BIOFUEL INDUSTRY

The Economics of India's Biofuel Transition: Business Opportunities, Investment Risks and Energy Market Disruption

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Abstract

India's biofuel transition has moved from a policy ambition to a significant industrial and energy-market development. The expansion of the Ethanol Blended Petrol (EBP) Programme has stimulated investment in distillation capacity, widened the range of eligible feedstocks and created new commercial relationships among agricultural producers, sugar mills, grain processors, ethanol manufacturers and oil marketing companies. This paper examines the economics of that transition, focusing on business opportunities, investment risks and its potential implications for India's energy market. It adopts a descriptive and comparative narrative-review approach based on government publications, industry reports and peer-reviewed research available up to November 2026. Official data indicate that average ethanol blending rose from 5.0% in ESY 2018–19 to 19.24% in ESY 2024–25, while installed production capacity reached approximately 1,953 crore litres as of 31 October 2025. The programme has supported investment, improved market access for domestic producers and contributed to crude-oil substitution and foreign-exchange savings. However, the next phase raises questions about capacity utilisation, feedstock-price volatility, competition between food and fuel uses, water and land pressures, technology costs and the durability of policy-supported demand. The analysis finds that ethanol can strengthen energy diversification and rural industrial activity, but commercial sustainability requires a balanced feedstock portfolio, predictable procurement arrangements, efficient logistics, credible lifecycle assessment and gradual development of advanced biofuels. The paper concludes that India's biofuel transition should be evaluated not only by blending percentages, but also by financial resilience, resource efficiency and the value created across the agricultural and energy supply chains.

1 Introduction

India's energy system faces a combination of rising transport-fuel demand, exposure to international crude-oil prices and the need to reduce the environmental intensity of economic growth. Petroleum products remain central to road transport, while a substantial share of crude oil requirements is met through imports. This creates economic exposure to global price movements, foreign-exchange requirements and geopolitical disruptions. Biofuels, particularly ethanol blended with petrol, have therefore become part of India's strategy to diversify transport energy and develop domestic agricultural and industrial value chains.

The Ethanol Blended Petrol (EBP) Programme has been the principal instrument for scaling fuel ethanol. Its progress has been supported by administered procurement prices, expanded feedstock eligibility, interest-subvention support, tax measures and purchase arrangements between oil marketing companies (OMCs) and ethanol producers. The 20% blending objective, originally associ-

ated with a 2030 horizon, was advanced to Ethanol Supply Year (ESY) 2025–26. Government reporting indicates that average blending reached 19.24% in ESY 2024–25 and 20% during the reported November 2025–June 2026 period.

The rapid expansion has changed the commercial structure of the sector. Ethanol is no longer only a by-product or secondary outlet for sugar mills. It has become a planned industrial product supported by dedicated distilleries, grain-based production, feedstock procurement systems, storage and transport infrastructure, and long-term demand from OMCs. This transition creates opportunities for agricultural suppliers, plant developers, engineering firms, logistics providers, financiers and energy companies.

At the same time, achieving a blending target does not automatically establish long-term commercial viability. A sector with expanding capacity can face underutilisation if procurement volumes, feedstock supply or pricing conditions change. Feedstock diversification can reduce dependence on a single crop but may create competition for maize, rice and other agricultural commodities. Water use, land allocation, food security and lifecycle emissions also affect whether ethanol delivers wider economic and environmental benefits.

This paper therefore examines the biofuel transition as a business and economic transformation rather than only a fuel-blending programme. It considers how policy creates market demand, how producers respond through investment, what risks affect project returns, and how ethanol may reshape relationships among agriculture, manufacturing and the petroleum industry.

2 Literature review and analytical framework

2.1 Ethanol blending as an energy and industrial policy instrument

Research on India's ethanol programme identifies energy security, crude-oil substitution, agricultural income and industrial development as interconnected policy objectives. A system-dynamics study of the EBP Programme highlights the interaction between feedstock supply, ethanol production, competing industrial demand, policy incentives and environmental outcomes. It argues that long-term performance depends on coordinating both the supply and demand sides of the ethanol value chain.

Government policy has helped reduce investment uncertainty by creating a large, structured buyer base through OMC procurement. The policy framework has included administered prices for different feedstocks, interest-subvention schemes, long-term offtake arrangements for dedicated ethanol plants and an expansion of eligible raw materials. These measures have supported capacity creation, although they also mean that project economics are influenced by policy decisions as well as market forces.

