

Center for Strategic Studies and Management's (CGEE) Contribution

Roadmap transitioning away from fossil fuels in a just, orderly, and equitable manner

Bioethanol as a FAIR (Fast, Accessible, Inclusive, and Renewable) Pathway for Transitioning Away from Fossil Fuels: Lessons from Brazil

This contribution is based on the comprehensive analysis presented in the book *Bioethanol: Fast track to mobility decarbonisation*, organised by BNDES and CGEE. The book consolidates over five decades of Brazilian experience in sustainable biofuel production and use. Drawing from the book's technical, economic, and environmental assessments, the following sections provide a structured contribution to the COP30 Presidency Roadmap. It outlines the urgency of bioethanol as an immediate decarbonisation solution, identifies critical barriers to a just transition, highlights proven policy and technological levers, shares best practices from Brazil, and offers recommendations for a fast, accessible, inclusive, and renewable energy transition that respects diverse national circumstances.

1. The urgency of implementation: bioethanol's role

Bioethanol is an immediate, proven, and scalable solution for decarbonising the transport sector, a critical area for climate action. With the transport sector accounting for approximately 30% of global energy consumption and a third of atmospheric fossil carbon emissions, the urgency to act is paramount. This biofuel offers a fast track because it can be implemented quickly using existing infrastructure (the global fleet of over two billion internal combustion engine vehicles) and established logistics, unlike other alternatives that require complete fleet turnover or massive new infrastructure that could not be afforded in the short-term by many countries.

It is a solution already used in over 70 countries as a gasoline blend (blend mandates vary from E10 to E30) and in flex-fuel vehicles (E100 & E85). The Brazilian experience demonstrates that in just 50 years, bioethanol has replaced 3.6 billion barrels of oil and avoided over 1.6 billion tonnes of CO₂ emissions, showcasing its capacity to deliver immediate, large-scale environmental and energy security benefits. Bioethanol enables over 80% GHG emissions reduction in light-duty vehicles, with the potential to achieve negative emissions through technologies such as bioenergy with carbon capture and storage (BECCS). This positions bioethanol not as a transitional solution but as a central pillar for transitioning away from fossil fuels, particularly for hard-to-abate sectors like aviation and heavy-duty transport via pathways like SAF (Sustainable Aviation Fuels).

2. Critical barriers for the just transition

The most critical barriers preventing a transition away from fossil fuels are:

- The economic competitiveness of biofuels is undermined by market distortions, such as subsidies for fossil fuels and a lack of balanced taxation based on energy content and negative externalities. When governments tax gasoline and ethanol differently, it can lead to a "disproportionate reduction" in bioethanol demand, as seen in Brazil in 2021-2022.
- Other significant barrier is the lack of stable, long-term policy frameworks and regulatory certainty. An example is the case of Guatemala, where a favourable bioethanol law existed for decades but was never implemented due to political inertia and misinformation campaigns, resulting in a "paradox" where the country exports its biofuel while importing gasoline. Beyond that, the absence of clear sustainability criteria and harmonized carbon accounting standards internationally creates uncertainty for producers.
- Misinformation and entrenched prejudices are major obstacles. Well-funded campaigns spread false information about bioethanol's impact on engines, fuel security, and the "food versus fuel" dilemma, creating public and political resistance. These narratives are often driven by economic interests opposed to the development of a sustainable biofuels market.
- Regarding technological and physical barriers, while first-generation (1G) ethanol is mature, the widespread adoption of advanced technologies like second-generation (2G) ethanol and BECCS faces challenges due to process complexity, high costs, and logistical hurdles in mobilizing feedstock (an example is the sugarcane straw) over large areas.

3. How to boost implementation

A multi-pronged approach, adaptable to national circumstances, is essential to accelerate implementation. It is essential to establish mandatory blending mandates (e.g., E10, E20, E30) to create predictable demand and reduce investor risk. This is an ongoing change that enables the adaptation of financial expectations and logistic arrangements. The success of India in accelerating its E20 target demonstrates the power of this initiative. Carbon pricing mechanisms, such as Brazil's RenovaBio programme, where decarbonisation credits (CBIOs) are traded, provide an additional revenue stream for producers and directly incentivize the reduction of carbon intensity.

Moreover, implementing a balanced taxation that aligns with the energy content of fuels and penalizes negative externalities is essential. Governments can also provide targeted financing and credit lines for innovation, as BNDES did with the PAISS and RenovaBio

credit lines, supporting the adoption of advanced technologies and sustainable practices.

Countries should promote a portfolio of technological pathways to diversify the bioenergy sector according to its national context and priorities. This includes advancing 2G ethanol, developing sugarcane energy with higher biomass yields, producing biogas and biomethane from by-products (like vinasse), and investing in BECCS to achieve negative emissions.

Finally, all of these efforts could be boosted by fostering international cooperation and dialogue to share best practices, harmonize standards, and build capacity. Initiatives like the Global Bioenergy Partnership (GBEP), the Biofuture Platform (BFP), and the Global Biofuels Alliance (GBA) are essential to foster and strengthen a stable and growing global market.

4. Experiences, best practices and lessons learned

Brazil's 50-year experience provides a rich repository of best practices that can be adapted to different national circumstances. It shows that bioethanol already replaces about half of the country's gasoline use. Between 1975 and 2023, this replacement prevented 1.37 billion tonnes of CO₂ emissions. This demonstrates that bioethanol is not a future promise but a proven, large-scale decarbonization vector.

The first of the instruments and initiatives for this success is having a long-term, consistent and adaptive policy that evolves with market and technological conditions. On the Brazilian case, the policy had an evolution from a simple 5% mandate in 1931 to the Proálcool program (1975), the introduction of flex-fuel vehicles (2003), the RenovaBio policy (2017), until the Future Fuel Law (2024).

