Bioenergy Burning:

A Compendium of Studies and Briefings Produced for The David and Lucile Packard Foundation's Beyond Bioenergy Program

September 2024

CEA CONSULTING

About this Document

Over the past few years, CEA Consulting has produced a range of materials as part of its responsibilities as the monitoring, evaluation, and learning (MEL) partner for the David and Lucile Packard Foundation's Beyond Bioenergy program. This compendium includes information from several previous CEA products, including:

1) **Briefing Presentation**: A briefing presented in July 2024 to the Climate and Land Use Alliance (CLUA) on the current trends, threats, and opportunities presented by bioenergy. (Slides 3-23); ⏯
2) **Bioenergy 101**: A primer on bioenergy including a high-level review of its economics and emissions profile. (Slides 24-34); ⏯
3) **Bioenergy Emissions Accounting**: An analysis to quantify the emissions footprint of bioenergy and evaluate it as a decarbonization pathway. (Slides 35-73); ⏯
4) **Beyond Bioenergy Mid-term Review:** High level findings from CEA's 2023 mid-term review of the David and Lucile Packard Foundation's 2020-2024 Beyond Bioenergy strategy. (Slides 74-80). ⏯

Use the ⏯ to navigate to a specific section in the document.

Photo source: Arnaud Mesureur/Unsplash.

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Section 1

Briefing Presentation (presented to the Climate and Land Use Alliance in July 2024)

Photo source: Dogwood Alliance

Bioenergy is a false climate solution. Here's why.

Bioenergy is the **burning** of plants, trees, and other organic matter for energy (power, heat, and transportation fuels).

Policies around the world support bioenergy on the basis that it is **carbon neutral**.

Bioenergy is **not** a carbon neutral source of energy, despite accounting for about 50% of global "renewable" energy today. **Biomass and biofuels each emit more CO_2** than their fossil fuel counterpart when land use/carbon debt is considered.

Bioenergy is **not** cost competitive with wind and solar and depends on heavy subsidies.

Bioenergy is an extractive and land intensive form of energy. **It threatens biodiversity, public health, human rights, food security, and sovereignty**.

There are grossly insufficient amounts of feedstock and land available for bioenergy to serve as a meaningful climate solution.

Effects of Bioenergy

Biomass and biofuels each emit more carbon than the fossil fuels they aim to replace

<u>Carbon debt of biomass</u>

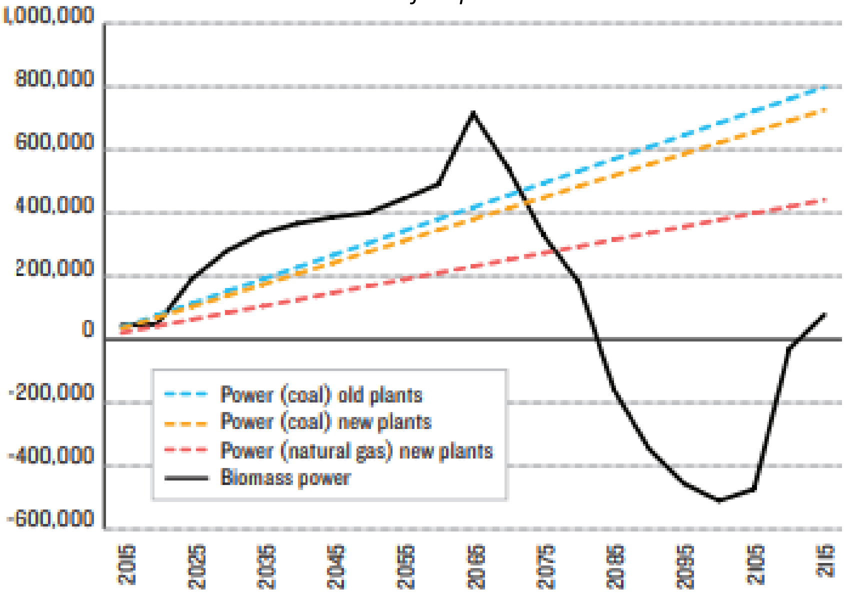
Published estimates suggest that it can take anywhere from **5 to 300 years for forest regrowth to lower the net carbon emissions of biomass below that of coal.**[1]

<u>Indirect land use change in biofuels</u>

Biodiesel, made from feedstocks including rapeseed, soy, and palm oil, generates on **average 1.8x more greenhouse gas (GHG) emissions fossil diesel.**[2]

Cumulative emissions ($MgCO2_e/MW$)

Pellets made of 70 percent whole trees



Source: NRDC, 2015.

