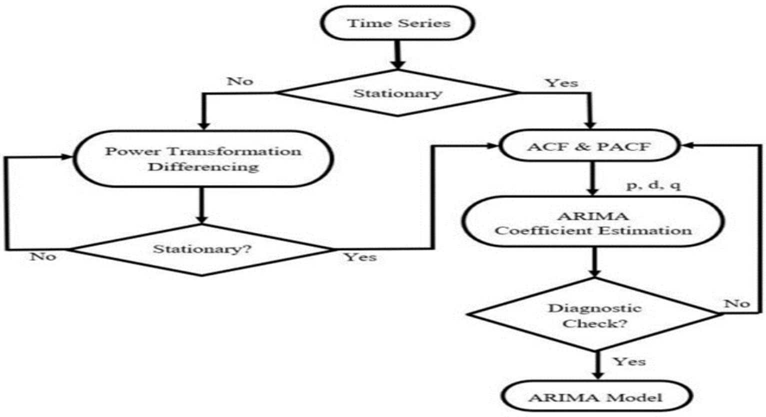


Figure 4.1: Block Diagram of ARIMA Model

Data transformation has been performed in the ARIMA model during data identification to make the non-stationary data to stationary data. A Stationary is a necessary condition for ARIMA Model. The stationary of the data is characterized by mean, standard -deviation, and auto-correlation structure. If the data present any trend, then applying the differencing and power transformation trend will be removed. Once the ARIMA model is identified, model parameters are estimated, and the final selected model is used for prediction purposes.

5. **Model Estimation:** Estimate the parameters of the selected time series model using the available data. This can be done through various techniques, such as maximum likelihood estimation or optimization algorithms, depending on the chosen model.
6. **Model Evaluation:** Evaluate the performance of the estimated model. Compare the predicted values against the actual values using evaluation metrics like MSE, RMSE, MAPE, or AIC/BIC. Assess the residuals for any remaining patterns or autocorrelation, which may indicate model inadequacy.

Performance Indices:

The statistical criteria such as MAPE, RMSE, and MAE are used to evaluate each developed model's performance measure.

a) Mean Absolute Percentage Error (MAPE)

MAPE measures the accuracy of fitted time series values. It expresses accuracy as a percentage.

$$\boldsymbol{MAPE} = \frac{\sum_{i=1}^{n}\left|\frac{x_i - \widehat{x_i}}{xi}\right| \times 100}{n} \qquad ,(xi \neq 0)$$

b) Root Mean Squared Error (RMSE)

RMSE is the square root of the mean of the squared errors. RMSE indicates how close the predicted values are to the actual values. Hence, the lower RMSE value signifies that the model performance is good. It is calculated as

$$\boldsymbol{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \widehat{x_i})^2} \qquad ,(xi \neq 0)$$

c) Mean Absolute Error (MAE)

MAE is the mean or average of the absolute value of the errors, the Predicted – Actual. It is calculated as

$$\boldsymbol{MAE} = \frac{1}{n}\sum_{i=1}^{n}|x_i - \widehat{x_i}| \qquad ,(xi \neq 0)$$

d) Mean Absolute Deviation (MAD):

The average absolute difference between each data point and the mean of the dataset, indicating the average variability or dispersion of the data.

$$\boldsymbol{MAD} = \frac{1}{n}\,\Sigma\,|x_i - \bar{x}|$$

e) Mean Squared Deviation (MSD):

The average squared difference between each data point and the mean of the dataset, providing a measure of the overall variability or spread of the data.

$$\boldsymbol{MSD} = \frac{\sum_{i=1}^{n}(x_i - \bar{x}_i)^2}{n}$$

7. **Forecasting:** Use the estimated model to make future predictions or forecasts. Extrapolate the model into the future based on the available historical data. Consider the uncertainty associated with the forecasts by calculating prediction intervals or using simulation techniques.
8. **Model Monitoring and Updating:** Continuously monitor the performance of the time series model as new data becomes available. Update the model and forecasts accordingly, ensuring that the analysis stays up-to-date and adapts to any changes in the underlying patterns.
9. **Double Exponential Smoothing:** Double Exponential Smoothing, also known as Holt's method, is an extension of the simple Exponential Smoothing technique used for forecasting time series data. While simple Exponential Smoothing is suitable for data with no trend or seasonality, Double Exponential Smoothing can handle data with a trend.

   Here's how it works:

   1) Initialization: Double Exponential Smoothing requires initial values for two components. These are typically determined using simple exponential smoothing for the level and an average of the initial trend values.

2) Updating the Level: The level component represents the smoothed value of the series at a given point in time. It's updated using a combination of the current observation and the previous level value.
$$Level_t = \alpha * Actual_t + (1 - \alpha) * \left(Level_{(t-1)} + Trend_{(t-1)}\right)$$

3) Updating the Trend: The trend component captures the rate of change in the series. It's updated using a combination of the difference between the current level and the previous level, and the previous trend value.
$$Trend_t = \beta * \left(Level_t - Level_{(t-1)}\right) + (1 - \beta) * Trend_{(t-1)}$$

4) Forecasting: Once the level and trend components are updated, future values can be forecasted by extrapolating the level and trend components.
$$Forecast_t = Level_t + Trend_t$$
Where t represents the current time period, and α and β are the smoothing parameters, typically between 0 and 1.
Double Exponential Smoothing is particularly useful when the time series exhibits both trend and seasonality. However, it may not perform well with highly irregular data or sudden changes in trends.

Chapter 5: Analysis of Feedstock

5.1 Evaluation of Feedstock Sources for Ethanol Production in India:

1. Diverse Feedstock Sources:

- **Sugarcane:** India is a major producer of sugarcane and utilizes it as a primary feedstock for ethanol production. The process involves extracting juice from sugarcane, which is then fermented and distilled to produce ethanol.
- **Corn:** Corn is another significant feedstock source, especially in regions where sugarcane cultivation is limited. Corn-based ethanol production involves the fermentation of starch in corn kernels.
- **Other Biomass:** Apart from sugarcane and corn, various biomass sources like agricultural residues, wood chips, and energy crops are explored for their potential in ethanol production. These can contribute to diversifying the feedstock base.

2. Sustainability:

- **Sugarcane:** Sugarcane-based ethanol is considered relatively sustainable due to the abundance of sugarcane in India. However, concerns regarding land use, water consumption, and potential impacts on food production must be addressed.
- **Corn:** Corn-based ethanol may face sustainability challenges due to competition with food production, intensive water and fertilizer usage, and environmental impacts associated with large-scale cultivation.

3. Availability:

- **Sugarcane:** The availability of sugarcane is high in India, especially in states like Maharashtra, Uttar Pradesh, and Karnataka. This makes sugarcane a readily available feedstock for ethanol production.
- **Corn:** Corn availability may vary, and it might be influenced by factors such as climate conditions and agricultural practices. The geographical distribution of corn cultivation needs consideration for sustainable sourcing.

4.Economic Viability:

- **Sugarcane:** Sugarcane-based ethanol is economically viable due to established sugar industries. The co-production of ethanol and sugar adds economic value to sugarcane processing.
- **Corn:** The economic viability of corn-based ethanol depends on factors like crop yield, market demand, and government policies supporting ethanol production.

5. Analysis of Sugarcane and Molasses Production:

- **Sugarcane:** A detailed analysis of sugarcane production involves assessing cultivation trends, yield per hectare, and the impact of climatic conditions on production. This data is crucial for predicting the availability of sugarcane for ethanol production.
- **Molasses:** Molasses, a byproduct of the sugar industry, is a key source for ethanol. Forecasting molasses production involves understanding sugar industry dynamics, processing efficiency, and potential variations.

6. Forecasting:

- **Sugarcane and Molasses:** Forecasting involves utilizing historical data, agricultural trends, and climate projections to estimate future sugarcane and molasses production. This information assists in planning for sustainable ethanol production and addressing potential supply chain challenges.

  In summary, the evaluation of feedstock sources for ethanol production in India involves considering sustainability, availability, and economic viability. A comprehensive analysis of sugarcane and molasses production, coupled with forecasting techniques, aids in developing strategies for a robust and sustainable ethanol industry in the country.

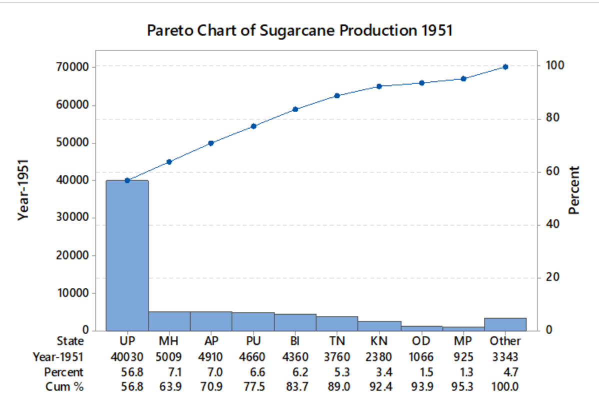
Table 5.1: Cost of feedstock and ethanol prices

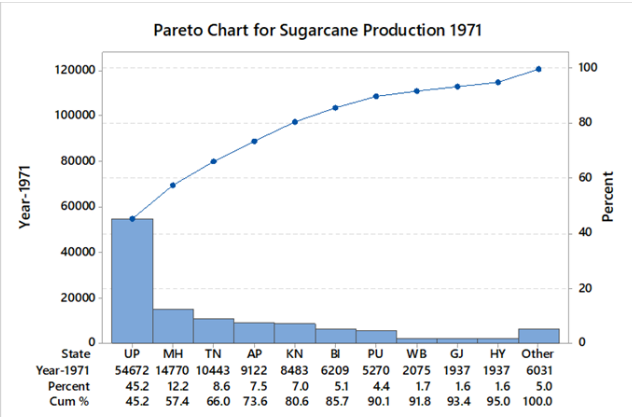
Feedstock	Cost/MT of the Feedstock (Rs)	Quantity of ethanol per MT of feedstock	Ex-mill Ethanol Price (Rs/litre)
Sugarcane juice / Sugar / Sugar syrup	2850 (Price of sugarcane at 10% sugar recovery)	70 litre per MT of sugarcane	62.65
B Molasses	13,500	300 litres	57.61
C Molasses	7123	225 litres	45.69
Damaged Food Grains (Broken Rice#)	16,000	400 litres	57.55
Rice available with FCI	20,000	450 litres	56.87
Maize#	15,000	380 litres	51.55

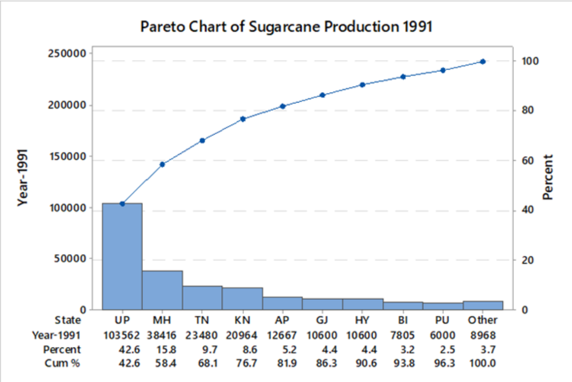
Source: Ministry of Petroleum & Natural Gas Office Memorandum Dated 13th January 2021 Accessed From http://mopng.gov.in/ files/article/articlefiles/OM-on-NBCC-decision-13012021.pdf

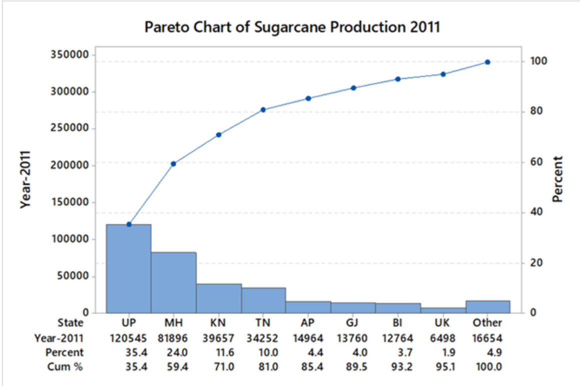
5.2 Graphical Representation of Feedstock:

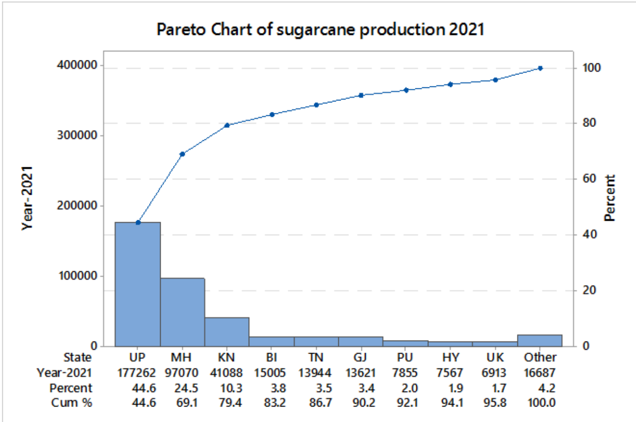
Sugarcane Production State wise:







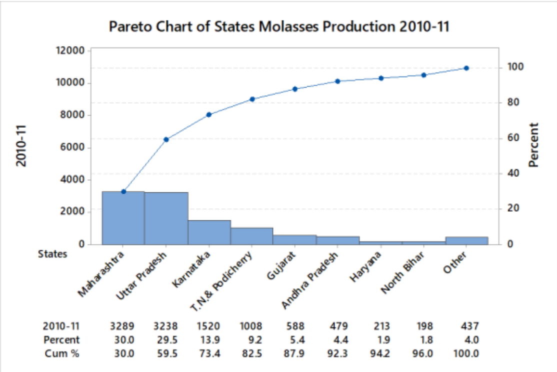


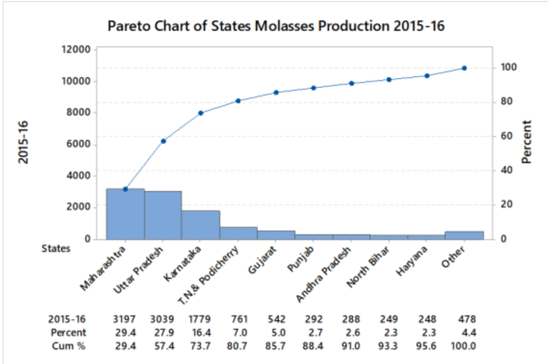


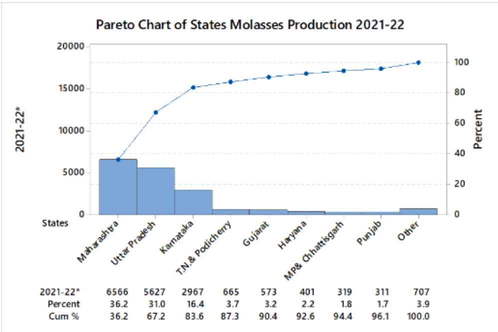
Interpretation:

- In 1951, the chart shows that Uttar Pradesh was the top produces of sugarcane followed by Maharashtra, Arunachal Pradesh, Punjab & Bihar. The top 5 states accounted for 83.7% of the total sugarcane production in India. The remaining 16.3% of total production.
- The chart shows that the top 5 states Uttar Pradesh, Maharashtra, Tamil Nadu, Arunachal Pradesh & Karnataka produced 80.6% of the sugarcane in India in 1951. The remaining 19.4% of the sugarcane was produced by other states.
- In 1991, the state with the highest percentage of sugarcane production is Uttar Pradesh with 42.6%. The states with the next highest percentages of sugarcane production are Maharashtra (15.8%), Tamil Nadu (9.7%), Karnataka (8.6%). The chart shows that Uttar Pradesh is the largest producer of sugarcane in India followed by Maharashtra, Tamil Nadu & Karnataka.
- The chart shows that Uttar Pradesh, Maharashtra, Karnataka & Tamil Nadu are the top 5 states in sugarcane production accounting for 81% of total production. The remaining states account for 19% of total production. Uttar Pradesh is the leading state in sugarcane production.
- The chart shows that Uttar Pradesh produced the most sugarcane in 2021 followed by Maharashtra, Karnataka, Bihar & other. The top 3 states are 79.4% which means that these 3 states produced more than four-fifths of the total sugarcane in India.

Molasses Production State wise:







Interpretation:

- In 2010-11, the molasses production of Maharashtra, Uttar Pradesh, Karnataka & Tamil Nadu were 30%, 29.5%, 13.9% & 9.2% respectively. Karnataka's production was decreased.
- In 2015-16, the molasses production of Maharashtra, Uttar Pradesh, Karnataka & Tamil Nadu were 29.4%, 27.9%, 16.4% & 7% respectively and remaining 19.3% from other states. Maharashtra and Uttar Pradesh were equally contributed.
- In 2021-22, the molasses production of Maharashtra, Uttar Pradesh & Karnataka were 36.2%, 31% & 16.4% respectively and remaining 26.4% production from other states.

Overall, it shows that Maharashtra is the largest producer of molasses in India followed by Uttar Pradesh, Karnataka & Gujrat.

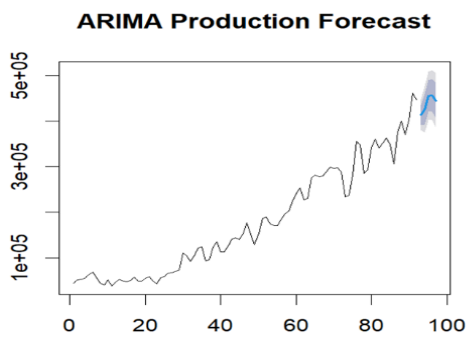
5.3 Forecasting Analysis of Sugarcane and Molasses production:

Sugarcane Production Forecasting:

Output of R code: (R code is given in Appendix 1):

```
Series: time_series
ARIMA(2,1,0) with drift

Coefficients:
```

```
              ar1       ar2          drift
            0.1077   -0.6422   4245.221
   s.e.     0.0818    0.0827   1173.306

sigma^2 = 299773177:  log likelihood = -1016.23
AIC=2040.45   AICc=2040.92   BIC=2050.49
arima_forecast
Point Forecast    Lo 80    Hi 80    Lo 95     Hi 95
   413538.2     391349.5 435727.0 379603.5 447473.0
   425824.5     392711.8 458937.1 375183.0 476465.9
   455151.2     420387.3 489915.0 401984.5 508317.8
   456933.9     421360.8 492507.0 402529.6 511338.3
   444806.6     405717.3 483895.9 385024.7 504588.5
accuracy(arima_forecast)
                     ME     RMSE       MAE        MPE      MAPE
Training set 0.4499149 16933.39 11060.33 -2.971775 8.267061
                   MASE          ACF1
Training set 0.7158399 -0.007556592
```



Interpretation:

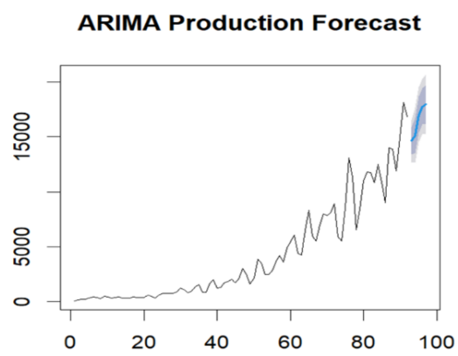
It gives forecast values of sugarcane production for next 5 years from 2023-24 to 2027-28 are

Year	Forecast value ('000' MT)
2023-24	413538.2
2024-25	425824.5
2025-26	455151.2
2026-27	456933.9
2027-28	444806.6

- **Molasses Production Forecasting:**

Output of R Code :(R code is given in Appendix 2)

```
Series: time_series
ARIMA(0,1,4) with drift

Coefficients:
         ma1      ma2    ma3    ma4    drift
      -0.1567 -0.8862 0.1571 0.4496 185.3003
s.e.   0.1047  0.1245 0.1109 0.1065  56.8060

sigma^2 = 947725:  log likelihood = -753.74
AIC=1519.48   AICc=1520.48   BIC=1534.55

arima_forecast
 Point Forecast    Lo 80    Hi 80    Lo 95    Hi 95
   14642.43     13394.82 15890.03 12734.38 16550.47
   15129.48     13497.50 16761.45 12633.58 17625.37
   17016.72     15383.86 18649.58 14519.48 19513.96
   17773.47     16134.41 19412.52 15266.75 20280.18
   17958.77     16175.21 19742.32 15231.05 20686.48
accuracy(arima_forecast)
                   ME       RMSE        MAE         MPE       MAPE
MASE
Training  set  3.686523  941.2315  592.0393  -26.05994  32.77775
0.721825
                  ACF1
Training set 0.0184636
```



Interpretation:

It gives forecast values of molasses production for next 5 years from 2023-24 to 2027-28 are

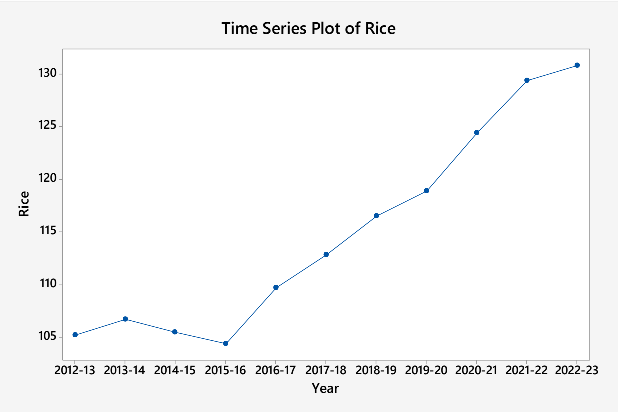
Year	Forecast Molasses ('000' MT)
2023-24	14642.43
2024-25	15129.48
2025-26	17016.72
2026-27	17773.47
2027-28	17958.77

5.4 Forecasting Analysis of Rice and Maize Production:

Rice:

Rice is the other main feedstock using for ethanol production.

Time Series Plot



After 2015 the production of rice increases fastly to onward.

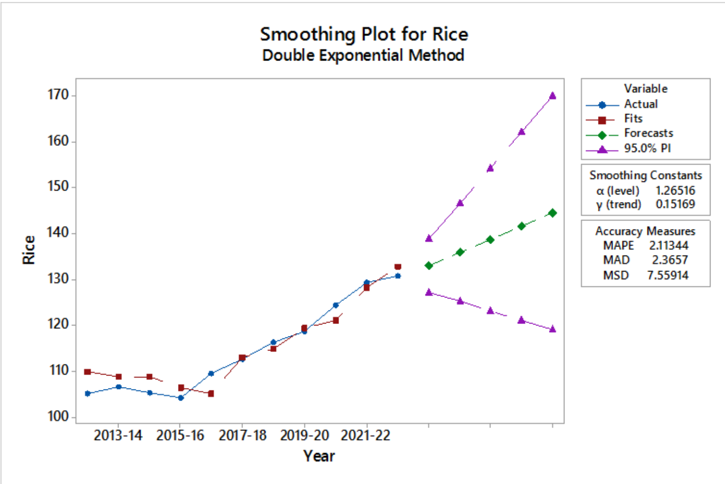
Double Exponential Smoothing Plot for Production

MTB > DES Production;
SUBC> Forecasts 5;
SUBC> Stamp ' Rice&# 39;

Double Exponential Smoothing for Production

```
Data Production
Length 11

Smoothing Constants
α (level) 1.26516
```

```
γ (trend) 0.15169

Accuracy Measures
MAPE 2.11344
MAD 2.36572
MSD 7.55914

Forecasts
Period Forecast Lower    Upper
2022-23 133.086 127.290 138.882
2023-24 135.945 125.351 146.539
2024-25 138.805 123.292 154.317
2025-26 141.664 121.200 162.128
2026-27 144.523 119.094 169.953
```

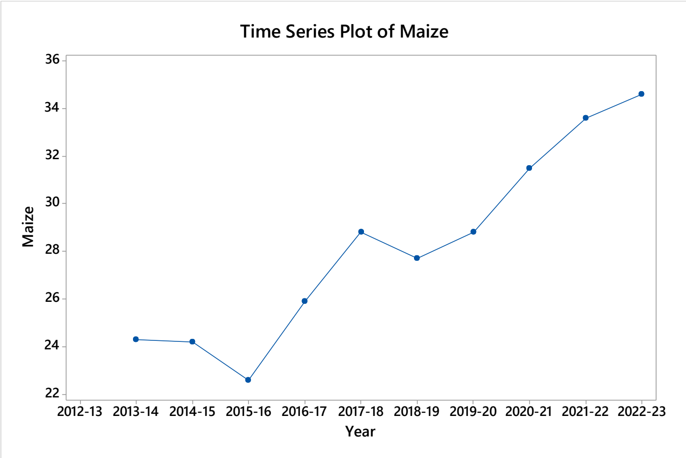


Interpretation:

- The projected production of rice in 2025-26 is 141.664 MMT.
- Near about 115 to 118 MMT demand of rice in India.

Maize:

Maize is other main feedstock use for ethanol production. Grain base project of ethanol production use 50% maize production.



