



## GREEN FUEL OR GREENWASHING? EVALUATING THE TRUE CARBON FOOTPRINT OF ETHANOL BLENDING

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### ABSTRACT

*Ethanol blending is widely promoted as a cleaner alternative to conventional fuels and a key step towards achieving climate goals. However, an important question remains: is it genuinely reducing carbon emissions, or is it simply another form of greenwashing? This article critically examines the environmental claims surrounding ethanol blending by analysing its complete carbon footprints, from crop cultivation and water consumption to fuel production and distribution. It also evaluates India's legal and policy framework to determine whether existing regulations ensure real environmental benefits and accountability. The article argues that only transparent, science-based policies and effective regulations can ensure ethanol blending delivers genuine sustainability rather than symbolic climate action.*

**Keywords:** Ethanol Blending, Climate Goals, Social-Political Effects, Sustainability.

### INTRODUCTION

Ethanol blending is not a simple 'yes' or 'no' climate solution. It can cut some greenhouse-gas emissions compared with petrol, but the size of that benefit depends heavily on what the ethanol is made from, how the crop is grown, whether land use change is involved, and how much ethanol is actually blended into fuel.

In common language: ethanol can be cleaner than gasoline in some cases, but it can also become a polished climate story that looks greener on paper than it is in the real world. That is why the honest answer to "green fuel or greenwashing?" is often: both, depending on the feedstock, policy design, and the accounting method used.

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## WHY ETHANOL BECAME ATTRACTIVE?

Ethanol entered the climate conversation because it seems intuitive: if the carbon came from plants rather than underground fossil reserves, then maybe the fuel is “renewable” and therefore better. The idea is also politically appealing because it promises energy security, farm income, rural jobs, and a domestic alternative to imported oil. India’s ethanol roadmap explicitly frames ethanol blending as a way to save foreign exchange, support farmers, and reduce emissions while building a domestic biofuel economy.

That promise matters in India because transport still relies overwhelmingly on fossil fuels, and the country imports most of the oil it consumes. The NITI Aayog roadmap says India imported 185Mt of petroleum at a cost of US \$551 billion in 2020-21 and argues that a successful E20 program could save about US \$4 billion per year.<sup>1</sup> But the climate policy is not just about the story a fuel tells. It is about the full chain of effects: crop cultivation, fertiliser use, transport, refining, blending, vehicle performance, and the land decisions behind the feedstock. That is where the picture becomes more complicated.

## HOW DOES CARBON ACCOUNTING WORK?

To judge ethanol fairly, you have to look at life cycle emissions, not just tailpipe smoke. That means counting emissions from farming, harvesting, processing, shipping, fuel production, and vehicle use, then comparing the result with petrol on an equal energy basis.<sup>2</sup> This matters because ethanol is not automatically low carbon simply because it came from a plant. If growing the feedstock requires heavy fertilisers, irrigation, diesel for farm machinery, land conversion from forest or grassland, the climate benefit can shrink fast or even reverse. The literature on second-generation ethanol shows that land use change can overwhelm other gains, and that results vary sharply by feedstock and system design.

The accounting method also matters. One study on integrated biorefineries found that different allocation methods changed the absolute numbers, though the ranking of feedstocks remained broadly similar. In other words, the labels can shift depending on the maths, which is exactly why carbon claims around biofuels often feel more confident than they should.

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<sup>1</sup> <https://doi.org/10.1016/j.scca.2025.100128>

<sup>2</sup> [www.Pmc.ncbi.nlm.nih.gov](http://www.Pmc.ncbi.nlm.nih.gov)

## INDIA'S ETHANOL STORY

India's ethanol program has moved quickly. The 2021 NITI Aayog roadmap describes the national shift towards E20, notes that E10 was already being rolled out, and says the government advanced the target for 20% blending from 2030 to 2025. It also reports a projected ethanol demand of 1016 crore litres and a planned expansion of production capacity from molasses- and grain-based distilleries.

The official<sup>3</sup> case is straightforward: ethanol blending can improve energy security, reduce oil imports, and lower emissions. The roadmap also says ethanol has a higher-octane number, which can support efficient combustion when engines are properly tuned and cites emission reductions for CO, hydrocarbon, and in some cases particulate matter.

At the same time, the same reports acknowledge trade-offs. It notes fuel efficiency losses for some vehicles using E20, the need for compatible vehicles, and the need to expand storage, handling, and retail infrastructure. It also warns that sugarcane and paddy together use a very large share of irrigation water, and recommends lower-water crops like maize and more 2G feedstocks. That mix of ambition and caution is important. The policy is not pure greenwashing, but neither is it a magically clean solution. It is a large industrial transition with real benefits, real costs, and real winners.