Sources: 1) CEA review of multiple papers, 2) Transport & Environment, 2016.

Communities on the frontlines of bioenergy production face a variety of public health threats

Public health threats affecting frontline communities include high-levels of air pollution, water pollution, and decreased resilience to climate change (e.g., flooding).

In addition to carbon, wood pellet plants emit levels of air pollutants comparable to coal-fired plants, including **nitrogen oxides, carbon monoxide, particulate matter, black carbon**, **dioxins,** and a range of **volatile organic compounds such as benzene and formaldehyde**.

The US South is one of the world's largest wood-producing regions. Production here disproportionately harms the health and well-being of communities of color, as well as rural, low income, and minority communities.

Robeson County, North Carolina residents protest new bio-coal wood pellet production facility. Source: Dogwood Alliance, 2020.

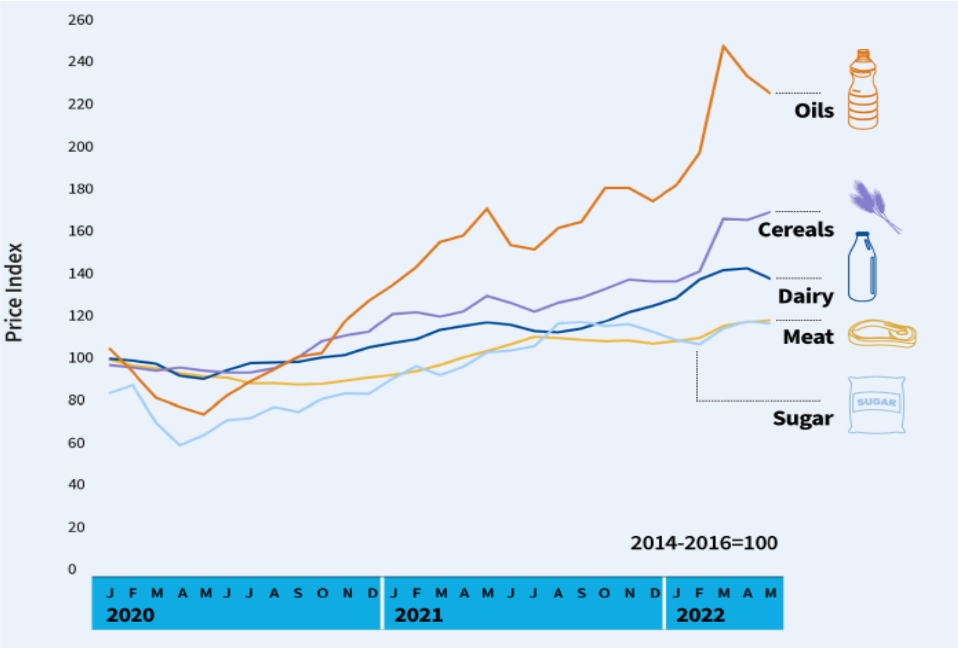
Biofuels clearly contribute to rising food prices

Globally, **the vast majority of biofuels come from food crops** (70-98% in most producing regions).[1]

There is consensus in the economic literature that **growing demand for biofuels increases food prices.** [2]

Biofuels make food prices less resilient to other supply shocks (e.g., vegetable oil price spike at the beginning of the war in Ukraine, see graph on right).

"Every year we burn millions of tonnes of wheat and other vital grains to power our cars. This is unacceptable in the face of a global food crisis."[4]



Price increases across key food categories[3]

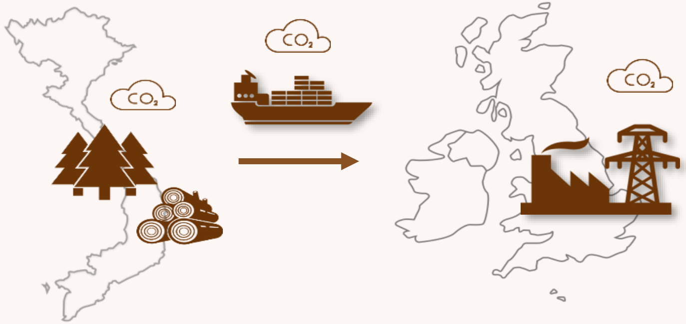
Sources: 1) US GAIN, 2) Malins, 2017, 3) FAO Food Price Index, in Transport & Environment, 2022, 4) Transport & Environment, 2022b.

