Funded by the European Union

This activity is part of the European Union Climate Dialogues (EUCDs) project

CSTEP

TOWARDS THE *Long-Term Sustainability of Ethanol Use in India*

Center for Study of Science, Technology and Policy (CSTEP) is a private, not-for-profit (Section 25) research organisation registered in 2005.

Edited and Designed by CSTEP

Disclaimer

While every effort has been made for the correctness of data/information used in this policy brief, neither the authors nor CSTEP accepts any legal liability for the accuracy or inferences of the material contained in it and for any consequences arising from the use of this material.

Contributors: Kaveri Ashok, Ramya Natarajan

Editor: Reghu Ram R

Designer: Pooja Senthil

This policy brief should be cited as: CSTEP. 2024. *Towards the long-term sustainability of ethanol use in India. (CSTEP-PB-2024-05)*

December 2024

Center for Study of Science, Technology and Policy

Bengaluru	**Noida**
18, 10th Cross, Mayura Street Papanna Layout, Nagashettyhalli RMV II Stage, Bengaluru 560094 Karnataka (India)	1st Floor, Tower-A Smartworks Corporate Park Sector 125, Noida 201303 Uttar Pradesh (India)

Tel.: +91 (80) 6690 2500
Email: cpe@cstep.in

Introduction

It is well established that to achieve net-zero emissions, decarbonising the transport sector is crucial. In 2022, road transport contributed to around 12% of India's energy-related CO2 emissions. The contribution is expected to double by 2050 (IEA, 2023). To decarbonise the sector, India is targeting a 20% ethanol blending rate (E20) by 2025 (NITI Aayog, 2021), which also aims to reduce crude oil imports, boost farmer income, and manage surplus sugar.

However, recent studies, particularly in the United States where maize is the source of ethanol production, have revealed that the biofuel blending policy, known as the Renewable Fuel Standard (RFS), carries more disadvantages than advantages. One research effort (Lark et al., 2022) observed that the RFS programme contributed to rising prices of maize and other crops, resulting in increased farming activity, greater fertiliser usage, emissions from land-use changes, and an overall spike in the carbon intensity of maize-based ethanol production. A separate study (Chen et al., 2021) corroborated these findings, determining that the mandatory blending of ethanol caused a net increase in costs in the United States, encompassing both economic and environmental ramifications when compared to a hypothetical scenario without the mandate.

Such an exhaustive study for India does not exist. Examining the broader effects of India's ethanol blending policy is, therefore, crucial, considering its impacts on groundwater, land use, food security, and emissions. Further, there is no long-term policy on ethanol use in India yet. The Center for Study of Science, Technology and Policy (CSTEP) aims to fill this critical research and policy gap through the study *Decarbonising India's Transport Sector: Navigating Trade-offs of Biofuel Use and Electrification* (CSTEP, 2024). We adopted a nexus approach through system dynamics modelling using the Sustainable Alternative Futures for India (SAFARI)[1] model (Ashok et al., 2021; CSTEP, 2021, 2022, 2023; Kumar et al., 2021) to develop scenarios illustrating the consequences of sustaining ethanol blending practices in India until 2070. After analysing these scenarios, we proceeded to outline a roadmap aimed at ensuring the long-term sustainable use of ethanol in India.

1 The transport module in SAFARI, driven by GDP and population, projects the demand for petrol and ethanol and, subsequently, emissions. The agriculture module—driven by population, food security goals, and ethanol demand—projects the land, water, energy, and emissions implications under different scenarios.It is a dynamic model where all sectors of the economy are modelled and interact with each other, competing for the same resources.

Scenarios

No Policy
A counterfactual scenario where the National Policy on Biofuels 2018 does not exist and blending rates remain 0% until 2070.

E20 via 50/50 Maize–Sugarcane (E20 50–50)
This scenario achieves and maintains E20, with half of the ethanol demand met by maize and the other half by sugarcane, as outlined in the policy roadmap (NITI Aayog, 2021).

E20 via 50–50 With High Yield Maize (E20 50–50 HYM)
This scenario is similar to the previous one except that the average yield of maize is assumed to increase to 8.5 tonnes/hectare by 2070 (in contrast to reaching 5 tonnes/hectare by 2070 in the previous scenario). The current yield of maize (India average) is 3 tonnes/hectare.

