

Economic and Environmental Impact of Sugarcane-Based Ethanol in India

Dr. Sangashetty Shetkar

Associate Professor

Department of Commerce

Govt. First Grade College Naubad Bidar, India

Abstract — The growing demand for energy and increasing environmental concerns have led India to explore alternative and sustainable fuel sources. Ethanol produced from sugarcane has emerged as a significant solution to reduce dependence on fossil fuels and enhance energy security. This study examines the economic and environmental impact of sugarcane-based ethanol in India. The research highlights how ethanol blending in petrol contributes to substantial foreign exchange savings by reducing crude oil imports. It also supports the agricultural sector by ensuring stable demand and better income for sugarcane farmers, thereby strengthening rural livelihoods. From an environmental perspective, ethanol is a cleaner fuel that helps in reducing greenhouse gas emissions and air pollution. The study also discusses challenges such as water consumption, infrastructure limitations, and policy constraints. Despite these challenges, sugarcane-based ethanol presents a promising pathway toward sustainable development and a greener economy. The paper concludes that with appropriate policy support and technological advancements, ethanol production can play a crucial role in India's economic growth and environmental protection.

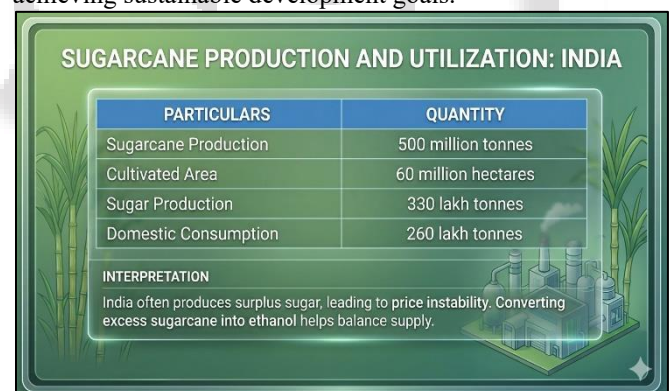
Keywords: Agriculture, Ethanol; India, Sustainability, Sugarcane

I. INTRODUCTION

India's rapid economic growth and expanding population have significantly increased the demand for energy in recent decades. As one of the world's largest consumers of petroleum products, the country depends heavily on imported crude oil to meet its energy needs. This dependence exposes the Indian economy to global oil price fluctuations, geopolitical uncertainties, and a substantial outflow of foreign exchange. At the same time, rising environmental concerns, including air pollution and climate change, have created an urgent need to shift towards cleaner and more sustainable sources of energy. In this context, the development and promotion of alternative fuels have become a key priority for policymakers. Among various renewable energy options, ethanol has emerged as a promising and viable alternative to conventional fossil fuels. Ethanol is a biofuel that can be produced from agricultural feedstocks such as sugarcane, molasses, and grains. In India, sugarcane serves as the primary raw material for ethanol production due to its widespread cultivation and high sugar content. The integration of ethanol into the energy mix, particularly through ethanol blending in petrol, has gained significant attention as an effective strategy to reduce dependence on imported fuels while simultaneously addressing environmental challenges.

The Government of India has taken several initiatives to promote ethanol blending under its Ethanol Blending Programme (EBP). The achievement of 20 percent ethanol blending (E20) marks a significant milestone in the

country's transition towards cleaner fuels. This initiative not only contributes to energy security but also generates multiple economic benefits. One of the most notable advantages is the reduction in foreign exchange expenditure on crude oil imports. By substituting a portion of petrol consumption with domestically produced ethanol, India can conserve valuable foreign exchange and improve its trade balance. In addition to its economic advantages, sugarcane-based ethanol plays a crucial role in supporting the agricultural sector. Sugarcane is an important cash crop cultivated by millions of farmers across the country. The demand for ethanol provides an additional revenue stream for sugar mills and ensures timely payments to farmers, thereby enhancing their income stability and improving rural livelihoods. Furthermore, ethanol production helps in managing surplus sugar production, which often leads to price volatility and financial stress in the sugar industry. From an environmental perspective, ethanol is considered a cleaner and greener fuel compared to traditional fossil fuels. Its use in transportation significantly reduces greenhouse gas emissions and lowers the release of harmful pollutants, contributing to improved air quality. This aligns with India's commitments towards reducing carbon emissions and achieving sustainable development goals.



Source: Compiled from news paper

However, despite its numerous benefits, the expansion of ethanol production faces several challenges. Issues such as high-water consumption in sugarcane cultivation, inadequate infrastructure for ethanol production and distribution, and regulatory constraints need to be addressed. Therefore, a balanced and strategic approach is essential to maximize the potential of sugarcane-based ethanol.