Double Exponential Smoothing Plot for Maize Production

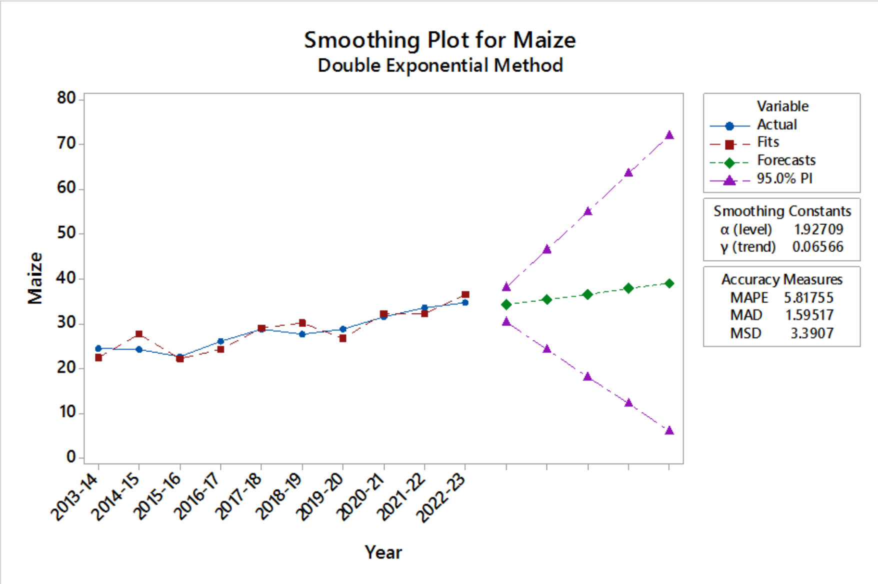
```
MTB > DES Maize;
SUBC>   Forecasts 5;
SUBC>   Stamp 'Maize'.
```

Double Exponential Smoothing for Maize Production

* NOTE * Second weight outside region of invertibility; adjusted weight will be used.

```
Data    C5
Length 10


Smoothing Constants

α (level) 1.92709
γ (trend) 0.06566


Accuracy Measures

MAPE 5.81755
MAD   1.59517
MSD   3.39073


Forecasts

Period         Forecast    Lower     Upper
2022-23        34.1381     30.2300   38.0462
```

2023-24	35.3454	24.1774	46.5133
2024-25	36.5526	18.1235	54.9817
2025-26	37.7599	12.0694	63.4504
2026-27	38.9671	6.0152	71.9191



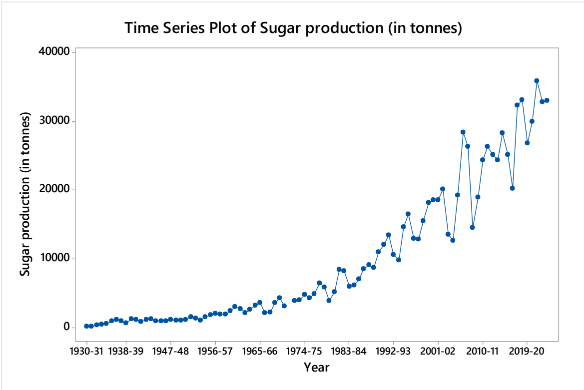
Interpretation:

- Indian maize consumption is annually 34.6 in 2022-23. Its largest consumer is the feed industry (both cattle and poultry) that absorbs about 55-60% of country maize.
- The second largest consumer is starch industry including pharma, textile and cosmetic industries.
- Maize consumption as food is low in the country.
- Indian maize exports are residual in nature are not a regular feature.
- In the previous year, India exported about 3.453 MMT of maize annually.
- The projected production of 2025-26 is 37.75 MMT.

5.5 Sugar Production Analysis:

Sugar Production (By product of Sugarcane):

Time Series plot of Sugarcane:

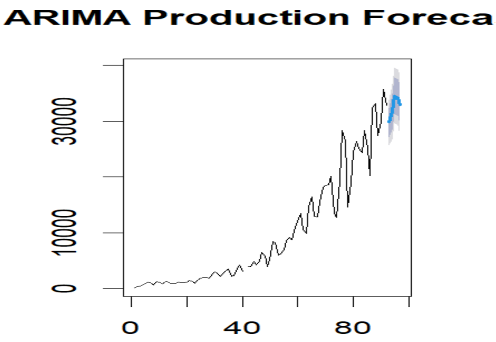


Mainly two by product of sugarcane, one is ethanol and other is sugar. Ethanol is already explained above. Now, we discuss sugar production level in India.

OUTPUT : Rcode (R code is given in Appendix 3)
Series: time_series
ARIMA(2,1,1) with drift

Coefficients:

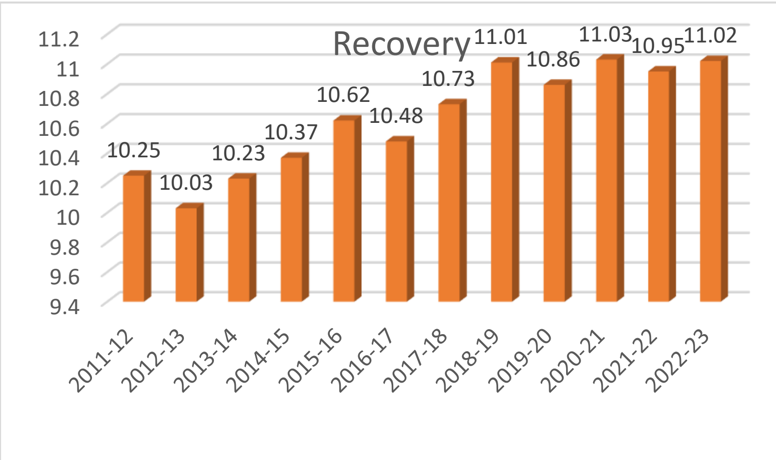
```
    ar1       ar2       ma1      drift
      0.1572  -0.6618  -0.4522  352.9137
s.e.  0.0998   0.0819   0.1213   78.7145

sigma^2 = 4294161:  log likelihood = -814.03
AIC=1638.07   AICc=1638.77   BIC=1650.62
 #Forecast using ARIMA Model

      Year          Point Forecast    Lo 80         Hi 80            Lo 95
Hi 95
2023-24      29706.09       27050.41   32361.77   25644.58   33767.60
2024-25      31680.14       28430.94   34929.34   26710.91   36649.36
2025-26      34582.22       31333.00   37831.43   29612.97   39551.46
2026-27      34262.92       31006.64   37519.20   29282.87   39242.97
2027-28       32823.13      29240.44   36405.81   27343.89   38302.36
# Calculate forecast accuracy

                    ME       RMSE        MAE         MPE      MAPE        MASE
ACF1
Training set -4.193122 2014.502 1375.342 -24.33395 31.3182 0.8216288
0.04013288
```



Interpretation:

From 1930 to 1975 slightly increase in sugar production. But after 1975 to onward due to government support, subsidies, privatization of sugar miles. Kindly increase the production of sugar.

Recovery rate of Sugarcane:
Sugar recovery plot



The quality of sugarcane is judged by the recovery rate of sugar from sugarcane During last 100 years the sugarcane recovery observed between 8.96 to 11.1

Chapter 6: Ethanol Production

6.1 Ethanol production in India:

- India is one of the world's leading producers of ethanol. Ethanol production in India has been growing steadily over the years due to various factors such as government policies promoting biofuels, increasing demand for ethanol-blended fuels, and efforts to reduce reliance on fossil fuels.
- The Indian government has implemented various schemes and policies to boost ethanol production. One significant initiative is the Ethanol Blended Petrol (EBP) program, which mandates the blending of ethanol with petrol to reduce carbon emissions and promote the use of renewable fuels. The government has set targets to achieve a certain percentage of ethanol blending with petrol, gradually increasing the blend ratio over time.
- Additionally, India has abundant feedstock resources for ethanol production, including sugarcane, molasses, grains, and biomass. Sugarcane and molasses are the primary feedstocks used for ethanol production in India, given the country's substantial sugarcane cultivation.
- Several government-owned and private ethanol plants operate across India, producing ethanol for various purposes, including fuel blending, industrial applications, and alcoholic beverages.
- Furthermore, India has been actively exploring second-generation (2G) ethanol production technologies, which utilize non-food biomass such as agricultural residues, forest residues, and municipal solid waste. This approach aims to mitigate concerns related to food security and land use competition.
- Overall, ethanol production in India is a dynamic sector with significant growth potential, driven by government policies, technological advancements, and increasing environmental awareness.

Production and Capacity:

- India has a robust ethanol production capacity, reaching around 1380 crore litters (138 billion litters) as of November 2023.
- Of this molasses-based production contributes about 875 crore litters, while grain-based production is at 505 crore litters.

Growth and Government Push:

- Ethanol production has witnessed significant growth in recent years, with capacity increasing more than 2.5 times in the last 8 years.
- The government actively promotes ethanol blending in petrol (EBP) with a target of achieving 20% blending by 2025 (earlier target was 2030).

Feedstock and Sustainability:

- Traditionally, sugarcane molasses was the primary feedstock for ethanol production.
- To achieve blending targets and promote sustainability, the government allows using damaged food grains and is encouraging production from non-food feedstock like agricultural waste.

Benefits:

- Increased ethanol production reduces reliance on imported petrol, leading to foreign exchange savings. Estimates suggest savings of ₹24,300 crore in 2022-23.
- Ethanol blending lowers carbon emissions, contributing to a cleaner environment.

Outlook:

- India is continuously expanding its ethanol production capacity to meet the EBP program's blending targets.
- Focus is shifting towards using alternative feedstock and cleaner technologies for sustainable ethanol production.

Table.no: 6.1 Production Capacity

Category	Production (Million Liters)
Total Ethanol Production Capacity (as of Nov 2023)	13800
Molasses-based Production	8750
Grain-based Production	5050

6.2 International Status of Ethanol Production:

In this section we have discuss international ethanol production scenario. The overall world needs ethanol but only few countries made ethanol due that reason not fulfilment of ethanol.