E20 via Sugarcane Alone (E20 100–SC)
A hypothetical scenario where all ethanol demand for E20 is met by sugarcane, continuing the current practice.

E10 Continuation
A scenario where the E10 blending rate is maintained until 2070 without any increase from the current average blending.

Key Insights

Rising ethanol demand to maintain E20, if met partly by maize (50%–50%), will require an additional ~8 million hectares (Mha) of land, leading to the uptake of fallow land and increased conversion of forest land into agricultural land unless there is a drastic improvement in maize yields. If met by sugarcane (100%), it would lead to an additional ~3.5 Mha of land being brought under sugarcane cultivation, in turn leading to excessive water withdrawals in India's drought-prone regions, up to 60 billion cubic metres more annually. Instead, sustaining the E10 blend offers fewer trade-offs while retaining the benefits of ethanol blending. E10 can be supported by the existing sugarcane cultivation for sugar production and used in current vehicles without infrastructure or design changes.

The following section elaborates further on these insights.

» Because of the rising petrol demand, despite the expected increase in electric vehicle (EV) uptake, maintaining the E20 target leads to an increase in demand for fuel ethanol: 10 billion litres by 2025, 12 billion litres by 2030, and 20 billion litres by 2050.

» The rising demand corresponds to a considerable amount of additional land requirement (compared to a No Policy scenario):

  - In E20 50–50, where half the demand is met via sugarcane and the other half by maize, ~8 Mha of additional land needs to be brought under maize cultivation (Figure 1). The existing area under sugarcane cultivation is adequate to meet the remaining demand.
  - If there is a drastic increase in maize yield—8.5 t/ha by 2070—the additional land requirement is lower (~3.6 Mha) and only until 2050, as shown in Figure 1.
  - In E20 100–SC, where all the demand is met via sugarcane, ~3.5 Mha of additional land will have to come under sugarcane cultivation (Figure 2). No increase in maize cultivation is needed.