II. REVIEW OF LITERATURE

Mohanty and Mishra (2017) examined the role of ethanol in transforming traditional energy consumption patterns in India. Their study highlighted that ethanol blending improves fuel efficiency and reduces dependence on fossil fuels. The authors emphasized that ethanol can play a significant role in achieving energy security in the long run. They also

concluded that the adoption of ethanol contributes to sustainable development by promoting cleaner energy alternatives. Singh (2018) analyzed the economic implications of ethanol production from sugarcane in India. The study found that ethanol production provides an additional revenue stream for sugar mills, thereby improving their financial stability. It also helps in stabilizing sugar prices by reducing surplus production in the market. Furthermore, the research indicated that increased demand for sugarcane benefits farmers through better price realization and timely payments.

Kumar and Sharma (2019) focused on the environmental advantages of biofuels, particularly ethanol. Their study concluded that ethanol blending significantly reduces greenhouse gas emissions compared to conventional fuels. It also lowers air pollutants, contributing to improved air quality in urban areas. The authors highlighted ethanol as a sustainable and eco-friendly alternative to fossil fuels. Patel (2019) studied the operational and infrastructural challenges faced by the ethanol industry in India. The research identified inadequate storage facilities and transportation issues as major constraints. It also pointed out inconsistencies in government policies that hinder smooth production and distribution. The study suggested the need for improved infrastructure and policy support to enhance ethanol adoption.

The International Energy Agency (2020) provided insights into global ethanol production trends and policies. The report highlighted that countries like Brazil and the USA have successfully implemented large-scale ethanol blending programs. It emphasized the importance of strong policy frameworks and infrastructure development. The findings suggest that India can learn from these countries to strengthen its ethanol sector. The Government of India (2020) report on the Ethanol Blending Programme outlined strategies to increase ethanol usage in fuel. It emphasized reducing dependence on imported crude oil and improving energy security. The report also highlighted the economic benefits, including foreign exchange savings. It encouraged investments in ethanol production and infrastructure development. Reddy and Reddy (2021) examined the impact of ethanol production on rural development in India. Their study found that ethanol production generates employment opportunities in rural areas. It also strengthens the agricultural sector by increasing demand for sugarcane. The authors concluded that ethanol production contributes significantly to rural economic growth and livelihood improvement.

Food and Agriculture Organization (2021) report discussed the importance of sugarcane as a primary feedstock for biofuel production. It highlighted the efficiency of sugarcane in producing ethanol compared to other crops. However, the report also raised concerns about high water consumption in sugarcane cultivation. It stressed the need for sustainable farming practices to ensure long-term viability. Sharma (2022) analyzed policy-related challenges in ethanol production in India. The study identified regulatory barriers and pricing issues as major obstacles. It emphasized the need for a stable and supportive policy environment. The research suggested reforms to simplify procedures and encourage private sector participation in ethanol production. The Economic Survey of India (2023) highlighted the progress

made in ethanol blending in the country. It emphasized the economic benefits, particularly in reducing crude oil imports and saving foreign exchange. The survey also noted improvements in ethanol production capacity. It concluded that ethanol blending is a key component of India's energy strategy. The Ministry of Petroleum and Natural Gas (2023) provided updated data on ethanol production and blending levels. The report indicated that India has achieved 20% ethanol blending in petrol. It highlighted the role of ethanol in reducing environmental pollution. The ministry emphasized further expansion of ethanol infrastructure and production capacity.

The International Energy Agency (2024) emphasized the growing importance of biofuels in the global energy transition. The report noted that ethanol demand is increasing worldwide due to environmental concerns. It highlighted India's potential to become a major ethanol producer. The study recommended policy support and technological advancements to fully utilize this potential.

III. OBJECTIVES OF THE STUDY.

- 1) To study the role of sugarcane in ethanol production in India.
- 2) To examine the economic and environmental impact of ethanol.
- 3) To identify challenges and suggest improvements in ethanol production.