2.2 Feedstock economics and the food-versus-fuel question

The economics of ethanol production depend heavily on the price, availability and conversion efficiency of feedstocks. First-generation ethanol in India is produced mainly from sugarcane-based materials and food grains such as maize and rice. The use of multiple feedstocks can improve supply flexibility, but each feedstock has a different cost structure, seasonality, yield, logistics requirement and opportunity cost.

Saini and Hussain examine whether India's agricultural feedstock base can support the E20 target and highlight potential constraints involving land, water, climate and competing nutritional requirements. The Economic Survey 2025–26 also notes that the expansion of grain-based ethanol, particularly maize, can influence agricultural incentives and crop choices. These findings suggest that ethanol procurement prices can affect not only distillery economics but also broader agricultural markets.

The food-versus-fuel debate should not be treated as a simple binary. The relevant question is whether feedstock is surplus, damaged, residual or otherwise available without creating excessive pressure on food supply, farm prices, land and water. A diversified strategy must therefore evaluate the full resource cost of each feedstock.

2.3 Investment economics and production technology

Ethanol plants require substantial fixed investment in land, process equipment, utilities, storage, effluent treatment, safety systems and logistics. First-generation facilities generally use established fermentation technologies and may benefit from integration with sugar mills or grain-processing operations. Dedicated grain-based plants can operate independently of sugar production but are exposed to grain-price movements and procurement competition.

Second-generation (2G) ethanol uses lignocellulosic biomass such as agricultural residues. It offers the possibility of converting non-food materials into fuel and may create additional value from residues that are otherwise underused or burned. However, commercialisation is constrained by higher capital and operating costs, biomass aggregation, pretreatment complexity, process reliability and the need for continuous feedstock supply. Reviews of 2G ethanol in India identify supply-chain organisation and the gap between pilot-scale and commercial-scale performance as important barriers

2.4 Environmental and resource implications

Ethanol is renewable in origin, but its environmental performance depends on how it is produced. Land-use change, irrigation, fertiliser use, processing energy, transport and co-product management all influence lifecycle outcomes. assess the environmental implications of ethanol blending in India and emphasise the importance of feedstock and production pathways. More recent modelling research also identifies potential trade-offs involving land, water, nitrogen emissions and food prices under alternative feedstock scenarios.

The literature therefore cautions against treating the renewable label as proof of sustainability. Commercial decisions increasingly need to consider lifecycle emissions, water intensity, residue availability and traceability alongside the purchase price of ethanol.

2.5 Research gap and analytical framework

Existing research examines blending policy, feedstock availability, environmental outcomes and production technologies, but these dimensions are often considered separately. This paper brings them together through a business-economics framework linking five elements: (1) policy-created demand and procurement; (2) feedstock availability and price; (3) capital investment and plant utilisation; (4) supply-chain and technology performance; and (5) wider energy-market and resource outcomes. The framework is intended as an integrative review, not as a new econometric model.

2.6 Research questions

The review is guided by four questions:

1. How has India's ethanol blending programme created new business opportunities and investment activity across the agricultural and energy value chains?
2. Which feedstock, production, financing and policy factors most strongly influence the commercial viability of ethanol projects?
3. What economic, environmental and supply-chain risks could constrain the long-term expansion of India's biofuel industry?
4. How could ethanol expansion reshape India's petroleum market and contribute to energy security and industrial diversification?

3 Methodology

This study adopts a descriptive and comparative narrative-review design based on secondary information. The principal sources include publications of the Government of India, the Department of Food and Public Distribution, the Ministry of Petroleum and Natural Gas, the Economic Survey 2025–26, the International Energy Agency's Advanced Motor Fuels programme, the United States Department of Agriculture Foreign Agricultural Service, and peer-reviewed research on ethanol economics, feedstock availability and environmental impacts.

Sources were selected for their relevance to the Indian ethanol market, blending progress, production capacity, policy instruments, feedstock economics, investment requirements and sustainability. The analysis uses qualitative thematic synthesis and descriptive comparison. It does not include primary interviews, company-level audited financial modelling or a plant-by-plant assessment of project returns.