## THE CARBON MATHS

The strongest case for ethanol comes when it is made from the residues or other low-impact feedstocks and when the system captures co-product value. In a peer-reviewed life cycle study of integrated biorefineries, ethanol from second-generation feedstocks such as forest residue and poplar could save substantial GHG emissions relative to petrol, with pure ethanol savings up to 87% of GHG emissions per MJ compared with petrol.

But that number can mislead if it is treated as the normal everyday result of blending a small amount of ethanol into gasoline. The same study found that for current 5% blends, the savings were much smaller, below 3%. That is a crucial point: a fuel can look impressive in a full replacement scenario while delivering only tiny gains at the low blending levels used in real markets.

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<sup>3</sup> [www.niti.gov.in](http://www.niti.gov.in)

The study also found that a 5% ethanol blend would produce only about 2-2.8% GHG saving per MJ of fuel, and that the national benefits would be small unless much higher blends became widespread. So, the real climate value depends not just on whether ethanol is cleaner than petrol in principle, but on whether the blend rate is high enough to matter at scale.

**Feedstock matters most:** This is where the debate stops being abstract. Ethanol from different crops can behave like a different product entirely. The study found that poplar performed best across most impacts, forest residue often performed well, miscanthus had mixed results, and wheat straw was the worst option for many impacts.<sup>4</sup> The reason is simple: every feedstock comes with its own upstream burden. Some are residues that already exist, while others are dedicated energy crops that require land, water, fertilisers, and long growing cycles. The moment a fuel needs fresh land, the climate ledger can change dramatically. This is also why second-generation ethanol is often viewed as more promising than first-generation ethanol. Residues and wastes avoid some food versus fuel conflicts, but even then, the sustainability results depend on how much residue can be removed without harming soils or other uses.

**Land use change is the Trapdoor:** If there is one issue that can turn ethanol from climate solution to climate disappointment, it is land use change. The 2014 life cycle study found that direct land use change can overwhelm the carbon savings from ethanol, especially for energy crops like miscanthus and poplar. In one scenario, converting forest land to miscanthus increased the global warming impact to 6800g CO<sub>2</sub> eq./L, compared with negative values in the baseline case.

This is not a minor adjustment. It is a warning that ‘renewable’ does not automatically mean ‘low-carbon’. If forests or grasslands are cleared for fuel crops, the carbon released from the land can dwarf the emissions saved by replacing petrol. This is the heart of the greenwashing accusation. A company or government can advertise ethanol as clean because the fuel is renewable at the tailpipe, while ignoring the land carbon debt created upstream. If the accounting skips or soft pedals that debt, the environment story becomes marketing, not analysis.

**Water and Farming Burdens:** India’s own roadmap admits that water intensity is a serious issue. It says sugarcane and paddy together use 70% of the country’s irrigation water, which is one reason it recommends a shift towards lower water crops such as maize and toward second-

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<sup>4</sup> [www.pmc.ncbi.nlm.nih.gov.com](http://www.pmc.ncbi.nlm.nih.gov.com)

generation feedstocks. That matters because a climate solution that worsens water stress can create another environmental crisis. In a country like India, where agricultural water security is already tight in many regions, the question is not just does this cut carbon? but what do I do to rivers, aquifers, and crop choices?

Fertilisers and pesticide use also add hidden emissions. The lifecycle study found that for some feedstock, agriculture contributed heavily to acidification, eutrophication, and toxicity impacts. In other words, the environmental footprint of ethanol is not confined to carbon dioxide; it spills into water pollution, soil stress, and chemical exposure too.

### **WHAT INDIA GAINS?**

To be fair, ethanol blending can deliver real benefits. The NITI Aayog roadmap argues that ethanol improves octane, can support better combustion, and helps cut regulated vehicle pollutants such as carbon monoxide and hydrocarbons. It also says E20 compatible vehicles can be introduced with manageable engineering changes and modest cost increases.

The report cites estimated emissions reduction for E10 and E20 relative to gasoline, including lower carbon monoxide and hydrocarbon emissions, with some test results showing no severe malfunction or stall in vehicle operation. That means ethanol is not just a political slogan; it can work as a fuel component in the right technical context. There is also a national development argument. Ethanol can create demand for farm products, support distillery investment, and reduce import dependence. Those are real policy objectives, and they explain why countries keep coming back to biofuels even when the climate math gets messy.

### **WHAT INDIA RISKS?**

The downsides are just as real. The same roadmap notes fuel-efficiency losses of around 6–7% for some four-wheelers designed for E0 and tuned for E10, and lower but still noticeable losses in other vehicle classes. Consumers may end up paying more or getting fewer kilometres per litre, even if the policy looks beneficial at the national level.