International GHG accounting standards often fail to account for the full scope of biomass emissions and can perpetuate carbon colonialism

Scenario A: Missing emissions

Country A
(land-use sector)

Country B
(energy sector)



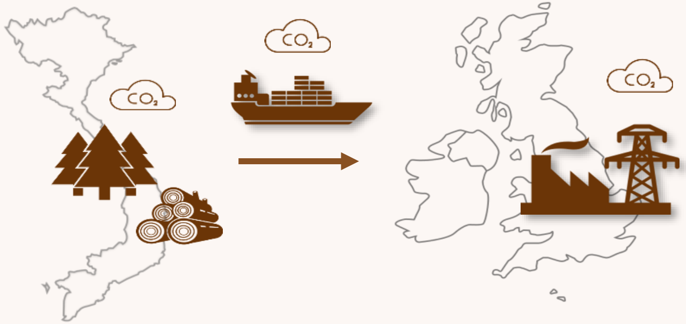
Country A **does not report** emissions from biomass harvesting.

Country B **does not report** emissions from biomass combustion.

Scenario B: Carbon colonialism

Country A
(land-use sector)

Country B
(energy sector)



Country A **reports** emissions from biomass harvesting.

Country B **does not report** emissions from biomass combustion.

See slide 32 for further discussion of bioenergy GHG accounting standards

Demand for bioenergy leads to land conversion and threatens land security and biodiversity

Land taken by Addax Bioenergy for its sugar cane plantation in Sierra Leone [3]

Demand for bioenergy drives land conversion globally, leading to a loss of biodiversity and the degradation of ecosystem function.

- From 2008 to 2016, the implementation of the US Renewable Fuel Standard **expanded US corn cultivation by 2.8 million hectares.**[1]
- Meeting projected biological carbon removal in **national climate pledges and commitments would require 1.2 billion hectares of land** – close to the amount of current global cropland.[2]
- Species threatened by bioenergy production include the critically endangered Orangutan, the vulnerable Cerulean Warbler, the endangered Woodland Caribou, commercial honeybee populations, and Monarch Butterflies.

Bioenergy production threatens land security.

- Between 2002 and 2012, there were **293 reported biofuel-related land grabs around the world, covering 17 million hectares of land.**[3]
- More than half of the 107,000 hectares of land registered to Brazilian palm oil export company Agropalma was **derived from fraudulent land titles.**[4]
- **This issue needs to be further studied.** Currently, Earth Insight and Trend Asia are conducting a threat mapping analysis to understand the impacts of woody biomass harvesting on the tenure and rights of Indigenous Peoples and local communities (IPLCs) and biodiversity across Indonesia, Japan, and South Korea.

Sources: 1) Lark et al., 2022, 2) Dooley et al., 2022, 3) GRAIN, 2013, 4) Mendes, 2022.

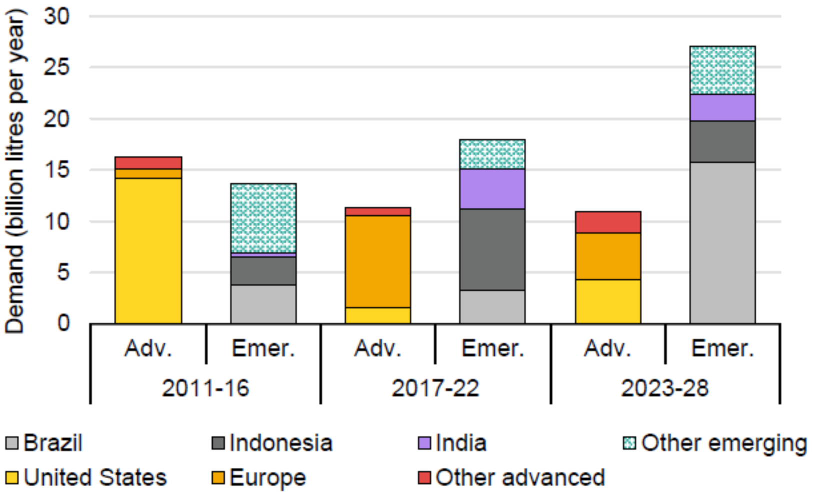
Live Threats

Growth trajectory (biofuels and biomass for heat)

The International Energy Agency projects 30% growth in biofuels between 2023 – 2028, up to 200 billion liters. Most new biofuels are expected to come from emerging economies, especially Brazil, Indonesia, and India.