A. Sugarcane in ethanol production

Sugarcane occupies a central position in ethanol production in India due to its abundance, high sucrose content, and well-established processing infrastructure. India is among the largest producers of sugarcane globally, with annual production of around 500 million tonnes. This large-scale availability makes sugarcane a reliable and continuous source for ethanol production. Ethanol is primarily produced from sugarcane through its by-products such as molasses, as well as directly from sugarcane juice and syrup. The fermentation of these materials followed by distillation results in ethanol, which is then used as a biofuel. The integration of sugarcane with ethanol production, has significantly transformed the structure of the sugar industry in India. Traditionally, sugar mills depended solely on sugar production, which often led to surplus output and price fluctuations in the market. By diverting excess sugarcane and molasses towards ethanol production, mills can maintain a balance between supply and demand. This diversification reduces the financial stress on sugar mills and ensures more stable revenue streams. It also improves liquidity, enabling mills to make timely payments to farmers, which has historically been a major issue in the sector.

Table 2: Ethanol Production and Capacity

Particulars	Quantity
Current Production	2,000 crore litres
Potential Production	7,000 crore litres
Distilleries	380 units
Blending Level	20%

Interpretation
India has significant untapped potential in ethanol production, which can be utilized with improved infrastructure.

Source: Compiled from news paper

Sugarcane-based ethanol is also a key component of India's energy policy, particularly under the Ethanol Blending Programme (EBP). The government has set targets for blending ethanol with petrol to reduce dependence on imported crude oil. Sugarcane plays a major role in achieving these targets, contributing significantly to the current 20% blending level. By increasing ethanol production from sugarcane, India can enhance its energy security, reduce foreign exchange expenditure, and protect itself from global oil price volatility. In addition to economic benefits, sugarcane-based ethanol supports rural development. The increased demand for sugarcane encourages farmers to expand cultivation and adopt better farming practices. It provides them with a stable market and improved income opportunities. Furthermore, ethanol production units and distilleries generate employment in rural areas, contributing to overall socio-economic development.

Country-wise Ethanol Use in Vehicles (Brazil, USA, and India)

COUNTRY	ETHANOL VEHICLES / BLENDING
Brazil	100% Ethanol Vehicles / E100
USA	High Blending from Corn / E85
India	20% Blending (Target) / E20

Inference: India can learn from Brazil's advanced ethanol ecosystem.

Source: Compiled from news paper

However, the role of sugarcane in ethanol production also brings certain challenges. Sugarcane is a water-intensive crop, and its large-scale cultivation can put pressure on water resources, especially in drought-prone regions. There are also concerns about over-dependence on a single crop for ethanol production. Therefore, while sugarcane remains a crucial feedstock, there is a need to adopt sustainable agricultural practices and explore alternative raw materials. Overall, sugarcane serves as the backbone of ethanol production in India, linking agriculture, industry, and energy sectors. Its effective utilization not only strengthens the economy but also contributes to environmental sustainability and energy independence.

B. Economic and Environmental Impact of Ethanol

Ethanol has emerged as a significant alternative fuel in India, offering both economic and environmental benefits. From an economic perspective, one of the most important advantages

of ethanol is its ability to reduce the country's dependence on imported crude oil. India imports a large portion of its petroleum requirements, which leads to a substantial outflow of foreign exchange. By blending ethanol with petrol under the Ethanol Blending Programme (EBP), the government can reduce fuel imports and save a considerable amount of foreign exchange. Estimates suggest that ethanol blending contributes to savings of thousands of crores annually, thereby improving the country's balance of payments and strengthening the economy.

Environmental Impact

Table 3: Environmental Benefits of Ethanol

Aspect	Impact
Carbon Emissions:	Reduced
Air Pollution:	Lower
Sustainability:	High
Renewable Source:	Yes

Analysis: Ethanol contributes to cleaner air and supports India's climate goals.

Source: Compiled from news paper

Another major economic benefit of ethanol production is its positive impact on the agricultural sector, particularly sugarcane farmers. Ethanol production increases the demand for sugarcane and its by-products such as molasses, ensuring better price realization for farmers. It also helps in reducing the problem of delayed payments by sugar mills, which has been a persistent issue in India. Additionally, ethanol production provides an alternative revenue stream for sugar mills, improving their financial stability and reducing their dependence on sugar sales alone. This diversification supports the overall growth of the agro-based industry.

Ethanol production also contributes to employment generation, especially in rural areas. The establishment of distilleries and related industries creates job opportunities and promotes regional development. It encourages investment in infrastructure, transportation, and storage facilities, thereby stimulating economic activity in rural and semi-urban regions. From an environmental perspective, ethanol is considered a cleaner and more sustainable fuel compared to conventional fossil fuels. It burns more efficiently and produces fewer greenhouse gas emissions, which helps in mitigating climate change. The use of ethanol-blended fuel reduces carbon monoxide, hydrocarbons, and other harmful pollutants, leading to improved air quality. This is particularly important in urban areas where vehicular emissions are a major source of pollution.