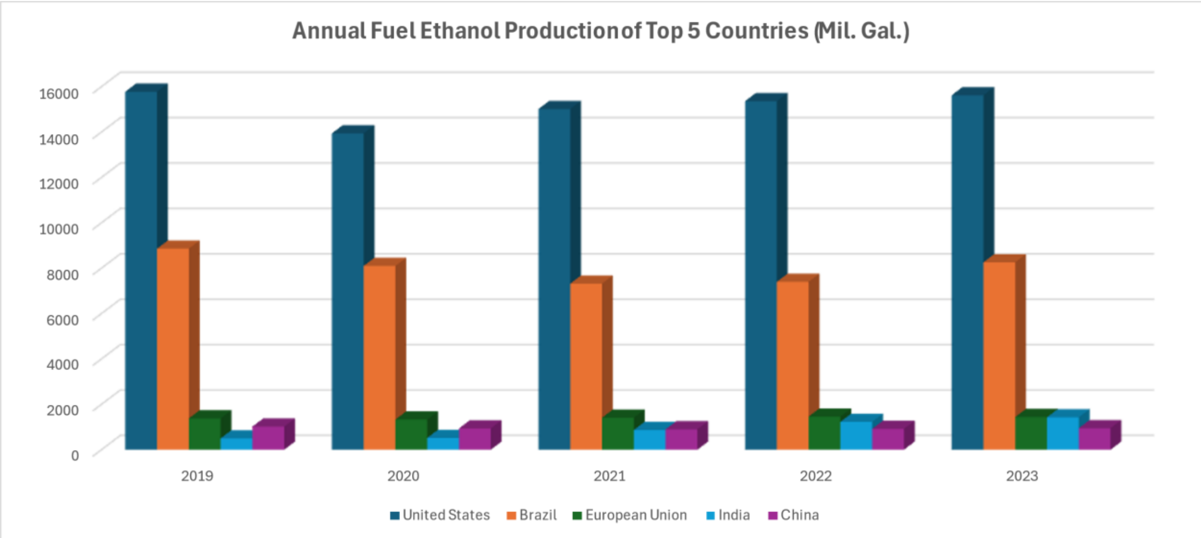


Fig.no 6.1 Ethanol Production of Top 5 Countries

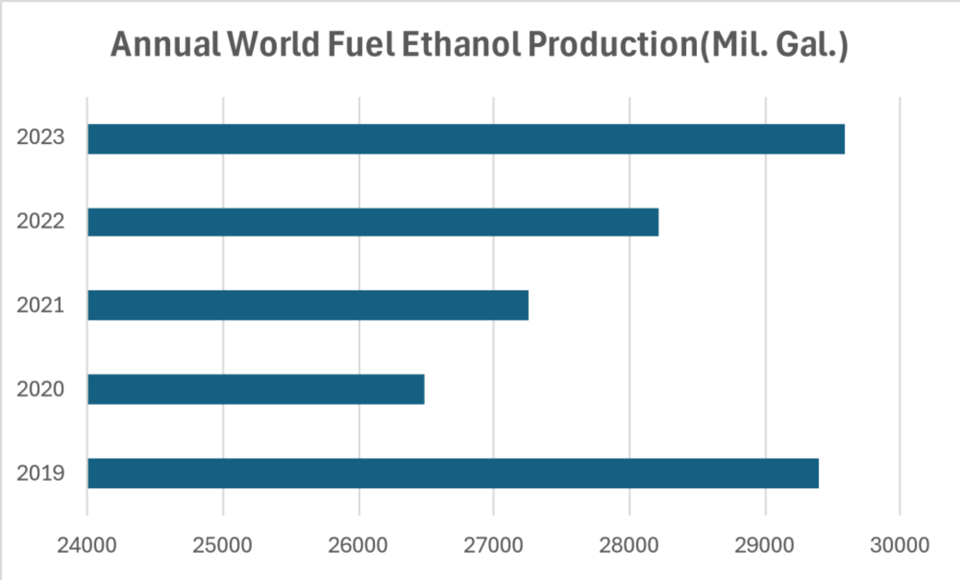


Fig.no 6.2: Annual World Fuel Ethanol Production

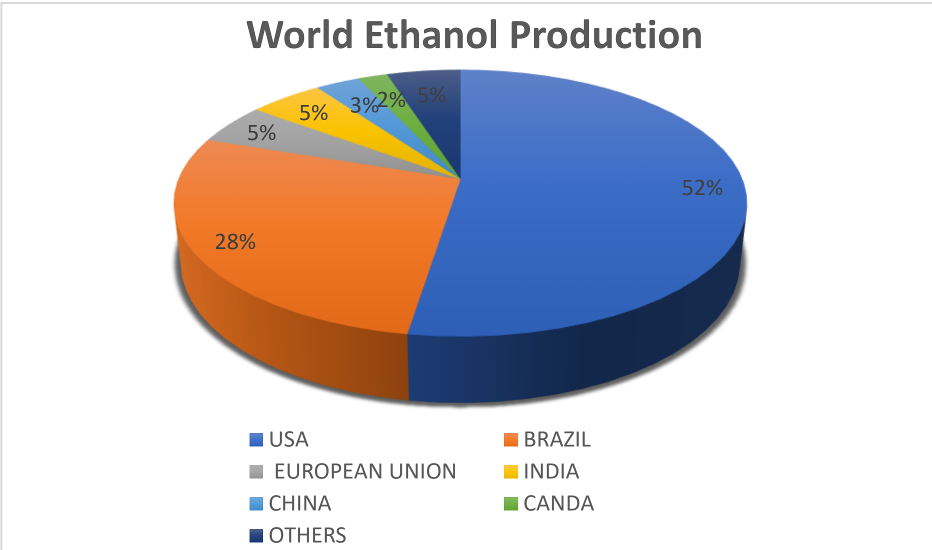


Fig.no 6.3: World Fuel Ethanol Production by Region

The USA and Brazil are both the big producer of ethanol in world. Those produce near about 80% production of total production. India produce only 5% ethanol in total production.

6.3 Graphical and Descriptive Analysis of Ethanol Production

- **Time Series Plot of ethanol production**

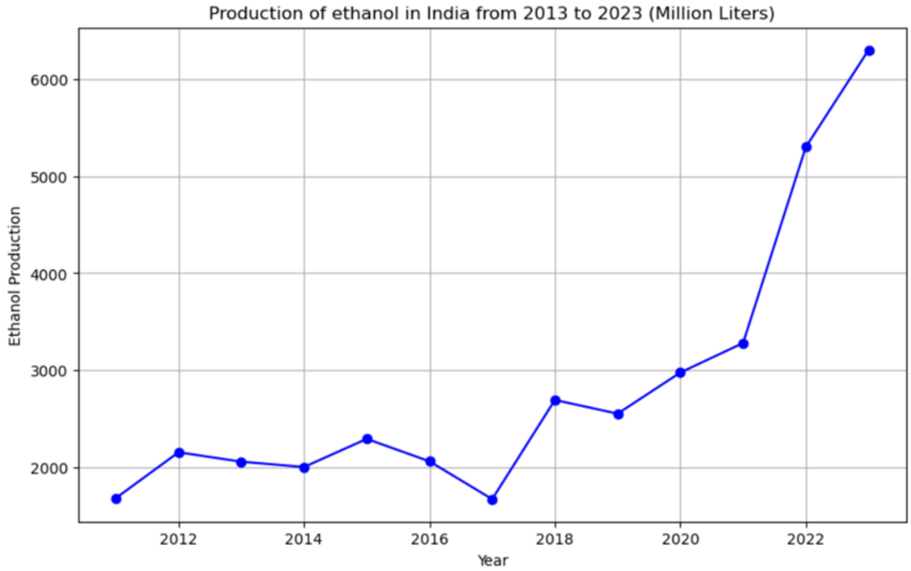


Figure 6.3: Time Series Plot of Ethanol production

The data plotted in the graph shows a significant increase in ethanol production in India over the ten years. Production increased from around 2057 million litters in 2013 to over 5300 million litters in 2022. This represents more than a doubling of ethanol production over that period.

This increase in production is due to several factors, including government policies that aim to increase the blending of ethanol with gasoline. These policies include financial assistance for setting up new ethanol plants and long-term agreements to purchase ethanol from producers.

Descriptive Statistics:

	Ethanol production (milion liter)	Sugarcane Production (Lakh tonnes)	Molasses production (000 tonnes)
count	13.000000	13.000000	13.000000
mean	2847.615385	3751.615385	12853.307692
std	1406.591953	475.021673	2594.826853
min	1671.000000	3036.000000	9026.000000
25%	2057.000000	3424.000000	10970.000000
50%	2292.000000	3610.000000	11824.000000
75%	2976.000000	4110.000000	14063.000000
max	6300.000000	4616.000000	18136.000000

Descriptive statistics for sugarcane production, molasses production, and ethanol production. Here's a summary of what we can learn from the table:

Sugarcane Production:

- Average production over the 13 years is 3751.62 lakh tonnes (likely around 375 million tonnes).
- There is a standard deviation of 475.02 lakh tonnes, indicating some variability in production from year to year.
- The minimum production year was 3036 lakh tonnes, and the maximum was 4616 lakh tonnes.

Molasses Production:

- Average production is 12853.31 thousand tonnes (likely around 12.8 million tonnes).
- Standard deviation is 2594.83 thousand tonnes, showing higher variability than sugarcane production.
- Minimum production was 9026 thousand tonnes, and the maximum was 18136 thousand tonnes.

Ethanol Production:

- Average production is 2847.62 million litters.
- Standard deviation is 1406.59 million litters, indicating the most variable production levels among the three.
- Minimum production was 1671 million litters, and the maximum was 6300 million litters.

Observations:

- Molasses production has the highest average annually followed by sugarcane production and then ethanol production.
- Ethanol production has the highest standard deviation, which means its yearly values fluctuate more compared to sugarcane and molasses production.

Correlation Analysis:

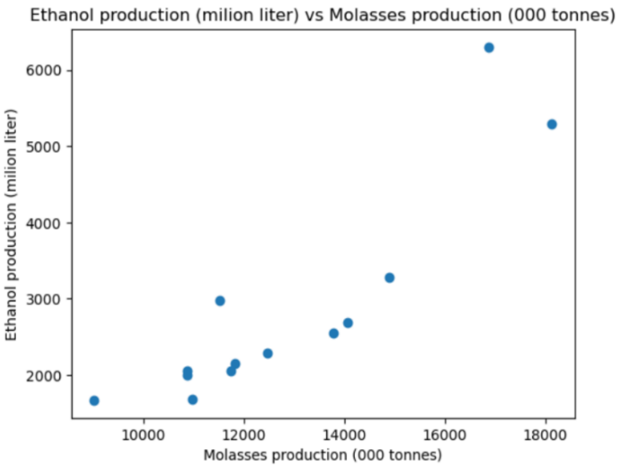
Here's what the table shows:

	Ethanol production (milion liter)	Sugarcane Production (Lakh tonnes)	Molasses production (000 tonnes)
Ethanol production (milion liter)	1.000000	0.834709	0.885984
Sugarcane Production (Lakh tonnes)	0.834709	1.000000	0.977719
Molasses production (000 tonnes)	0.885984	0.977719	1.000000

- Molasses production has the strongest correlation coefficient (0.978) with sugarcane production. This means that there is a strong positive correlation between these two factors. As sugarcane production increases, molasses production also tends to increase.

- Ethanol production has a moderate positive correlation with both sugarcane production (0.835) and molasses production (0.886). This means that as sugarcane or molasses production increases, ethanol production also tends to increase, but the relationship is not quite as strong as the one between sugarcane and molasses production.

6.4 Polynomial Regression Analysis (Molasses Production)



The graph shows the relationship between molasses production (in thousands of tonnes) and ethanol production (in millions of litters). It indicates that as molasses production increases, ethanol production also tends to increase. This suggests a positive correlation between the two variables: higher molasses production generally leads to higher ethanol production. And we see the exponential growth in Ethanol Production as molasses production increases. Therefor we decide to fit the polynomial regression model to the data for the prediction of Ethanol production for next 3 years.

Polynomial Regression

```
x_train=df3[['Molasses production (000 tonnes)']]
y_train=df3['Ethanol production (million litter)']
```

Here we use a molasses production and Ethanol production dataset as our training data.

#Test Data

Year	Molasses production (Forecasted) (‘000’MT)
2023-24	14642.43
2024-25	15129.48
2025-26	17016.72

Here we use a forecasted values of molasses production from previous chapter as our test data.

```
data = {'year': [2024,2025,2026],
       'Molasses production (000 tonnes)': [14642.43,15129.48,17016.72]}

df4 = pd. DataFrame(data)

x_test=df4[['Molasses production (000 tonnes)']]


#Model
model2 = make_pipeline (
   PolynomialFeatures(degree=2),    # Degree of polynomial features
   StandardScaler (),          # Standardize features
   LinearRegression()          # Linear regression model
)

# Fit the model on training data
model2.fit(x_train, y_train)

# Predict on testing data
y_test_pred = model2.predict(x_test)
y_test_pred
```

Year	Ethanol Production (Predicted)(million litter)
2023-24	3401.83
2024-25	3692.15
2025-26	5040.19

These are the predicted values for the testing data.

```
# Evaluate the model
train_score = model2.score(x_train, y_train)
```

```
Training R^2 score: 0.8452172056790159
```

The R^2 score for the training data is approximately 0.845, which indicates that about 84.5% of the variance in the training data is explained by the model.

Conclusions:

The polynomial regression model with degree 2 polynomial features appears to fit the training data well, as indicated by the high R^2 score of 0.845.

The model successfully generated predictions for the years 2023-24, 2024-25 and 2025-26.

To fully evaluate the model's performance, it would be important to also look at the R^2 score for the testing data, which is not possible here. Because we don't have response value (Ethanol production) for test data here.

6.5 Ethanol Production Capacity of Ethanol Projects in different States

- **Graphical Representation**

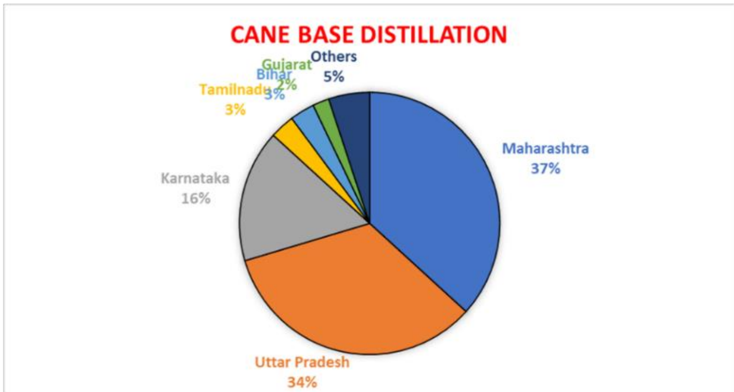


Figure.6.4 Cane Base Distillation

The total cane-based distillation capacity of 3.28 billion litres, 95% of the capacity is in 6 states. Maharashtra has the highest share of 37% followed by Uttar Pradesh (34%), Karnataka (16%), Tamil Nadu (3%), Bihar (3%), Gujarat (2%).