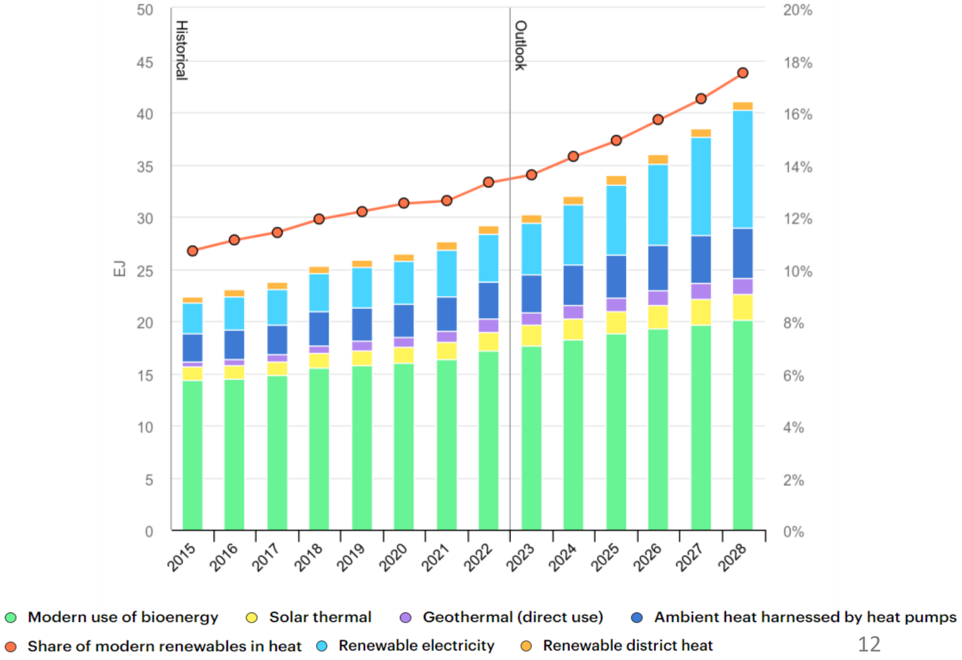
Biomass has been a dominant source of 'renewable' energy over the past decade, predominantly used for heat. Global dependence on biomass is likely to continue through 2030.