Furthermore, ethanol is a renewable source of energy as it is derived from agricultural crops. Unlike fossil fuels, which are finite and depleting, ethanol can be produced continuously through agricultural processes. This makes it an environmentally sustainable option in the long term. However, there are certain environmental concerns associated with ethanol production, such as high-water consumption in sugarcane cultivation and the potential impact on land use. Ethanol plays a dual role by promoting economic growth and environmental sustainability. While it offers numerous benefits, a balanced approach is necessary to address its challenges and ensure its long-term viability in India's energy framework.

C. Challenges in Ethanol Production in India

- High water consumption in sugarcane cultivation. Sugarcane requires a large amount of water, which puts pressure on water resources. This raises concerns about sustainability in water-scarce regions.
- Inadequate infrastructure for ethanol production and storage India lacks sufficient distilleries, storage, and distribution facilities. This limits large-scale ethanol production and supply.
- Limited number of distilleries in some regions Ethanol production units is unevenly distributed across the country. Some regions face shortages due to lack of processing units.
- Policy and regulatory restrictions affecting production Complex rules and approvals slow down ethanol production. Policy uncertainties also discourage private investment.
- Fluctuating availability of raw materials (sugarcane, molasses) Production depends on agricultural output, which varies due to climate conditions. This affects consistent ethanol supply.
- Delay in payments to sugarcane farmers Sugar mills often delay payments due to financial issues. This affects farmers' income and motivation to grow sugarcane.
- High production cost compared to fossil fuels Ethanol production involves high processing and operational costs. This makes it less competitive without government support.
- Lack of ethanol-compatible vehicles Many vehicles are not designed to run on high ethanol blends. This limits the demand and usage of ethanol fuel.
- Logistics and transportation issues Transporting ethanol requires proper infrastructure and safety measures. Poor logistics can delay supply and increase costs.
- Dependence on sugar industry performance Ethanol production is linked to sugar industry output. Any crisis in the sugar sector directly affects ethanol supply.
- Environmental concerns related to intensive farming Excessive use of fertilizers and water harms soil and environment. Sustainable farming practices are needed.
- Limited awareness and adoption among consumers Many consumers are unaware of ethanol benefits. This slows down its acceptance and usage in the market.

IV. FINDINGS OF THE STUDY

- 1) Sugarcane is the primary raw material for ethanol production in India. Sugarcane is widely available and has high sugar content, making it ideal for ethanol production. It serves as the backbone of India's ethanol industry.
- 2) Ethanol production has significantly increased in recent years. Government initiatives and policy support has boosted ethanol production. This growth reflects the increasing focus on alternative fuels.
- 3) The Ethanol Blending Programme has achieved up to 20% blending. India has successfully reached the E20 target in petrol blending. This marks a major milestone in reducing fossil fuel dependence.

- 4) Ethanol blending has reduced dependence on crude oil imports. By replacing a portion of petrol with ethanol, India imports less crude oil. This enhances energy security.
- 5) Significant foreign exchange savings have been achieved. Reduced oil imports help save large amounts of foreign currency. This strengthens the country's economy.
- 6) Ethanol production provides additional income for sugar mills. Sugar mills earn revenue not only from sugar but also from ethanol. This improves their financial stability.
- 7) It helps manage surplus sugar production. Excess sugarcane is diverted to ethanol production. This prevents oversupply and stabilizes sugar prices.
- 8) Sugarcane farmers benefit from increased demand. Higher demand for sugarcane ensures better prices and timely payments. This improves farmers' income and livelihood.
- 9) Ethanol production supports rural development. It creates employment opportunities in rural areas. It also promotes agro-based industries.
- 10) Ethanol reduces greenhouse gas emissions. Ethanol is a cleaner fuel compared to petrol. It helps in reducing environmental pollution.
- 11) Ethanol is a renewable energy source. It is produced from agricultural crops, making it sustainable. Unlike fossil fuels, it does not deplete over time.
- 12) High water consumption is a major concern. Sugarcane cultivation requires large amounts of water. This raises sustainability issues in water-scarce areas.
- 13) Lack of infrastructure limits production capacity. Insufficient distilleries and storage facilities hinder expansion. This affects large-scale ethanol supply.
- 14) Policy and regulatory challenges slow growth. Complex rules and approvals delay ethanol production. This discourages investment in the sector.
- 15) Limited ethanol-compatible vehicles affect adoption. Many vehicles cannot use high ethanol blends. This restricts widespread usage of ethanol fuel.