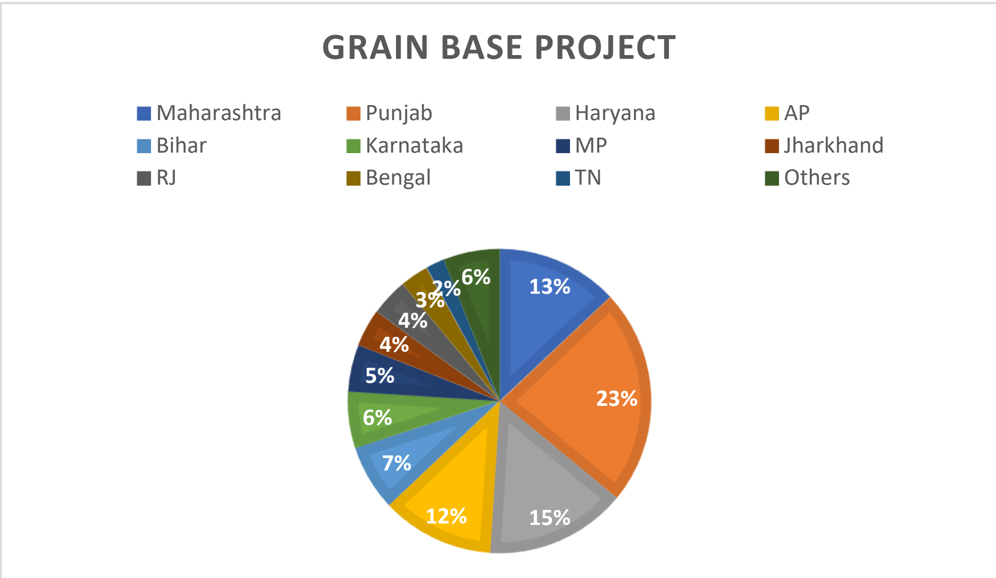


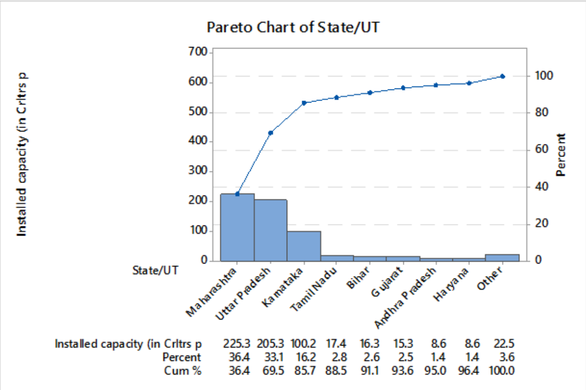
Figure.6.5 Grain Base Distillation

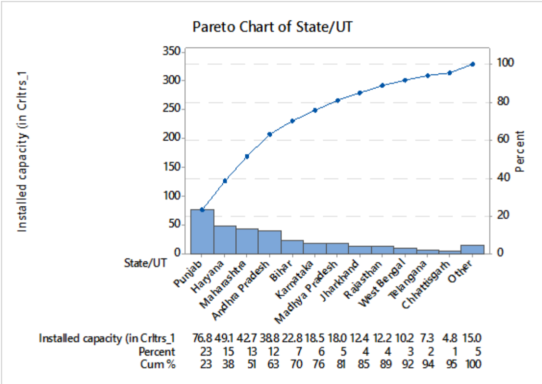
The total grain-based distillation capacity of 3.28 billion litres, 94% of the capacity is in 11 states. Punjab has the highest share of 23% followed by Haryana (15%), Maharashtra (13%), Andhra Pradesh (12%), Bihar (7%), Karnataka (6%), Madhya Pradesh (5%), Jharkhand (4%), Rajasthan (4%), West Bengal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

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

Table 6.3: Ethanol Projects in different states with capacities

State/UT	No. of Molasses based Project	Installed capacity (in Cr.Ltrs p)	No. of Grain based projects	Installed capacity (in Crltrs_1)	total Installed capacity (in Cr ltrs)
Andhra Pradesh	8	8.6	15	38.8	47.4
Bihar	8	16.3	5	22.8	39.1
Chhattisgarh	0	0	3	4.8	4.8
Gujarat	12	15.3	0	0	15.3
Haryana	4	8.6	15	49.1	57.6
Himachal Pradesh	0	0	3	2.7	2.7
Jharkhand	0	0	2	12.4	12.4
Karnataka	33	100.2	6	18.5	118.7
Madhya Pradesh	3	4.8	8	18	22.8
Maharashtra	116	225.3	28	42.7	268
Odisha	0	0	2	3.1	3.1
Punjab	3	5.1	18	76.8	82
Rajasthan	0	0	8	12.2	12.2
Tamil Nadu	12	17.4	0	0	17.4
Telangana	3	6.8	2	7.3	14.1
Uttar Pradesh	58	205.3	2	3.4	208.7
Uttarakhand	3	5.8	0	0	5.8
West Bengal	0	0	3	10.2	10.2
Assam	0	0	2	3.6	3.6
Sikkim	0	0	1	2.2	2.2
Total	263	619.4	123	328.5	947.9





Interpretation:

- The installed capacity of Molasses based production in India is more than other states i.e Maharashtra(36.4%), Uttar Pradesh(33.1), Karnataka(16.2%) and other(14.3%).
- The installed capacity of Grain based production in India is high for Punjab.Punjab(23%), Haryana(15%), Maharashtra(13%), Andhra Pradesh(12%), Bihar(7%), Karnataka(6%), Madhya Pradesh(5%) and other(19%).

Table 6.4 Current and Required Capacities

Current ethanol Capacity	7.89	2.91	10.82
Capacity required by 2025	10.79	5.31	16.1
Additional Capacity needed	2.9	2.4	5.2

Chapter 7: Ethanol Blending

7.1 Introduction

The energy demand in our country is rising due to an expanding economy, growing population, increasing urbanization, evolving lifestyles and rising spending power. About 98% of the fuel requirement in the road transportation sector is currently met by fossil fuels and the remaining 2% by biofuels. Today, India imports 85.2% of its oil requirement. The Indian economy is expected to grow steadily despite temporary setbacks due to the COVID pandemic. This would result in a further increase of vehicular population which in turn will increase the demand for transportation fuels. Domestic biofuels provide a strategic opportunity to the country, as they reduce the nation's dependence on imported fossil fuels. In addition, when utilized with appropriate care, biofuels can be environmentally friendly, sustainable energy sources. They can also help generate employment, promote Make in India, Swachh Bharat, doubling of farmers' incomes and promote Waste to Wealth generation

Ethanol is one of the principal biofuels, which is naturally produced by the fermentation of sugars by yeasts or via petrochemical processes such as ethylene hydration. It has medical applications as an antiseptic and disinfectant. It is used as a chemical solvent and in the synthesis of organic compounds, apart from being an alternative fuel source.

The National Policy on Biofuels – 2018, provides an indicative target of 20% ethanol blending under the Ethanol Blended Petrol (EBP) Programme by 2030. Currently petrol with 10% ethanol blend (E10) is being retailed by various Oil Marketing Companies (OMCs) in India, wherever it is available. However, as sufficient quantity of ethanol is not available, therefore, only around 50% of petrol sold is E10 blended, while remaining is unblended petrol (E0). The current level of average ethanol blending in the country is 5% (Ethanol Supply Year 2019-20). Due to several interventions in the supply side of ethanol, the Ministry of Petroleum aims to achieve 10% ethanol blending levels in the Ethanol Supply Year (ESY) – 2021-22 i.e. April, 2022. This step along with achieving E20 targets will require emission norms for nationwide standardization and adoption. The MoRT&H has notified BS-VI emission norms in Central Motor Vehicle Rules 1989 which are applicable to all vehicles post 1st April 2020. Newer vehicles on E-20 will have to meet BS-VI norms. MoRT&H has notified GSR 156(E) on 8th March 2021 for adoption of E20 fuel as automotive fuel and issued mass emission standards for it. MoRT&H has also notified Safety standards for ethanol blended fuels vide GSR 343(E) dated 25th May, 2021 on the basis of Automotive Industry Standard3 (AIS 171). It lays down safety requirements for type approval of pure ethanol, flex-fuel & ethanol-gasoline blended vehicles in India.

Currently the gasoline vehicles (2 wheelers & 4 wheelers) in the country are designed for running on pure gasoline and can be tuned to suit ethanol blended fuels ranging from E0 to E5 depending on the vehicle type. On the material compatibility front, the rubber and plastic components are compatible with E10. However, with the proposed target of E20, the vehicles are now required to become both material compatible and tuned for use of E20 fuel.

The task force on sugarcane and sugar industry5 constituted under the Chairmanship of Professor Ramesh Chand, Member (Agriculture), NITI Aayog estimated that sugarcane and paddy combined are using 70% of the country's irrigation water, depleting water availability for other crops. Hence there is a need for change in crop pattern, to reduce dependence on one particular crop and to move to more environmentally sustainable crops for ethanol production. Cereals, particularly maize, and Second Generation (2G) biofuels with suitable technological innovations offer promise of a more environmentally benign alternative feedstock for production of ethanol.

Besides, the entire supply chain and logistics of OMCs needs to be augmented to store, handle and dispense E20 blends.

As per the decision of the CCEA in its meeting of 21.12.2020, the Government aims to advance adoption of 20% blending in gasoline in the country by 2025. Accordingly, MoP&NG, DFPD, DHI and MoRT&H have worked out a plan to achieve this target, which this report synthesizes.

7.2 International Practices on Ethanol Blending in Petrol:

Global transportation sector is facing three major challenges, namely depletion of fossil fuels, volatility in crude oil prices and stringent environmental regulations. Alternative fuels specific to geographies can address these issues. Ethanol is considered to be one of most suitable alternative blending, transportation fuel due to its better fuel quality (ethanol has a higher-octane number) and environmental benefits. The global production of fuel ethanol touched 110 billion litres in 2019 showing an average growth of 4% year per year during the last decade. The United States of America (USA) and Brazil contribute for 92 billion litres (84% of global share) followed by European Union (EU), China, India, Canada and Thailand. In order to increase the availability of ethanol for transport use, many initiatives have been taken by various countries across the world (Table 2.1). Brazil legislated that the ethanol content in gasoline sold in the country should be in the range of 18% to 27.5%, which is currently at 27%. Concurrently, the use of 100% hydrous ethanol by flex-fuel vehicles in Brazil has increased the average share of ethanol in transportation, to 46% in 2019.

Table 7.1: Roadmap / Mandate for ethanol blending in various countries

Country	Roadmap for ethanol blends	Program	Implementation By	Vehicle Type
Brazil	National policy of Brazil continues the mandate for blending of 18-27.5% of ethanol in gasoline which originally started from 2015. This is currently at 27%.	National biofuels policy (Dec 2017	Ministry of mines and energy (MME)	Mainly flex. Motorbikes and other two wheeler engines use E27

United States	The clean air Act requires EPA to set the Renewable Fuel Standards (RFS) volume requirements annually. EPA updates volume requirements each year based on fuel availability.	Renewable fuel standard (RFS) program	Environmental protection agency (EPA)	Primarily normal; Flex for E30 or E85 only
European Union (EU)	EU aims to have 10% of the transport fuel of every EU country come from renewable sources, such as bio-fuels by 2020	Renewable energy directive	European commission	Flex and normal
China	In September 2017, the Chinese government announced legislation proposing the use of ethanol in fuel for all of China with the target of 10% ethanol blending.	Fuel quality standards	National energy administration	Primarily normal
Thailand	Alternative Energy Development Plan (ADEP) targets the share of renewable and alternative energy from biofuel to increase from 7% of total fuel energy use in 2015 to 25% in 2036	ADEP	Ministry of Energy	Primarily normal
India	National policy of India Continues the manmade for blending 3% to 10%. Set a target for 2025 is 20%, current 10.50% blending	National biofules policy 2021	Niti Aayog Ministry of petroleum and Natural Gas	Flex and normal

7.3 India Practices on Ethanol Blending in Petrol:

Table 7.3: Price of Ethanol per lit produced from different material

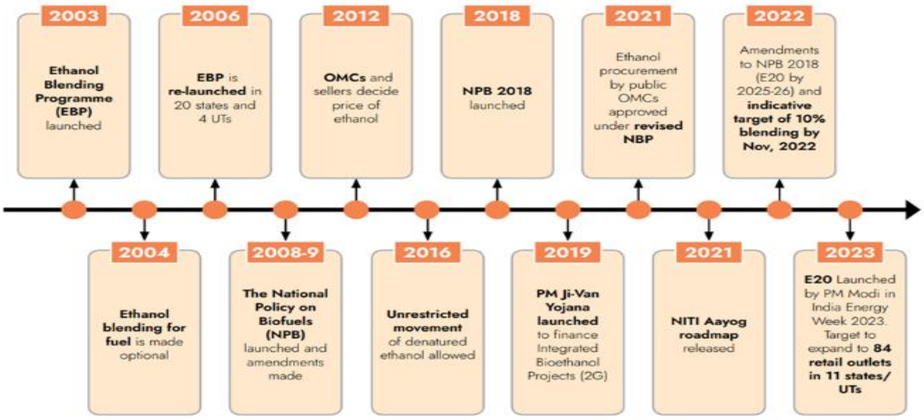
	C-heavy Molasses	B-heavy Molasses	Sugarcane Syrup	Damaged Grain	Maize	Surplus Rice
2015-16	42.0	NA	NA	NA	NA	NA
2016-17	39.0	NA	NA	NA	NA	NA

2017-18	40.9	NA	NA	NA	NA	NA
2018-19	43.5	52.4	59.2	47.1	NA	NA
2019-20	43.8	54.3	59.5	50.4	NA	NA
2020-21	45.7	57.6	62.7	51.6	NA	56.9
2021-22	47.8	60.6	65.1	55.3	NA	58.3
2022-23	49.4	60.7	65.6	55.54	56.35	58.5

Source: BPCL, PIB and NITI Aayog

7.3.1 Indian Government Policies

Chart 7.1: Evolution of Indian ethanol policy



7.3.2 Government Policies:

1. Interest subvention @ 6% per annum or 50% of rate of interest charged, whichever is lower, by banks/National Cooperative Development Corporation (NCDC)/ Indian Renewable Energy Development Agency Limited (IRDEA)/ Non-Banking Financial Companies (NBFCs)/ any other financial institutions which are eligible for re-finance from NABARD, on the loans to be extended shall be borne by the Central Government for five including one year moratorium against the loan availed by project proponents.
2. Interest subvention under the scheme shall be provided on loan amount sanctioned and disbursed in respect of each project based on the proposed capacity, limited to the in principle approval by Department of Food and Public Distribution (DFPD).
3. Interest subvention would be available to only those distillers which will supply at least 75% of ethanol produced in an Ethanol Supply Year (ESY) (Dec-Nov) from the added distillation capacity to OMCs for blending with petrol.