Biofuel demand growth by economy type and country, 2011-2028



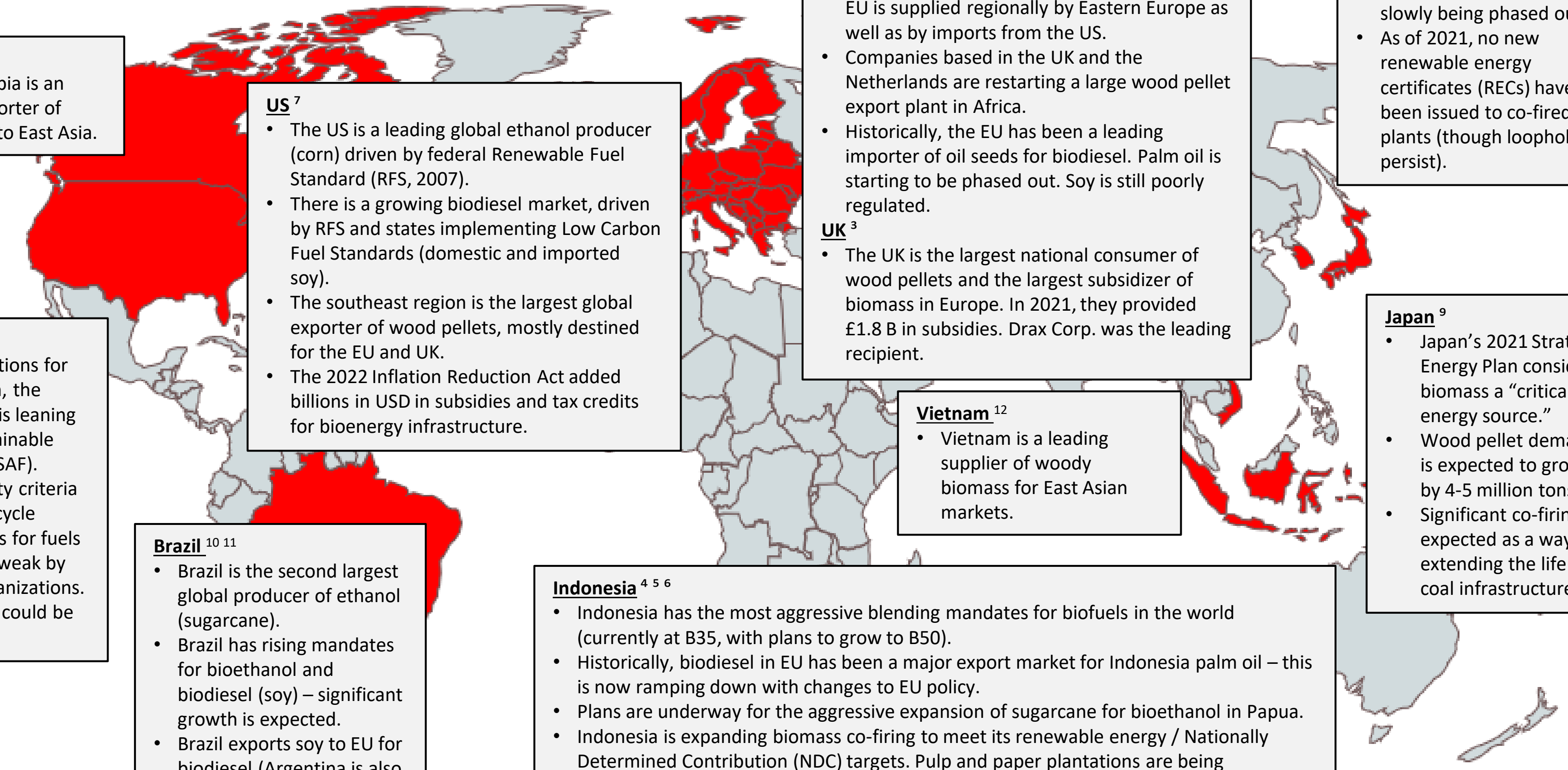
Notes: Adv. = advanced economies. Emer. = emerging economies.

Global renewable heat consumption and share of renewables in total heat consumption, 2015-2028



Source: IEA 2024.

Bioenergy as a global contagion



Canada
- British Columbia is an emerging exporter of wood pellets to East Asia.

US [7]
- The US is a leading global ethanol producer (corn) driven by federal Renewable Fuel Standard (RFS, 2007).
- There is a growing biodiesel market, driven by RFS and states implementing Low Carbon Fuel Standards (domestic and imported soy).
- The southeast region is the largest global exporter of wood pellets, mostly destined for the EU and UK.
- The 2022 Inflation Reduction Act added billions in USD in subsidies and tax credits for bioenergy infrastructure.

EU [1 2]
- The EU is the largest regional consumer of woody biomass for heat and power, driven by the Renewable Energy Directive (2005). The EU is supplied regionally by Eastern Europe as well as by imports from the US.
- Companies based in the UK and the Netherlands are restarting a large wood pellet export plant in Africa.
- Historically, the EU has been a leading importer of oil seeds for biodiesel. Palm oil is starting to be phased out. Soy is still poorly regulated.

UK [3]
- The UK is the largest national consumer of wood pellets and the largest subsidizer of biomass in Europe. In 2021, they provided £1.8 B in subsidies. Drax Corp. was the leading recipient.

South Korea [8]
- Support for biomass is slowly being phased out.
- As of 2021, no new renewable energy certificates (RECs) have been issued to co-fired plants (though loopholes persist).

Japan [9]
- Japan's 2021 Strategic Energy Plan considers biomass a "critical energy source."
- Wood pellet demand is expected to grow by 4-5 million tons.
- Significant co-firing is expected as a way of extending the life of coal infrastructure.