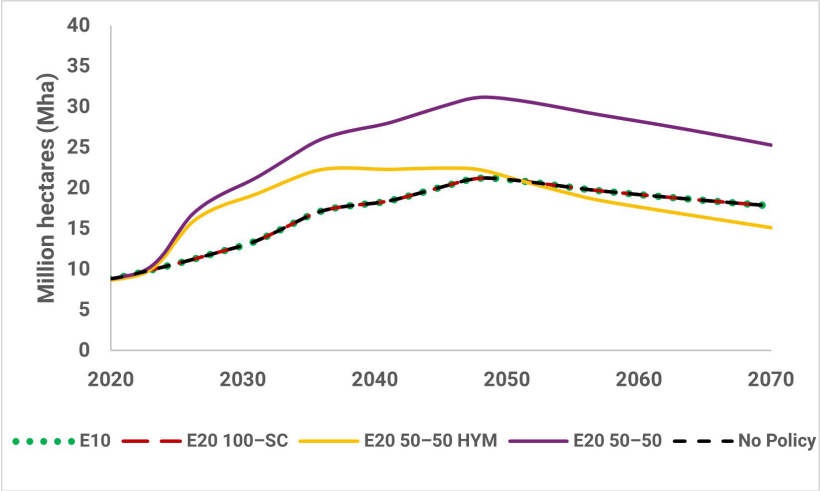

Figure 1: Area under maize cultivation

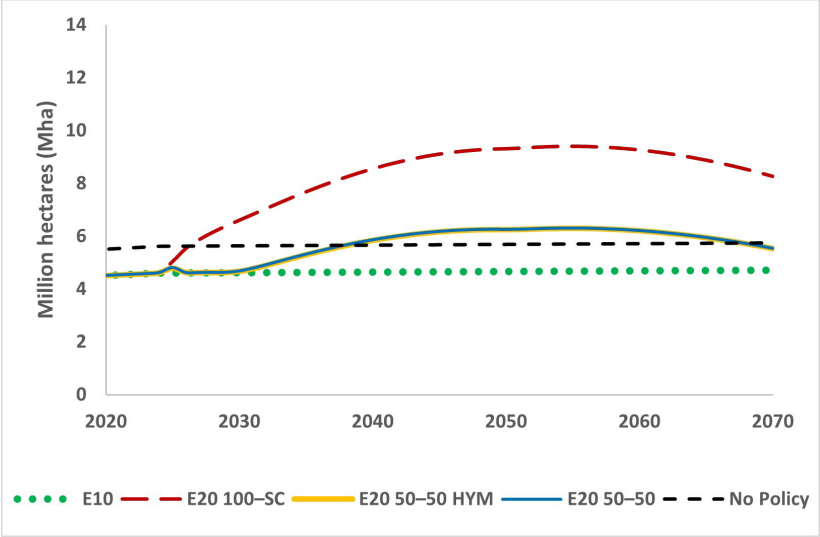

Figure 2: Area under sugarcane cultivation

» Because of the increased land footprint of E20, fallow land will run out by around 2044, particularly in scenarios where maize is used as feedstock. This would lead to an increase in land conversion, particularly from forests for agricultural expansion in the coming decades.

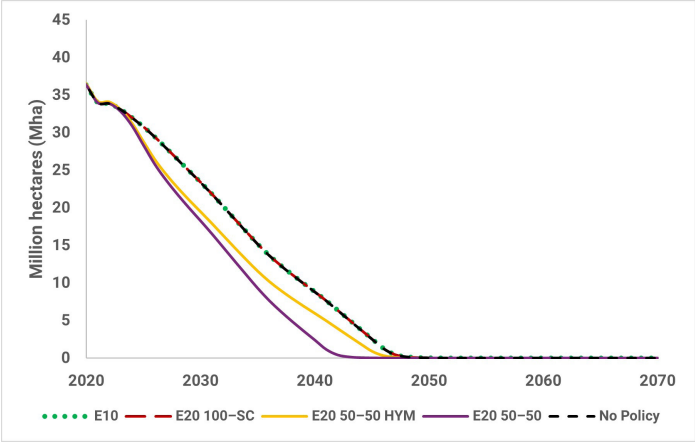

Figure 3: Fallow land (net remaining arable land available for cultivation)

» Maintaining E20 also has a high water footprint when compared to No Policy or E10.

- In E20 50–50, annual average total irrigation water demand will increase by around 30–50 billion cubic metres (BCM) by 2070 (Figure 4).
- In E20 100–SC, total annual irrigation water demand will increase by up to 60 BCM.

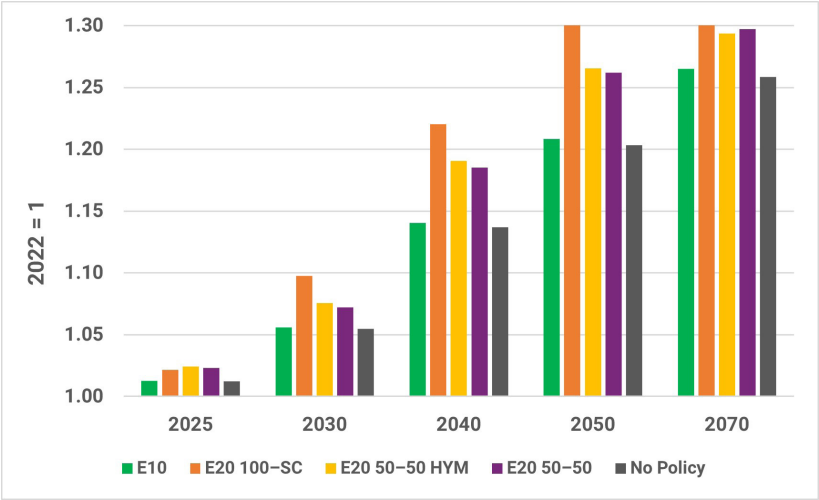

Figure 4: Increase in agriculture water demand compared to 2022 levels

» The High Yield Maize scenario (E20 50–50 HYM) has a relatively lower land and water footprint; however, when the yield increases substantially, India will have to decide between using more of the crop for ethanol versus improving livestock feed (whose actual demand is often underestimated now), which is discussed in detail in the CSTEP report (CSTEP, 2024).

Recommendations

» Limiting ethanol blending to E10 is a more prudent strategy given the long-term land and water implications of E20.

» As EVs become more prevalent and petrol demand decreases, surplus ethanol can be redirected towards producing alcohol-to-jet fuel. Preliminary estimates suggest this could meet up to 15% of aviation fuel demands by 2050.