Ethanol Supply Year (ESY) figures are reported using the period and definition stated by the source. Where official sources report different dates or scopes, the reference date is stated rather than combining the figures into a single series. Capacity figures represent installed or reported capacity and should not be interpreted as actual production or utilisation. Projections and estimates from industry reports are identified as such.

The study's limitations include differences in reporting periods, limited public disclosure of plant-level cost data, changing feedstock policies and uncertainty about future procurement volumes and prices. The findings should therefore be interpreted as a structured assessment of the available evidence, not as an independent forecast of ethanol demand or investment returns.

4 The economics of India's ethanol market

4.1 Growth of blending and production capacity

India's ethanol blending performance has increased substantially over the past decade. DFPD reports that average blending rose from 1.53% in ESY 2013–14 to 19.24% in ESY 2024–25. The same source reports ethanol production capacity of approximately 1,953 crore litres as of 31 October 2025, comprising about 980 crore litres of grain-based capacity and 973 crore litres of molasses- or dual-feed-based capacity.

The expansion reflects a combination of demand assurance and investment response. Procurement by OMCs provides a structured market for fuel ethanol, while policy support has encouraged existing sugar mills to add distillery capacity and new grain-based facilities to enter the sector. Government reporting states that ethanol sales generated more than ₹1.29 lakh crore in revenue for sugar mills over 2014–15 to 2024–25 and that investment opportunities exceeding ₹42,000 crore emerged during the period (Ministry of Heavy Industries, 2026). These are reported programme-level figures and should not be interpreted as the return earned by every individual investor.

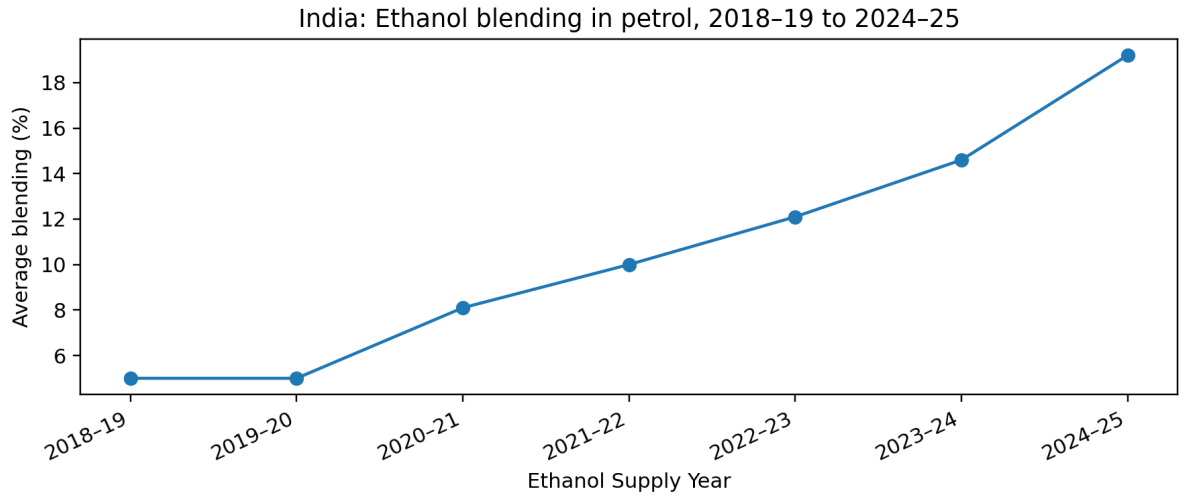

Figure 1. Average ethanol blending in petrol, ESY 2018–19 to ESY 2024–25.

4.2 Revenue models and business opportunities

The ethanol value chain creates opportunities across several business segments. Sugar mills can diversify revenue beyond sugar sales by processing molasses, B-heavy molasses or sugarcane juice into ethanol, subject to prevailing policy and feedstock availability. Grain processors and independent distillers can develop plants based on maize, damaged grains and other permitted materials. Engineering and technology firms can supply fermentation, distillation, dehydration, boiler, effluent-treatment and automation systems. Logistics companies can provide feedstock aggregation, storage, tank transport and finished-product movement.

For integrated sugar mills, ethanol can improve the utilisation of existing industrial assets and provide an alternative outlet for sugarcane-derived inputs. For standalone grain-based plants, the business model depends more directly on grain procurement, conversion yields, by-product revenue, plant utilisation and access to OMC tenders. In both cases, the difference between feedstock cost and realised ethanol price is central to gross operating economics.