There is also a feedstock risk. If ethanol demand rises faster than sustainable supply, the system may drift toward more resource-intensive crops or more pressure on grain markets. That can produce a classic policy failure: a climate program that starts by using “surplus” agricultural output and ends up reshaping agriculture in ways that are harder to justify. And then there is

the issue of perception. If the public is told ethanol is clean in a simple, absolute sense, but later experiences mileage loss, price changes, or engine-compatibility concerns, trust can erode. A fuel policy that oversells itself can backfire politically even when the underlying technology has some merit.

**Brazil and the US:** India is not the only country wrestling with this. Brazil has built a large ethanol market, with flexible-fuel vehicles and a much higher ethanol share in transport than India currently uses. The NITI Aayog roadmap notes that Brazil's gasoline contains about 27% ethanol and that hydrous ethanol use in flex-fuel vehicles has raised the average ethanol share in transport substantially.

The United States offers a different model, centred on renewable fuel standards and a huge corn ethanol industry. That model has long been controversial because corn is a food crop, and because the climate value of corn ethanol depends on farming practices, land use, and process emissions. The broader <sup>5</sup>academic literature reflects that tension: ethanol can reduce some fossil fuel use, but first-generation feedstocks are more vulnerable to the food-versus-fuel critique. These international examples show that ethanol is not a single thing. It can be a mature blending platform, a rural development tool, a transition fuel, or a disguised way to keep combustion vehicles alive longer. Which of those it becomes depends on policy discipline.

**Greenwashing warning signs:** When does ethanol cross from "imperfect but useful" into greenwashing? The warning signs are pretty clear. First, when officials or companies cite tailpipe or renewable origin only, while ignoring land-use change and agricultural emissions, the climate claim is incomplete.

Second, when blend percentages are used to imply large climate wins even though the actual life-cycle saving is tiny at current levels, the public is being sold a bigger result than the numbers justify. The second-generation ethanol study is explicit that 5% blends deliver only a small greenhouse-gas benefit.

Third, when water stress, soil impacts, biodiversity loss, and food-system pressure are left out of the story, the claim is too narrow to be honest. A fuel is not green just because it is not fossil-based; it has to be better across the system or at least better in the dimensions that matter most.

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<sup>5</sup> [www.ScienceDirect.com](http://www.ScienceDirect.com)

**When ethanol is genuinely useful:** Ethanol is most defensible when it comes from residues, wastes, or carefully managed low-impact feedstocks, and when the system is designed to avoid land conversion. It is also more credible when the policy is transparent about trade-offs instead of presenting ethanol as a magic substitute for petrol.

It helps when vehicle technology is aligned with the blend, because engine mismatch can erase some of the practical gains through reduced efficiency or compatibility issues. India's roadmap repeatedly emphasises that E20 vehicles, proper tuning, and supporting fuel infrastructure are part of the transition. Most importantly, ethanol works best as part of a broader decarbonization strategy, not as a permanent excuse to delay electrification, efficiency improvements, public transit, or cleaner freight systems. In that role, ethanol can be a bridge fuel, but bridges are not destinations.

**Better Policy Design:** A sensible ethanol policy should be selective rather than ideological. It should prioritise residues, used oils, and other low-carbon feedstocks, avoid land conversion, and use strong sustainability criteria for water, soil, and biodiversity. It should also publish full life-cycle emissions accounting, not just headline numbers. That means disclosing the assumptions behind the calculation, including fertiliser inputs, irrigation, transport distance, energy source for distilleries, and treatment of co-products.<sup>6</sup>

Finally, policymakers should be honest about scale. If a 5% blend only cuts emissions modestly, then that is what it should be called: a modest improvement, not a climate breakthrough. Exaggeration is what turns a climate tool into a branding exercise.

## FINAL JUDGMENT

So, is ethanol blending green fuel or greenwashing? The accurate answer is that it is conditional. Under the right conditions, especially with residues and second-generation feedstocks, it can reduce fossil dependence and cut some emissions.

But if ethanol is promoted without land-use accounting, without honest treatment of water and farming impacts, or with claims that exceed its real life-cycle benefit, then it becomes greenwashing in green clothing. India's ethanol program has genuine policy logic, but it will only stay credible if it treats sustainability as a measurement problem, not a marketing slogan.

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<sup>6</sup> [www.Pmc.ncbi.nlm.nih.gov](http://www.Pmc.ncbi.nlm.nih.gov)

In the end, ethanol is not a clean miracle and not a total fraud. It is a useful but limited tool, and the difference between climate progress and climate theatre lies in the details.