Roadmap for the Long-Term Use of Ethanol in India

2024

Maintaining E10

- Cap sugarcane cultivation at existing levels (<=5Mha)
- Ramp up ethanol supply to 6 billion litres by 2030 by increasing the share of B-molasses and sugarcane juice as feedstock
- Existing vehicles are already compatible with E10 and no extra crop cultivation needed

2030

E10 + EV Focus

- Promote EV uptake for new purchases, as cost parity is achieved
- Sustain E10 for existing vehicles at 6 to 8 billion litres
- Less drain on groundwater and competition for land (compared to E20)

2040

Ethanol to Jet Fuel

- High EV penetration (almost 100% of new vehicles sales)
- Remaining petrol vehicles continue to use E10
- Ethanol surplus conversion to jet fuel (alcohol to jet) can meet almost 15% of jet fuel demand by 2050

2050 and beyond

Funded by the European Union

This activity is part of the European Union Climate Dialogues (EUCDs) project

CSTEP

Benefits

Existing vehicles and infrastructure can handle E10 without modifications.

E10 avoids additional stress on land and water resources, sidestepping the food versus feed versus fuel dilemma. This is particularly important as we expand land-intensive power sources, increase urbanisation, and strive to achieve forestry goals.

Surplus ethanol can be used to produce aviation fuel, benefiting a sector that is difficult to decarbonise.

Since India has not yet announced a long-term ethanol policy, maintaining E10 would not require significant changes to long-term policy commitments.

References

Ashok, K., Natarajan, R., Kumar, P., Sharma, K., & Mathur, M. (2021). Sustainable alternative futures for agriculture in India—The energy, emissions, and resource implications. *Environmental Research Letters, 16*(6), 064001. https://doi.org/10.1088/1748-9326/abf0cd

Chen, L., Debnath, D., Zhong, J., Ferin, K., VanLoocke, A., & Khanna, M. (2021). The economic and environmental costs and benefits of the renewable fuel standard. *Environmental Research Letters, 16*(3), 034021. https://doi.org/10.1088/1748-9326/abd7af

CSTEP. (2024). *Decarbonising India's transport sector: Navigating trade-offs of biofuel use and electrification.* https://cstep.in/publications-details.php?id=3055

CSTEP. (2021). *Energy and emissions implications for a desired quality of life in India via SAFARI - Phase 3 & 4*. https://www.cstep.in/drupal/sites/default/files/2021-07/CSTEP_SAFARI_Final_Report_July2021.pdf

CSTEP. (2022). *No silver bullet: Essays on India's net-zero transition*. https://cstep.in/publications-details.php?id=2229

CSTEP. (2023). *Forests: An essential piece in the decarbonisation puzzle*. https://cstep.in/publications-details.php?id=2511

IEA. (2023). *Transitioning India's road transport sector*. https://www.iea.org/reports/transitioning-indias-road-transport-sector

Kumar, P., Natarajan, R., & Ashok, K. (2021). Sustainable alternative futures for urban India: The resource, energy, and emissions implications of urban form scenarios. *Environmental Research: Infrastructure and Sustainability, 1*(1), 011004. https://doi.org/10.1088/2634-4505/ac048e

Lark, T. J., Hendricks, N. P., Smith, A., Pates, N., Spawn-Lee, S. A., Bougie, M., Booth, E. G., Kucharik, C. J., & Gibbs, H. K. (2022). Environmental outcomes of the US Renewable Fuel Standard. *Proceedings of the National Academy of Sciences, 119*(9), e2101084119. https://doi.org/10.1073/pnas.2101084119

NITI Aayog. (2021). *Roadmap for ethanol blending in India 2020-25*. https://www.niti.gov.in/sites/default/files/2021-06/EthanolBlendingInIndia_compressed.pdf

CENTER FOR STUDY OF SCIENCE, TECHNOLOGY & POLICY

Bengaluru
No. 18, 10th Cross, Mayura Street, Papanna Layout,
Nagashettyhalli (RMV II Stage), Bengaluru-560094
Karnataka, India

Noida
1st Floor, Tower-A, Smartworks Corporate Park, Sector-125,
Noida-201303, Uttar Pradesh, India


www.cstep.in


+91-8066902500


cpe@cstep.in


@cstep_India