4. Assistance shall not be available to sugar mills and distilleries which have availed benefits under any other scheme of Central Government for the same project.
5. In case of grain based distilleries, interest subvention would be applicable only if they are using or will be using dry milling technique to produce DDGS.

7.4 Impact of Existing Ethanol Pricing Mechanism:

1. Central Government: While petrol is subject to excise duty, GST is levied on ethanol. While GST would be in the range of Rs. 2.28/litre to Rs. 3.13 per litre of ethanol based on an ex-mill price in the range of Rs. 45.69/litre to Rs. 62.65/litre, excise duty on petrol is Rs. 32.98/litre. Considering total national ethanol blending volumes of 332 crore litre, revenue loss to the central government due to replacement of petrol by ethanol amounts to Rs. 10,950 crore per annum.

2. Oil PSUs: OMCs pass on to the consumers any change in the price of fuel due to blending of ethanol and are therefore not impacted by the pricing of ethanol. At present, excise duty on landed cost of petrol at oil depots is higher than GST on the landed cost of ethanol and the benefit is being passed on to the retail consumers. However, in the future, should the price of ethanol increase beyond that of petrol, consumers may have to pay more for ethanol blended fuel. In such a scenario, tax (GST) breaks on Ethanol may become necessary.

3. Environmental Cost: Sugarcane is a water intensive crop. On an average, one tonne of sugarcane can produce 100 kg of sugar, and 70 litres of ethanol. Cultivation of each kg of sugar requires 1600 to 2000 litres of water. Hence, one litre of ethanol from sugar requires about 2860 litres of water. It is estimated that sugarcane and paddy combined use 70% of irrigation water of the country. Keeping in view the need for water conservation, it is advisable to shift some of the area under sugarcane to less water intensive crops by providing suitable incentives to farmers. The Task Force on sugarcane and sugar Industry constituted under the Chairmanship of Professor Ramesh Chand, Member (Agriculture), NITI Aayog has suggested ways to minimize water consumption through various means to encourage farm diversification.

4. Ethanol production from non-sugar sources: Share of production of ethanol from non-sugar sources like damaged food grains and FCI rice is relatively small. The net returns from sugarcane are much higher than those from food crops; for example, in Karnataka it was about Rs. 1,13,590 per hectare as compared to Rs. 33,877 per hectare from paddy and 22,931 per hectare from maize during FY 2018-19. The situation is similar in other states also. A high price of sugarcane leads to a higher price of sugar and its by-products like molasses, ethanol

5. Environmental impact of choice of feedstock: In the interest of environmental sustainability, making ethanol available on a pan-India basis and sharing the benefits of EBP widely, measures to promote production from non-sugarcane sources, food grains, especially maize and second generation sources may be promoted through suitable pricing mechanisms.

7.5 Indian Economy:

Chart no. 7.2 Petrol Sale (‘000’Metric Tonnes)

Year	Petrol Sale
2008-09	11257.8
2009-10	12818.3
2010-11	14194.4
2011-12	14992.4
2012-13	15743.9
2013-14	17128.3
2014-15	19075.4
2015-16	21846.6
2016-17	23764.9
2017-18	26174.5
2018-19	28284.4
2019-20	29975.5
2020-21	27960.3
2021-22	30848.9
2022-23	34976.0

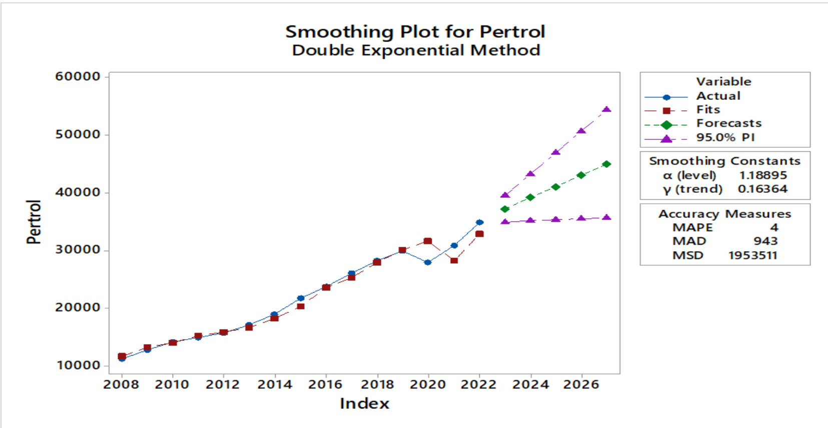
Forecasting and analysis of petrol sale

Petrol sale forecasting:
Double Exponential Smoothing for Petrol

```
Data     Petrol
Length     15


Smoothing Constants

α (level) 1.18895
γ (trend) 0.16364


Accuracy Measures

MAPE         4
MAD        943
MSD    1953511


Forecasts

Period Forecast Lower   Upper
```

```
2023    37305.3 34994.9 39615.6
2024    39233.0 35223.6 43242.4
2025    41160.7 35399.2 46922.2
2026    43088.5 35558.7 50618.3
2027    45016.2 35711.2 54321.2
```

Double Exponential Smoothing Plot for Petrol



Year A	Petrol Sale (MMT) B	Petrol Sale (Cr Litre) B1=B*141.1	Blending (in %) C	Requirement of ethanol For blending in Petrol (Cr Litres)
2020-21	27.9	3936.69	8.5	334.61
2021-22	30.8	4345.88	10	434.58
2022-23	34.9	4924.39	12	590.92
2023-24	37.3	5263.03	15	789.45
2024-25	39.23	5535.353	15	830.30
2025-26	41.16	5807.67	20	1161.53

Conclusion:

- In India need of petrol is very high because of developing country and highly increase rate of population and uses of vehicles.
- That’s why near about 25.1% petrol import by India.
- For current status of blending in India is near about 10.50% need 517 Cr. Liter ethanol.
- Indian Government to set a target of 20% blending in 2025-26 to achieve this target we need 1161.53 Cr. Liter ethanol

Chapter 8: Various Aspects Related with Ethanol

8.1 Engineering Aspects

- The 1990s saw the introduction and operation of variable fuel vehicles. These vehicles are capable of operating on unleaded fuel with ethanol mixtures up to 85 percent without having to make any engine adjustments. These vehicles were introduced in 1992 and have been used extensively in federal and state fleets and in some city governments.
- Chrysler began offering E-85 minivans in the 1998 model year and Ford continues to offer the Taurus and added Windstar and Ranger to the E-85 flexible fuel vehicles in the 1999 model year. Ford, GMC, Chevrolet and Daimler-Chrysler are now offering E-85 variable fuel vehicles.

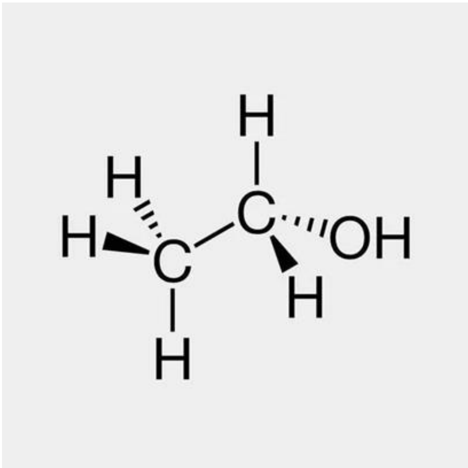
Engine Performance & Ethanol

- Auto manufacturers today are recommending ethanol-blended gasoline for the vehicles they sell. A recent survey revealed that nine out of ten auto dealers use ethanol-blended gasoline in their personal vehicles. Over half of the dealerships surveyed indicated their customers reported benefits that included: reduced knocking and pinging, improved gas mileage, better acceleration, and improved starting qualities.
- A 1997 Iowa survey indicated that nine out of ten technicians used ethanol in their personal vehicles and reported the same benefits as the auto dealers.
- E-10 Unleaded (10% ethanol / 90% gasoline) is approved under the warranties of all domestic and foreign automobile manufacturers marketing vehicles in the United States.
- Ethanol is a good cleaning agent. In newer vehicles it helps keep the engine clean. In older vehicles it can sometimes loosen contaminants and residues that have already been deposited in a vehicle's fuel delivery system. Occasionally, these loosened materials collect in the fuel filter, and can then be removed simply by changing the fuel filter.
- All alcohols have the ability to absorb water. Condensation of water in the fuel system is absorbed and does not have the opportunity to collect and freeze. Since ethanol blends contain at least 10 percent ethanol, they are able to absorb water and eliminate the need for adding a gas-line antifreeze in winter.
- Ethanol is a fuel for old and new engine technology. Automotive engines older than 1969 with non-hardened valve seats may need a lead substitute added to gasoline or ethanol blends to prevent premature valve seat wear. Valve burning is decreased when ethanol blends are used because ethanol burns cooler than ordinary unleaded gasoline. Many high performance racing engines use pure alcohol for that reason.
- Modern computerized vehicles of today, when operating correctly, will perform better than non-computer equipped vehicles. Improved performance is due to the vehicle's computerized fuel system being able to make adjustments with changes in operating conditions or fuel type.

- Some of the chemicals used to manufacture gasoline, such as olefins, have been identified as a cause of deposits on port fuel injectors. Today's gasolines contain detergent additives that are designed to prevent fuel injector and valve deposits.
- The owner/driver should note the octane requirement or Antiknock Index (AKI) number of gasoline required for proper engine performance for the vehicle. Then note the octane number on the sticker on the gas pump to make sure it is not less than the required number. Using a higher octane number will not realize better economy unless engine knock or ping already exists.
- The Nebraska State Highway Patrol has been using ethanol-blended gasoline more than 20 years.

8.2 Chemical Aspects

Ethanol is a colourless, volatile, flammable liquid that is the intoxicating agent in liquors and is also used as a fuel or solvent. Ethanol is also called ethyl alcohol or grain alcohol. Ethanol is the most important member of a large group of organic compounds that are called alcohols. Alcohol is an organic compound that has one or more hydroxyl (OH) groups attached to a carbon atom. Alcohol is shown as: C-O-H or C-OH.



In its pure form, ethanol is a colourless clear liquid with a mild characteristic odour which boils at 78º C (172º F) and freezes at -112º C (-170º F). Ethanol has no basic or acidic properties. Ethanol mixes readily with water and with most organic solvents. It is also useful as a solvent and as an ingredient when making many other substances including perfumes, paints, lacquers, and explosives.

8.3 Agricultural Aspects

Ethanol production in India has a significant impact on agricultural practices, particularly in the cultivation of feedstock crops such as sugarcane, maize, and other biomass sources. The increasing demand for these crops due to ethanol production has led to changes in cropping patterns, farming techniques, and resource allocation. This section explores these impacts, highlighting both the positive and negative consequences for Indian agriculture.

8.3.1 Shifts in Cropping Patterns

The emphasis on ethanol production has incentivized farmers to grow more feedstock crops, particularly sugarcane. This shift can be quantified by examining the increase in acreage dedicated to sugarcane and maize cultivation. According to the Ministry of Agriculture, the area under sugarcane cultivation increased by approximately 8% from 2018 to 2022, reaching around 5.15 million hectares.