V. SUGGESTIONS.

- 1) Remote water-efficient farming techniques Farmers should adopt drip irrigation and modern methods to reduce water usage. This will make sugarcane cultivation more sustainable.
- 2) Expand ethanol production infrastructure the government should encourage setting up more distilleries and storage facilities. This will increase production capacity and ensure smooth supply.
- 3) Simplify policy and regulatory procedures Approval processes should be made faster and more transparent. This will attract private investment in ethanol production.
- 4) Encourage ethanol-compatible vehicles Automobile companies should manufacture flexible fuel vehicles (FFVs). This will increase the use of higher ethanol blends.
- 5) Increase ethanol blending targets gradually the government should aim beyond 20% blending in a

- phased manner. This will further reduce dependence on fossil fuels.
- 6) Ensure timely payment to farmers Strong policies should be implemented to avoid delays in payments. This will improve farmer confidence and income stability.
 - 7) Promote alternative raw materials for ethanol Crops like maize and agricultural waste should also be used. This will reduce over-dependence on sugarcane.
 - 8) Provide financial support and subsidies Government incentives should be given to ethanol producers and sugar mills. This will reduce production costs and boost the industry.
 - 9) Improve logistics and transportation systems Better transport and storage facilities should be developed. This will ensure efficient distribution of ethanol.
 - 10) Create awareness among consumers Public awareness campaigns should be conducted on ethanol benefits. This will increase acceptance and usage.
 - 11) Encourage research and technological innovation Investment in R&D will improve production efficiency. It will also help develop eco-friendly and cost-effective technologies.
 - 12) Strengthen coordination between sectors Better coordination between agriculture, industry, and energy sectors are needed. This will ensure balanced and sustainable growth of ethanol production.

VI. CONCLUSION

The study concludes that sugarcane-based ethanol has emerged as a vital component in achieving India's energy security, economic development, and environmental sustainability. The experience of Brazil provides a strong model, where sugarcane is efficiently utilized by allocating a portion for domestic sugar consumption and diverting the surplus toward large-scale ethanol production. This integrated approach has enabled Brazil to successfully promote the use of ethanol as a major transport fuel. Moreover, Brazil's focus on manufacturing 100% ethanol-compatible and flexible fuel vehicles has significantly increased ethanol adoption. Drawing lessons from this, India can strengthen its ethanol ecosystem by balancing sugar and ethanol production, expanding infrastructure, and encouraging ethanol-compatible vehicles. While challenges such as water usage, policy gaps, and infrastructure limitations persist, strategic reforms and technological advancements can address these issues. Overall, with a planned and sustainable approach, India can replicate Brazil's success and move towards a cleaner, self-reliant, and eco-friendly energy future driven by ethanol.

REFERENCES

- [1] Solomon, B. D., Barnes, J. R., & Halvorsen, K. E. (2007). Grain and cellulosic ethanol: History, economics, and energy policy. *Biomass and Bioenergy*, 31(6), 416–425.
- [2] Zapata, C., & Nieuwenhuis, P. (2009). Driving on liquid sunshine: The Brazilian biofuel experience. *Business Strategy and the Environment*, 18(8), 528–541.
- [3] International Energy Agency. (2008). National biofuel policy: Ethanol blending policy (EBP), India.

- [4] FAO. (2008). Biofuel development in Brazil: Sugarcane ethanol program.
- [5] Government of India. (2013). National policy on biofuels. Ministry of New and Renewable Energy.
- [6] Kumar, S., et al. (2018). Indian scenario of ethanol fuel and its utilization in automotive transportation sector. *Resources, Conservation and Recycling*, 132, 102–120.
- [7] Kumar, G. (2021). Ethanol blending program in India: An economic assessment. *Energy Sources, Part B: Economics, Planning, and Policy*.
- [8] NITI Aayog. (2021). Roadmap for ethanol blending in India 2020–25. Government of India.
- [9] Ministry of Petroleum and Natural Gas. (2022). Ethanol blending programme in India: Progress and achievements. Government of India.
- [10] International Energy Agency. (2023). India's ethanol blending policy and energy transition.
- [11] Tyner, W. E. (2023). Global ethanol policy and economic implications.
- [12] Curcio, E. (2025). Accelerating transportation decarbonization: The strategic role of ethanol blends and regulatory incentives.
- [13] Reuters. (2025). India allows production of ethanol from sugarcane juice and molasses.
- [14] Reuters. (2025). India achieves 20% ethanol blending target under national policy.
- [15] Reuters. (2026). Brazil plans to increase ethanol blending in gasoline to 32%.