Additional opportunities may emerge in 2G ethanol, biomass aggregation, enzyme and process technology, residue logistics and waste-to-value services. However, these opportunities require a longer investment horizon and should not be assumed to offer immediate profitability.

4.3 Procurement prices, demand assurance and market structure

The Indian ethanol market is shaped by a distinctive relationship between public policy and commercial demand. OMC procurement, administered pricing and long-term offtake arrangements have helped reduce demand uncertainty for producers. This structure can support financing because lenders and investors may have greater visibility over the buyer base than in a fully merchant market.

However, administered procurement does not remove business risk. Producers remain exposed to feedstock price changes, seasonal availability, transport costs, plant breakdowns, working-capital requirements, quality standards and changes in procurement allocations. If capacity expands faster than offtake or if the feedstock mix becomes uneconomic, plants may operate below nameplate capacity. A project should therefore be evaluated using realistic utilisation assumptions rather than installed capacity alone.

5 Business opportunities and investment risks

5.1 Investment opportunities

- **Distillery expansion and modernisation:** existing sugar mills can add or upgrade distillation assets and improve integration between sugar processing, ethanol production and co-generation.
- **Grain-based ethanol:** dedicated plants can diversify supply beyond sugarcane-linked feedstocks, although their economics are sensitive to grain prices and procurement availability.
- **Engineering and industrial services:** plant design, process equipment, automation, storage, quality testing and maintenance services can benefit from capacity additions.
- **Agricultural logistics:** collection, drying, storage and transport of maize, rice-based feedstocks and biomass residues create opportunities for specialised supply-chain operators.
- **Advanced biofuels:** 2G ethanol and other waste-based pathways may create long-term opportunities if technology, feedstock aggregation and offtake economics become commercially reliable.
- **Financial and digital services:** project finance, working-capital facilities, commodity risk management, traceability and plant-performance monitoring can support sector development.

5.2 Key investment risks

- **Feedstock price and availability risk.** Feedstock is a major variable cost. A rise in maize, rice or sugarcane-derived input prices can compress margins if procurement prices do not adjust correspondingly. Seasonal variation and competition from food, feed and other industrial uses can also affect supply.
- **Policy and offtake risk.** Ethanol project returns depend partly on administered prices, eligibility rules, procurement allocations and blending policy. A change in policy, tender terms or the pace of future blending could alter revenue expectations. The Government stated in July 2026 that no decision had been taken to raise the nationwide base blending level beyond E20; higher blends would require further technical studies and stakeholder consultation.
- **Capacity utilisation risk.** Rapid capacity expansion can create the possibility of underutilised plants if supply, procurement and logistics are not aligned. Investors should distinguish nameplate capacity from actual production and contracted offtake.
- **Technology and execution risk.** 2G plants face process-integration challenges, higher capital intensity and uncertain commercial operating performance. Delays, lower-than-expected yields and biomass supply interruptions can materially affect project economics.
- **Environmental and social risk.** Water stress, land-use pressure, fertiliser use, air emissions and food-price effects can weaken the sustainability case. These risks may also lead to regulatory, reputational and financing challenges.

- **Financing and working-capital risk.** Ethanol plants require capital expenditure and continuous funding for feedstock procurement, inventories, utilities and receivables. Interest rates, debt servicing and payment cycles influence project viability, particularly for smaller or less integrated producers.

5.3 First-generation and second-generation ethanol

Table 1. Comparison of first-generation and second-generation ethanol.

Dimension	First-generation (1G) ethanol	Second-generation (2G) ethanol
Typical feedstock	Sugarcane juice, molasses, maize and permitted grains	Agricultural residues and other lignocellulosic biomass
Technology maturity	Established commercial fermentation and distillation	More complex pretreatment and conversion processes
Investment profile	Generally lower technology and process risk; costs vary by plant and feedstock	Higher capital and operating complexity; commercial scale-up risk
Supply-chain challenge	Commodity price, seasonality and competition with food/feed uses	Biomass aggregation, storage, moisture, transport and seasonal availability
Strategic opportunity	Near- to medium-term supply expansion	Longer-term residue utilisation and potential diversification away from food crops
Main commercial test	Feedstock-to-ethanol margin and plant utilisation	Reliable conversion yields, biomass logistics and competitive production cost

The comparison indicates that 1G ethanol is currently central to near-term scale, while 2G ethanol may offer a longer-term pathway to diversify feedstocks. The two routes should be treated as complementary rather than interchangeable. A commercially credible 2G strategy requires dependable biomass contracts, aggregation infrastructure, proven process performance and offtake terms that recognise higher initial costs.