Area Under Sugarcane Cultivation (2018-2023)
2018: 4.74 million hectares
2019: 5.06 million hectares
2020: 4.60 million hectares
2021: 4.85 million hectares
2022: 5.15 million hectares
*2023: 5.50 million hectares

8.3.2 Adoption of Improved Farming Techniques

The demand for higher yields to meet ethanol production targets has encouraged the adoption of improved farming techniques and technologies. Farmers are increasingly using high-yield varieties, precision farming methods, and better irrigation practices. For instance, drip irrigation systems, which enhance water use efficiency, have seen a rise in adoption among sugarcane farmers. According to the Indian Council of Agricultural Research (ICAR), the adoption of drip irrigation in sugarcane fields has increased by 15% over the last five years.

8.3.3 Water Resource Management

Sugarcane is a water-intensive crop. A study by the National Academy of Sciences, USA, suggests that expanding biofuel production can lead to intensified water usage. Here are some concerning figures for India:

1) Water Consumption: Sugarcane cultivation requires an estimated 2,500 litters of water per kilogram of sugar produced. This translates to a significant strain on water resources, especially in drought-prone regions.

2) Groundwater Depletion: Excessive reliance on sugarcane cultivation for ethanol production can lead to over-extraction of groundwater, impacting the availability of water for other agricultural activities and drinking purposes.

8.3.4 Potential for Alternative Feedstocks

To mitigate the potential drawbacks associated with sugarcane cultivation, there's a growing interest in exploring alternative feedstocks for ethanol production:

1) Cellulosic Biomass: Agricultural residues like rice straw and bagasse (sugarcane residue) hold promise as sustainable feedstocks with minimal competition for food production. However, cost-effective technologies for converting cellulose to ethanol are still under development.

2) Starch-based Crops: While corn is a popular feedstock for ethanol production globally, its water footprint raises concerns in India. Alternative starch-based crops like cassava or sweet potatoes could be explored with proper research and development.

8.3.5 Economic Benefits to Farmers

The ethanol production boom has provided economic benefits to farmers through higher and more stable income streams. The government's procurement policies and the assured market for ethanol feedstock have reduced price volatility, ensuring better returns for farmers. For example, the Fair and Remunerative Price (FRP) for sugarcane has seen a consistent increase, enhancing the profitability for sugarcane farmers.

The Fair and Remunerative Price (FRP) for sugarcane in India is set by the government to ensure a minimum price that mills must pay to farmers.

Fixed FRP: ₹ 315.10 per quintal (qtl) for sugar factories having recovery of 9.5% or less.

Base FRP: ₹ 340/quintal for a sugar recovery rate of 10.25%.

Additional Points:

This is a historic high, representing an 8% increase compared to the FRP for the 2023-24 sugar season.

The FRP increases by ₹ 3.07/qtl for every 0.1% increase in recovery above 10.25%.

Conversely, the FRP decreases by ₹ 3.07/qtl for every 0.1% decrease in recovery below 10.25%.

Source:

Press Release by the Press Information Bureau, Government of India: Cabinet approves 'Fair and Remunerative Price' (FRP) of sugarcane payable by sugar factories for sugar season 2024-25 (October-September)

8.3.6 Environmental Impact

While ethanol production has economic advantages, it also poses environmental challenges. The intensive cultivation of sugarcane, a water-intensive crop, has exacerbated water scarcity in some regions. Additionally, the increased use of fertilizers and pesticides to boost yields can lead to soil degradation and water pollution. Sustainable agricultural practices are therefore essential to mitigate these negative impacts.

8.3.7 Government Initiatives

To address these issues, the Indian government has implemented several initiatives aimed at promoting sustainable agricultural practices. Programs such as the Pradhan Mantri Krishi Sinchai Yojana (PMKSY) encourage efficient water management practices, while the Soil Health Card Scheme aims to optimize fertilizer use. These initiatives are crucial for balancing the needs of ethanol production with environmental sustainability.

8.4 Environmental Aspects

8.4.1 Potential Benefits

Ethanol production in India offers several potential environmental benefits compared to traditional fossil fuels:

1)Reduced Greenhouse Gas Emissions: Ethanol combustion releases fewer greenhouse gases like carbon dioxide compared to gasoline. Studies suggest a reduction of 44-52% ([source about ethanol emission reduction]). This contributes to mitigating climate change.

2)Improved Air Quality: Ethanol blends in petrol can help reduce harmful emissions like carbon monoxide and hydrocarbons, leading to cleaner air, especially in urban areas.

3)Waste Management: Utilizing agricultural residues like rice straw for ethanol production can provide a sustainable solution for waste management. This reduces open burning of agricultural waste, which contributes to air pollution and respiratory health problems.

8.4.2 Potential Concerns

Despite the potential benefits, there are also environmental concerns associated with ethanol production in India:

1)Land Use Change: Increased demand for sugarcane cultivation for ethanol production could lead to deforestation or conversion of land currently used for food crops. This can disrupt ecosystems and biodiversity.

2)Water Resource Depletion: Sugarcane is a water-intensive crop. Expanding sugarcane cultivation can put a strain on water resources, especially in drought-prone regions. As discussed earlier, sugarcane production requires an estimated 2,500 litters of water per kilogram of sugar produced.

3)Soil Degradation: Intensive monoculture practices associated with large-scale sugarcane cultivation can lead to soil degradation, erosion, and loss of soil fertility.

8.4.3 Mitigating the Environmental Impact

Several strategies can help minimize the environmental impact of ethanol production in India:

1)Promoting Sustainable Practices: Encouraging water-efficient irrigation methods, using recycled wastewater for sugarcane cultivation, and adopting precision agriculture techniques can minimize water usage.

2)Land Use Planning: Implementing zoning regulations and promoting crop rotation can ensure that land is used efficiently, with dedicated areas for food production and others for ethanol feedstock cultivation.

3)Exploring Alternative Feedstocks: Research and development on cellulosic biomass and other sustainable feedstocks like sweet potatoes can reduce reliance on water-intensive sugarcane.

4)Biorefineries: Investing in biorefineries that can utilize various agricultural residues for ethanol production can maximize resource efficiency and minimize waste.

Chapter 9: Industrial Visit

Padmashri Dr. Vitthalrao Vikhe Patil Sahakari Sakhar Karkhana Limited (PDVVPSSKL) is a sugar cooperative factory located in Loni, Ahmednagar, Maharashtra, India. It was founded in 1948 by Vithalrao Vikhe Patil, a renowned Indian industrialist and social worker. The factory is one of the largest in India, with a crushing capacity of 6,500 tonnes per day. It produces a wide range of sugar products, including white sugar, refined sugar, and raw sugar. The factory also has a distillery that produces ethanol.

History

PDVVPSSKL was established in 1948 with the aim of empowering sugarcane farmers in the region. It was the first sugar cooperative factory in India and played a pivotal role in the development of the cooperative movement in the country. The factory has been at the forefront of technological innovation and has adopted several modern techniques to improve its efficiency and productivity.

Products and Services

PDVVPSSKL produces a wide range of sugar products, including:

- White sugar
- Refined sugar
- Raw sugar
- Environmental protection initiatives

Awards and Recognition

PDVVPSSKL has received numerous awards and recognitions for its excellence in operations and social responsibility. Some of the notable awards include:

- National Productivity Award
- Greentech Environment Award
- Social Responsibility Award

Contact Information

Padmashri Dr. Vitthalrao Vikhe Patil Sahakari Sakhar Karkhana Limited Loni, Rahata Ahmednagar, Maharashtra 413712 India

Website:

https://indialei.in/detailed-information/360510/335800PP5ZA84RZYZK63/padmshri-dr-vitthal-rao-vikhe-patil-sahakari-sakhar-karkhana-limited/

Additional Information

- PDVVPSSKL is a member of the Indian Sugar Mills Association (ISMA).
- The factory is accredited with ISO 9001:2015 and ISO 14001:2015 certifications.
- PDVVPSSKL is committed to sustainable development and has adopted several practices to reduce its environmental impact.

Report on Padmashri Dr. Vitthalrao Vikhe Patil Sahakari Sakhar Karkhana Limited (PDVVPSSKL) Ethanol Production Distillery Plant

9.1. Introduction

This report details the visit to Padmashri Dr. Vitthalrao Vikhe Patil Sahakari Sakhar Karkhana Limited (PDVVPSSKL) located in Loni, Ahmednagar, Maharashtra, India. The focus of the visit was on the ethanol production in a distillery plant operated by the cooperative.

Background

PDVVPSSKL was established in 1948 with the aim of empowering sugarcane farmers in the region. It was the first sugar cooperative factory in India and played a pivotal role in the development of the cooperative movement in the country. The factory has been at the forefront of technological innovation and has adopted several modern techniques to improve its efficiency and productivity.

9.2 Purpose of Visit

The purpose of our visit to Padmashri Dr. Vitthalrao Vikhe Patil Sahakari Sakhar Karkhana Limited (PDVVPSSKL) ethanol production distillery plant was to:

- Understanding the process of Ethanol Production at (PDVVPSSKL):

Our visit to the PDVVPSSKL ethanol production plant provided a fascinating look at how biofuel is made. The PDVVPSSKL plant's use of both sugarcane juice and molasses demonstrates its commitment to efficiency and maximizing resource utilization. This approach not only contributes to cleaner energy solutions but also fosters sustainable practices within the sugar industry.

- Gather data on the plant's operations, specifically focusing on ethanol production. This data could include:
    1. Daily, weekly, or monthly ethanol production volumes.
    2. Raw material consumption rates (e.g., sugarcane juice, molasses).
    3. Production efficiency metrics (e.g., yield per unit of raw material).
    4. Information on any byproducts generated during the process.
- Evaluate the effectiveness of the current production processes from a statistical standpoint. This might involve assessing:
    1. Production variability and potential areas for improvement.
    2. The relationship between raw material quality and ethanol yield.
    3. The efficiency of waste management practices.

- Identify opportunities for improvement in the distillery's operations through statistical analysis. This could include:
    1. Recommending strategies to optimize production processes and increase efficiency.
    2. Identifying areas for further data collection to gain deeper insights.
    3. Contributing to the development of quality control procedures based on statistical analysis.

By collecting and analysing data from the distillery plant, my aim to support PDVVPSSKL in optimizing their ethanol production and achieving their operational goals.

9.3 Production Process observed:

PDVVPSSKL plant utilizes sugarcane juice and molasses, here's a breakdown of the likely production process:

1. Feedstock Preparation

- Sugarcane Juice:
    1. The sugarcane stalks are likely crushed to extract the juice.

2. The juice may undergo clarification and filtration to remove impurities like fibers and soil particles. This ensures a cleaner fermentation process.

- Molasses:

Molasses, a byproduct of sugar production, is likely stored in large tanks before being used for ethanol production.

2. Fermentation

- For both sugarcane juice and molasses:
  1. The prepared feedstock (either clarified sugarcane juice or molasses) is mixed with water and nutrients like yeast and ammonium sulphate in large fermentation tanks.
  2. The yeast consumes the sugars present in the feedstock and converts them into ethanol and carbon dioxide through a biological process called fermentation.
  3. The resulting fermented broth is a mixture of ethanol, water, yeast cells, and other byproducts.

3. Distillation

- The fermented broth is then transferred to distillation columns.
- Distillation is a process that separates ethanol from the fermented broth based on their different boiling points.
- The broth is heated, and the ethanol, having a lower boiling point than water, evaporates first.
- The ethanol vapor is then captured and condensed back into liquid form, resulting in a higher concentration of ethanol (around 95%).
- The remaining liquid after distillation, often called stillage, contains water, yeast cells, and other non-volatile components.

5. Dehydration

- The 95% ethanol from distillation still contains some water.
- Depending on the final use, the ethanol might undergo further dehydration to remove residual water and achieve a higher purity.

Products:

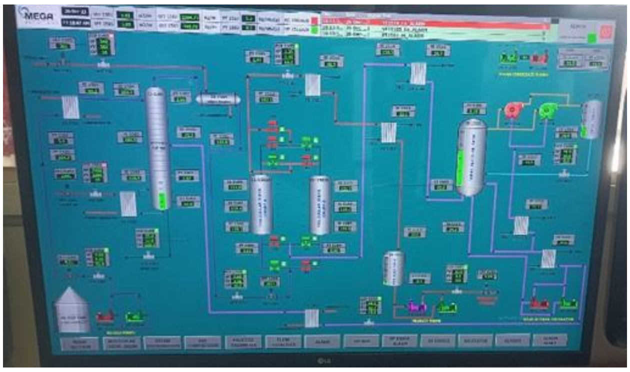
- Rectified Spirit: This is a high-purity ethanol product (around 95% alcohol by volume) used for industrial applications or further purification.
- Anhydrous Ethanol: This is nearly pure ethanol (around 99.5% or higher) used as a biofuel or blended with gasoline.