It is important to develop national innovation systems (NSIs). Brazil's success is built on a robust system for technology innovation with strong public-private partnerships. Collaboration between universities (RIDESA), research institutes (IAC, EMBRAPA, LNBR/CNPEN), and private companies (CTC) has driven continuous productivity gains, from 46 tonnes per hectare in 1970 to 76.5 tonnes per hectare in 2019.

Furthermore, the Brazilian agroindustry showcases a high level of circularity. Cogeneration of bioelectricity from bagasse and straw provides a significant share of the national grid. The use of vinasse for fertigation recycles nutrients, and the production of biogas and biomethane from effluents creates a new fuel from a former waste product. The second harvest corn ethanol industry, fuelled by wood from planted forests, produces DDGS, a high-protein animal feed, creating a perfect synergy between food and fuel.

A critical lesson is the successful avoidance of negative land-use change through agroecological zoning. Brazil has a zero-deforestation rule under RenovaBio, and the strategic expansion of second harvest corn ethanol and sugarcane culture primarily onto degraded pasturelands, which can lead to net carbon sequestration.

5. For a just, orderly and equitable transition

Bioethanol is a cornerstone of a just transition, particularly for the Global South, because it reflects diverse realities and development needs. Unlike electrification, which requires massive grid and infrastructure investment, bioethanol can be deployed immediately using existing infrastructure (gas stations, internal combustion engines). This makes it an accessible decarbonization option for countries with limited capital and infrastructure, where electrification is not a short-term solution.

Regarding socioeconomic development, the bioenergy agroindustry is a powerful driver for job creation and regional development. Biofuels generate 5.86 times more jobs per unit of energy compared to the oil refining sector, and a greater share of the sectoral GDP impact is attributed to labour compensation (44.4% vs. 17.9% for fossil fuels), indicating a more equitable distribution of income.

Beyond that, the "food versus fuel" dilemma is refuted by Brazil's example. From 1975 to 2021, biofuel production multiplied while food production grew significantly, often at rates exceeding GDP and population growth. The use of second-crop maize on land, and the production of DDGS, shows the synergy between food and fuel production without expanding land use.

Finally, it is important to consider differentiated pathways, and the transition must respect national contexts. For countries like Guatemala, other Latin-American, Caribbean and Asean countries, the pathway is about implementing domestic blending mandates. For others in Africa, it's about building new agro-industries. International cooperation should support these differentiated pathways, offering science-based solutions tailored to local potential and needs, as exemplified by the bioelectric cars (hybrid vehicles running with biofuels), which can be a more effective decarbonization path than pure electric vehicles for nations with less developed grids.

6. Recommendations

CGEE's following recommendations are made to ensure a fast, accessible, inclusive, and renewable energy transition, in line with the COP28 consensus and with the roadmap in a just, orderly and equitable manner (paragraph 28.d/GST1):

6.1 Adopting and strengthening long-term, stable policy frameworks

Governments should establish mandatory blending mandates and implement balanced taxation based on energy content to create market predictability and ensure fair competition between biofuels and fossil fuels. Policies like RenovaBio in Brazil must be insulated from short-term market fluctuations to provide the investor confidence needed to scale up sustainable biofuel production. Encouragement to the development of sustainable technology solutions like modern bioelectric vehicles should be highlighted.

6.2 Prioritizing productivity and sustainable land use.

Rather than expanding the agricultural frontier, countries should focus on closing agricultural yield gaps through improved management practices and technological adoption. Implementing agroecological zoning and enforcing zero-deforestation rules are essential to ensure that biofuel feedstock expansion occurs primarily on degraded and underutilized lands, such as pastures, thereby preserving native vegetation, protecting biodiversity, and fostering complementarity with food production. Promoting integrated systems like crop-livestock-forestry further maximizes land-use efficiency and enhances soil carbon stocks.

6.3 Promoting a circular bioeconomy through technological innovation.

Public and private research and development funding should support a diverse portfolio of technologies—from efficient first-generation (1G) ethanol to advanced second-generation (2G) ethanol, biogas, biomethane, and bioenergy with carbon capture and storage (BECCS). Creating incentives for integrated biorefineries that maximize value from all biomass streams—including the valorization of by-products such as vinasse, sugarcane straw, and dried distillers grains with solubles (DDGS)—enhances both economic and environmental sustainability. These innovations improve process efficiency, generate new revenue streams, and strengthen the synergy between food and fuel production.

6.4 Strengthening international cooperation to build global markets.

Leveraging platforms such as the Global Biofuels Alliance (GBA), the Clean Energy Ministerial (CEM) Biofuture Platform (BFP), and the Global Bioenergy Partnership (GBEP) is essential for facilitating technology transfer, capacity building, and the harmonization of carbon accounting and sustainability standards. International cooperation is key to overcoming misinformation, sharing best practices, and fostering a stable and growing global biofuels market that enables developing countries to leapfrog to sustainable energy pathways. Such collaboration must respect diverse national circumstances and support differentiated pathways tailored to local potential and needs.

6.5 Ensuring a just transition that maximizes socioeconomic benefits.

Policies must be designed to create high-quality, skilled jobs across the bioenergy value chain and to support the reskilling of workers displaced by mechanization. Recognizing

that bioenergy is not only an energy solution but also a powerful engine for rural and national development, income distribution, and food security, governments should focus on developing the bioeconomy in regions that can benefit most from new agricultural and industrial opportunities. By prioritizing economic profitable labour-intensive sectors and ensuring that a larger share of sectoral GDP is directed to labor compensation, the bioenergy transition can contribute directly to poverty eradication and the achievement of the UN Sustainable Development Goals.