6 Energy market disruption and global comparison

6.1 Implications for India's petroleum market

Ethanol blending changes the composition of petrol supplied to consumers and creates a domestic industrial input into the transport-fuel market. Higher blending can displace a portion of petroleum-derived petrol demand, diversify supply sources and reduce exposure to crude imports. The Economic Survey 2025–26 reports that, as of August 2025, ethanol blending had saved more than ₹1.44 lakh crore in foreign exchange and substituted approximately 245 lakh metric tonnes of crude oil. These are cumulative programme estimates, not annual savings or guaranteed future outcomes.

For OMCs, ethanol introduces additional procurement, storage, blending, quality-control and distribution requirements. For refineries and fuel retailers, the transition requires planning around blend specifications, terminal infrastructure, seasonal supply and vehicle compatibility. Ethanol is therefore more likely to reshape the petroleum value chain progressively than to displace conventional fuels immediately.

The scale of disruption will depend on future blending policy, vehicle technology, fuel demand growth, the relative price of ethanol and petrol components, and the development of flex-fuel

vehicles. E20 achievement should not be interpreted as an automatic mandate for E25 or higher blends. The Government's July 2026 clarification explicitly stated that no decision had been taken to increase the nationwide base blend beyond 20%.

6.2 International comparison: India and Brazil

Brazil provides a useful comparison because it has developed a mature ethanol ecosystem over several decades. Its model includes sugarcane-based ethanol production, a long-established fuel-blending framework and a large fleet of flex-fuel vehicles. The International Energy Agency's Advanced Motor Fuels programme reports that Brazil's mandatory ethanol blend in regular gasoline increased to 30% from 1 August 2025, with higher levels subject to technical viability.

India's programme has expanded rapidly through OMC procurement and a growing mix of sugar- and grain-based feedstocks. However, India's agricultural structure, vehicle fleet, regional water availability and food-security priorities differ from Brazil's. The Brazilian model is therefore a source of policy and industrial lessons, not a template that can be copied without adjustment.

Table 2. Comparison of the ethanol programmes of India and Brazil.

Dimension	India	Brazil
Policy pathway	Rapid scale-up through EBP procurement and administered pricing	Long-standing bioethanol programme with established domestic fuel market
Feedstock base	Sugar-derived inputs and growing grain-based contribution	Predominantly sugarcane, with expanding maize ethanol
Vehicle ecosystem	E20 rollout; higher blends require further technical and policy decisions	Large flex-fuel vehicle fleet and established use of hydrous ethanol
Key opportunity	Energy diversification, rural industrial investment and domestic supply chains	Integrated sugar-energy model and mature ethanol distribution
Key constraint	Feedstock competition, resource pressures, capacity utilisation and policy dependence	Exposure to agricultural cycles, sugar-ethanol price trade-offs and market conditions

7 Policy framework and strategic priorities

India's biofuel framework combines the National Policy on Biofuels, the EBP Programme, feedstock permissions, administered procurement prices, interest-subvention measures and support for advanced biofuel projects. Policy support has been central to the creation of a large domestic ethanol market. The next phase should focus on improving the quality and resilience of the market rather than measuring success only through higher blending targets.

7.1 Improve feedstock diversification and resource efficiency

Policy should encourage a balanced feedstock portfolio that considers price, availability, food and feed competition, water intensity and lifecycle emissions. Procurement incentives should be periodically reviewed against agricultural conditions and should avoid creating excessive price signals that distort crop allocation. Regional planning can help align distillery locations with sustainable feedstock availability and transport economics.

7.2 Strengthen commercial discipline in project finance

Project appraisal should use realistic assumptions for feedstock costs, plant utilisation, conversion yields, power and water requirements, working capital, debt servicing and offtake. Lenders should stress-test projects against lower procurement volumes, adverse feedstock prices and changes in policy support. Long-term offtake arrangements can reduce uncertainty, but should not substitute for operational efficiency.