9.4 Observations at the PDVVPSSKL Ethanol Plant.

- Our visit to the PDVVPSSKL ethanol plant was an eye-opening experience that showcased the large-scale conversion of agricultural resources into biofuel.
- The sheer size of the operation was impressive, with vast tanks for storing molasses and a network of pipes transporting materials between different stages.
- The level of automation was evident throughout the process. We observed automated systems likely controlling tasks like feedstock metering, fermentation temperature regulation, and distillation processes. This automation suggested a focus on efficiency and consistency in production.
- An interesting aspect we learned about was the plant's utilization of dual feedstock. The ability to process both sugarcane juice and molasses allows for flexibility and

potentially reduces dependence on a single raw material source. This approach also struck us as a sustainable practice, maximizing resource utilization within the sugar industry.

Some Photos:



A distillery plant specifically designed for ethanol production utilizes various raw materials to create alcohol through fermentation and distillation processes. Here's a breakdown of key aspects:

Raw Materials:

This is a common option, where sugarcane juice or molasses (a byproduct of sugar production) is fermented to produce ethanol.

Data Collection Potential: Given our expertise in statistics, a key takeaway from the PDVVPSSKL visit is the immense potential for data analysis to optimize their operations. The distillery likely maintains a wealth of production data encompassing various aspects like:

1. **Feedstock quality**: Sugarcane juice quality parameters like sugar content, brix levels, and impurities.

2. **Fermentation efficiency**: Data on yeast strain performance, fermentation duration, and ethanol yield.
3. **Distillation parameters**: Information on temperature, pressure, and ethanol purity at each distillation stage.
4. **Energy consumption**: Records of energy usage throughout the production process.

By employing statistical methods like:

1. **Regression analysis**: We could identify key factors influencing ethanol yield and optimize them for maximum production.
2. **Time series analysis**: Analysing trends in production data can help predict potential bottlenecks and proactively address them.
3. **Control charts**: Statistical process control can monitor critical parameters in real-time, ensuring consistent quality and minimizing production variability.

Implementing such statistical techniques could significantly enhance the PDVVPSSKL's production efficiency, reduce costs, and potentially identify areas for further research and development.

Significance of Ethanol Production Plants in Renewable Energy and Fuel Blending

Distillery plants that produce ethanol play a crucial role in promoting renewable energy and fuel blending.

Anton Paar Snap 51

The Anton Paar Snap 51 is a portable alcohol meter designed for determining the alcohol concentration in distilled spirits, which are typically binary mixtures of ethanol and water.

The Anton Paar Snap 51 is known for providing alcohol content readings quickly and accurately. In some contexts, especially in the brewing industry, it may also display outputs in terms of specific gravity (SG) or related units such as degrees Plato (°P).

Here’s how the process works in terms of specific gravity:

1. Sample Measurement: A small volume of the liquid sample (beer, wine, or spirits) is introduced to the device.

2. Ultrasound and Density Measurement: The Snap 51 uses ultrasound technology to measure the speed of sound in the liquid. This measurement, in combination with the density of the liquid, provides crucial information about the liquid’s composition.

3. Calculation of Specific Gravity: The device calculates specific gravity based on the data collected from the ultrasound measurement and the density of the liquid. Specific gravity

is the ratio of the density of the liquid compared to the density of water at a specific temperature.
4. Display of Results: The calculated specific gravity value is displayed on the device's screen.
5. Conversion: Depending on the user's preferences or the industry's standards, the specific gravity can be converted to other units such as degrees Plato (°P) or alcohol by volume (ABV).

9.5 Conclusion

Key Takeaways from the PDVVPSSKL Distillery Visit

- The PDVVPSSKL Ethanol Plant is a large facility located in Loni, Rahata, Ahmednagar, Maharashtra with a production capacity of 230 KLPD.
- The plant uses sugarcane juice and molasses as the primary raw material for ethanol production.
- The plant has a large-scale operation with a high production capacity, considering its location in a major sugarcane producing area.
- An interesting aspect of the process it was a high level of automation in the process, with minimal human intervention for better efficiency and safety.
- we also learned about whole ethanol production process steps include like Feedstock Preparation, Fermentation, Distillation, Dehydration, etc.

9.6 Recommendations

Recommendations and Areas for Exploration (Statistician's Perspective)

1. **Data Collection and Analysis:**

- **Production Efficiency**: Recommend implementing a system for collecting detailed production data, including daily/weekly ethanol yield, raw material consumption rates, and fermentation times. Statistical analysis of this data can help identify areas for improvement in terms of yield optimization and process consistency.
- **Quality Control**: Explore the potential for statistical process control (SPC) techniques to monitor key parameters throughout the production process (e.g., fermentation temperature, ethanol concentration). This can help ensure consistent product quality and minimize deviations.
- **Waste Management**: If data on waste generation and disposal is available, statistical analysis can help identify opportunities for waste reduction or exploring alternative uses for byproducts like distiller's grains.

2. Predictive Modelling:

Develop statistical models to predict ethanol yield based on various factors like feedstock quality, fermentation conditions, and yeast strain used. This can be a valuable tool for optimizing production processes and maximizing output.

3. Advanced Analytics:

Explore the potential for implementing advanced statistical techniques like machine learning to analyse complex datasets and identify hidden patterns within the production process. This could lead to further insights for process optimization and potential breakthroughs.

- On basis of following table we check the percentage of moisture in alcohol And verify the purity of ethanol

Sr. No.	Specific Gravity	A/c % v/v/	Moisture%
1	0.7941	99.9	0.1
2	0.7942	99.88	0.12
3	0.7943	99.86	0.14
4	0.7944	99.84	0.16
5	0.7945	99.82	0.18
6	0.7946	99.8	0.2
7	0.7947	99.78	0.22
8	0.7948	99.76	0.24
9	0.7949	99.74	0.26
10	0.795	99.72	0.28
11	0.7951	99.7	0.3
12	0.7952	99.68	0.32
13	0.7953	99.66	0.34
14	0.7954	99.64	0.36
15	0.7955	99.62	0.38
16	0.7956	99.6	0.4

Overall Conclusion:

- The production of feedstock used for ethanol production is increasing every year.
- The demand of ethanol increasing day to day.
- The USA and Brazil both are the major producers of ethanol as they produce about 80% of ethanol production because of the large amount of feedstock is available.
- The forecasted values of the production of sugarcane and molasses in 2025-26 are 45.5 MMT and 17 MMT respectively. On the basis of this result we conclude that the feedstock is readily available.
- The demand of petrol is incresing day by day. The forcasted demand of the petrol sale in 2025-26 is 41.16 MMT. The petrol is non renewable sources.In future less stock available of petrol so need to increse production of ethanol.
- Indian Government set a target in 2025-26 to blending 20% ethanol in petrol.
- To achieve 20% target in blending we need 1161.53 Cr Liter ethanol.
- To achieve 20% target, we have to increase the number of projects on the basis of grain and increase its capacities.
- India is the largest producer of sugar after fulfilment of our need we will export 6.8 million tons of sugar .This sugar production is minimizes and those remaining sugarcne is use for ethanol production this help to increse production of ethanol.
- In India presently only 1% rice is available for ethanol production. After fulfilment of our need India export 20% rice. We should restrict rice export upto 15% .
- India exported about 3.453 MMT of maize annually. We can use that maize for ethanol production more beneficial than export.
- Blending of ethanol in petrol affects on Indian economy. It's save large scale of foreign currency.To achieve 20% target required 1161.53 Cr liter ethanol. We can save near about 4.0 billion dollars.
- Increase ethanol production in our country is also beneficial for farmers.

APPENDIX 1

(R-code for Sugarcane Production)

```
library(tseries)   #For time series analysis
library(forecast)  #For forecasting
# Assuming your sugarcane production data, Molasses Production , Maize Production
,Rice Production
Sugarcane_data=read.csv("C:\\Desktop\\Avishkar\\devenpr.csv")
View(Sugarcane_data)
m_production=Sugarcane_data$production
time_series=ts(m_production)#frequency = 12
plot(time_series,main="Time series Plot")
arima_model=auto.arima(time_series)
arima_model
#Forecast using ARIMA Model
arima_forecast=forecast(arima_model,h=5) # h =number of future periods a forecast
arima_forecast
# Calculate forecast accuracy
accuracy(arima_forecast)
#Plot forecast
plot(arima_forecast,main="ARIMA Production Forecast")
```

APPENDIX 2

(R-code for Molasses Production)

Molasses production

```
library(tseries)   #For time series analysis
library(forecast)  #For forecasting
# Assuming your Molasses Production
Sugarcane_data=read.csv("C:\\Desktop\\Avishkar\\devenpr.csv")
View(Sugarcane_data)
m_production=Sugarcane_data$molasses
time_series=ts(m_production)#frequency = 12
plot(time_series,main="Time series Plot")
arima_model=auto.arima(time_series)
arima_model
#Forecast using ARIMA Model
arima_forecast=forecast(arima_model,h=5)  # h =number of future periods a
forecast
arima_forecast
# Calculate forecast accuracy
accuracy(arima_forecast)
#Plot forecast
plot(arima_forecast,main="ARIMA Production Forecast")
```

APPENDIX 3

Rcode: sugar production

```
library(tseries)   #For time series analysis
library(forecast)  #For forecasting
Sugarcane_data=read.csv("C:\\Desktop\\Avishkar\\devenpr.csv")
View(Sugarcane_data)
sugar_production=Sugarcane_data$Total..sugar..produced....000..tonnes
time_series=ts(sugar_production)#frequency = 12
plot(time_series,main="Time series Plot")
arima_model=auto.arima(time_series)
arima_model
#Forecast using ARIMA Model
arima_forecast=forecast(arima_model,h=5) # h =number of future periods a forecast
arima_forecast
# Calculate forecast accuracy
accuracy(arima_forecast)
#Plot forecast
plot(arima_forecast,main="ARIMA Production Forecast")
```

References:

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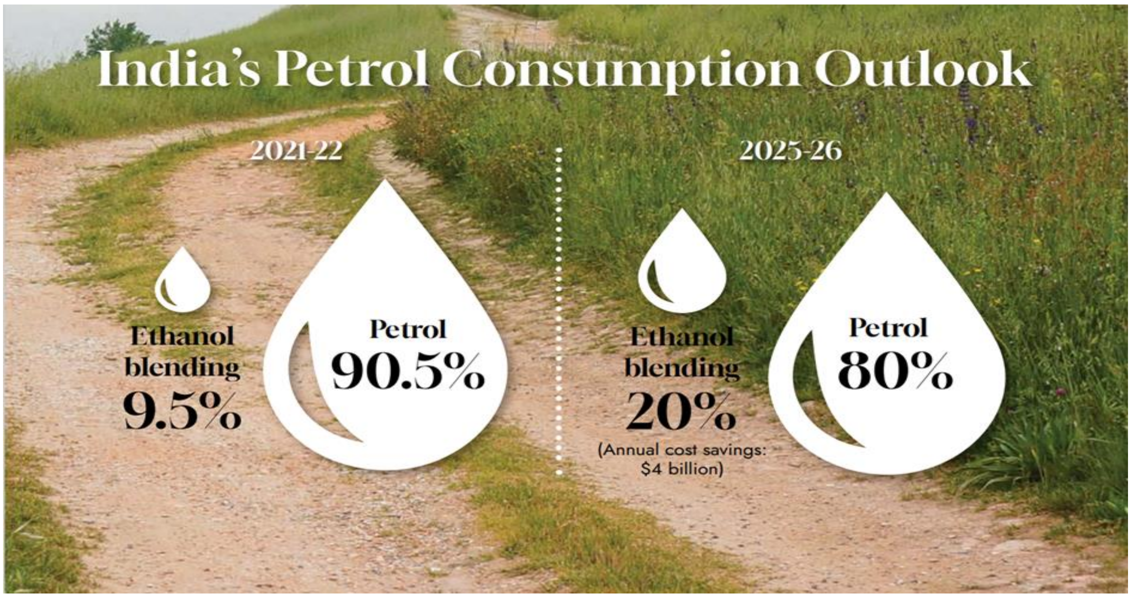
- https://consumeraffairs.nic.in

  https://www.niti.gov.in
- https://iimr.icar.gov.in
- https://agriwelfare.gov.in


India's Petrol Consumption Outlook
2021-22
Ethanol blending 9.5%
Petrol 90.5%
2025-26
Ethanol blending 20%
(Annual cost savings: $4 billion)
Petrol 80%