7.3 Build reliable biomass supply chains for 2G ethanol

Advanced biofuel projects require organised biomass collection, baling, aggregation, storage, quality control and transport. Partnerships among farmers, cooperatives, local enterprises, technology providers and project developers can reduce supply interruptions. Demonstration projects should be evaluated on actual operating performance and cost per litre, not only announced capacity.

7.4 Strengthen sustainability measurement

A credible biofuel strategy should publish transparent indicators covering feedstock origin, water consumption, energy use, lifecycle greenhouse-gas emissions, co-products and land-use effects. Sustainability standards can help investors distinguish between projects with genuine resource-efficiency benefits and projects that simply shift environmental burdens upstream.

7.5 Coordinate energy, agriculture and transport policy

Ethanol policy affects more than the petroleum sector. It influences crop choices, food and feed markets, rural employment, water use, vehicle compatibility and fuel distribution. Coordination among ministries, state governments, OMCs, agricultural institutions, producers and automobile manufacturers is therefore essential. Stable and clearly communicated policy signals can improve investment planning while preserving the ability to respond to food-security and resource constraints.

8 Discussion and managerial implications

The evidence suggests that India's ethanol transition has created a policy-supported industrial market with meaningful opportunities for producers and allied businesses. Its commercial logic is strongest where feedstock is available at competitive cost, plants achieve high utilisation, conversion yields are reliable and OMC procurement is predictable. Integrated sugar mills may benefit from asset sharing and multiple revenue streams, while grain-based producers may gain from geographic flexibility and a broader raw-material base.

However, rapid capacity expansion also raises the risk of a mismatch between installed capacity and economically viable demand. Management teams should avoid treating blending targets as a substitute for project-level feasibility. Investment decisions need sensitivity analysis across feedstock prices, procurement prices, plant utilisation, interest rates, logistics costs and policy scenarios.

The transition also creates strategic opportunities outside ethanol production itself. Agricultural aggregators, engineering companies, storage operators, transport providers, testing laboratories and financial institutions can participate in the wider ecosystem. Businesses that provide reliable feedstock traceability, process efficiency and supply-chain coordination may capture value even without owning distillery assets.

For policymakers, the central managerial challenge is balancing scale with resilience. A successful biofuel market should deliver dependable fuel supply and investment returns without imposing disproportionate costs on food systems, water resources or public finances. The next phase should therefore prioritise productivity, resource efficiency and transparent market information.

9 Limitations and future research

This paper relies on secondary information and does not conduct primary interviews with ethanol producers, farmers, OMCs, lenders or technology suppliers. It does not estimate plant-level internal rates of return, net present value, break-even feedstock prices or lifecycle emissions for individual production pathways. Publicly available capacity figures may not reflect actual production or utilisation, and policy announcements may differ from realised commercial outcomes.

Future research could undertake: (1) a comparative financial analysis of sugar-based and grain-based ethanol plants; (2) a state-level assessment of feedstock availability, water stress and logistics costs; (3) a project-finance model for 1G and 2G facilities; (4) interviews with OMCs, distillery operators and agricultural suppliers; and (5) a lifecycle assessment comparing ethanol pathways with conventional petrol under Indian conditions. Research could also examine how E20 affects fuel retailing, vehicle operating costs and consumer behaviour.

10 Conclusion

India's biofuel transition has developed into a significant intersection of energy policy, agriculture, manufacturing and investment. The EBP Programme has expanded ethanol blending, stimulated distillery capacity and created new revenue opportunities across the sugar, grain-processing, engineering and logistics sectors. It has also contributed to crude-oil substitution and foreign-exchange savings, according to government estimates.

Nevertheless, the long-term economics of the sector cannot be judged by blending percentages or installed capacity alone. Feedstock availability and cost, plant utilisation, procurement arrangements, capital intensity, technology performance and environmental resource constraints will determine whether investments remain commercially viable. The expansion of grain-based ethanol creates flexibility but requires careful management of food and feed markets. Second-generation ethanol offers a potential route to agricultural-residue utilisation, but its commercial scale-up depends on technology maturity and reliable biomass supply chains.

The central conclusion is that ethanol can become a durable component of India's energy economy if policy support evolves from rapid capacity creation towards market efficiency, feedstock sustainability and financially disciplined investment. A resilient biofuel industry will require coordination across agriculture, energy, transport and finance, supported by transparent data and credible environmental assessment. India's next challenge is therefore not simply to blend more ethanol, but to build a competitive and sustainable biofuel value chain.

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