Aviation sector [13]
- With limited options for decarbonization, the airline industry is leaning heavily on Sustainable Aviation Fuels (SAF).
- The sustainability criteria and default lifecycle emissions values for fuels are considered weak by civil society organizations. Volumes of SAF could be huge.

Vietnam [12]
- Vietnam is a leading supplier of woody biomass for East Asian markets.

Brazil [10 11]
- Brazil is the second largest global producer of ethanol (sugarcane).
- Brazil has rising mandates for bioethanol and biodiesel (soy) – significant growth is expected.
- Brazil exports soy to EU for biodiesel (Argentina is also a leading soy exporter).

Indonesia [4 5 6]
- Indonesia has the most aggressive blending mandates for biofuels in the world (currently at B35, with plans to grow to B50).
- Historically, biodiesel in EU has been a major export market for Indonesia palm oil – this is now ramping down with changes to EU policy.
- Plans are underway for the aggressive expansion of sugarcane for bioethanol in Papua.
- Indonesia is expanding biomass co-firing to meet its renewable energy / Nationally Determined Contribution (NDC) targets. Pulp and paper plantations are being repurposed for wood chip production, now referred to as "Energy Plantation Forests".

Sources: [1] Catanoso, 2023, [2] European Commission, 2024, [3] Seabrook, 2021, [4] Indonesia Palm Oil Association, 2024, [5] Antara, 2024, [6] Good Network, 2023, [7] US EPA, 2024, [8] Solutions for Our Climate, 2023, [9] EIA, 2024, [10] IEA, 2024, [11] Reuters, 2023, [12] Forest Trends, 2021, [13] WRI, 2024.

Indonesia

Suralaya coal-fired power plant in Indonesia.[2] *The Suralaya coal-fired power plant in Indonesia is one of 13 coal plants where the Ministry of Energy and Mineral Resources says it has successfully implemented a low percentage of cofiring.*

- The incoming Subianto administration has announced **plans to roll-out the use of a 50% biodiesel blend**. This policy is expected to drive demand for crude palm oil (CPO) fuel to 3.25 million tonnes a year and cause a CPO supply deficit of 1.2 million tonnes.[1]
- Demand for palm-based biodiesel has caused **edible oil prices to surge**, making palm-based cooking oil inaccessible to many Indonesians.
- Indonesia's plans for 10% biomass co-firing at 52 of its coal power plants requires 10.2 million metric tons of biomass, which would result in **anywhere between 1 to 1.05 million hectares of deforestation -** an area roughly 35 times the size of Jakarta.[2] To meet this commitment, the government has pledged to create “energy forests” to produce more biomass feedstock.
- Plans to establish a 2-million-hectare sugarcane plantation in eastern Papua would result in **the deforestation of a forest area 6 times the size of Jakarta**, with negative implications for Indigenous tenure and local biodiversity.[3]

Sources: 1) The Jakarta Post, 2024, 2) Trend Asia, 2022, 3) Mongabay, 2024.

Brazil

- Historically, Brazil has been the **second largest global producer of ethanol**, after the US – sugarcane is the main feedstock.[1]
- The IEA projects Brazil to contribute **40% of global biofuel expansion** between 2023-2028.[2]
- Brazil is aiming to **increase its blending mandates**: [3]
  - Rising from 27 to 30% for ethanol (mainly sugarcane)
  - Rising from 12% to 15% for biodiesel (mainly soy)
- The biofuels **export market for soy is important for Brazil**. Strong trade interests (primarily from the US, Brazil, Argentina - all members of the Global Biofuels Alliance) are the biggest obstacle to phasing out soy biofuels in the EU Renewable Energy Directive.[4]
- There are active policy discussions around support for **biojet fuel production** in Brazil.[2]

Sugarcane in Brazil's Cerrado Biome[5]

Sources: 1) US GAIN, 2) IEA, 2024, 3) Reuters, 2023, 4) Transport & Environment, 2023a, 5) Mongabay, 2017.

Emissions savings claims from SAF are undermined by indirect land use change

Sustainable aviation fuel, or SAF, is an alternative fuel made from non-petroleum feedstocks with the goal of reducing GHG emissions from air transportation. However, **the climate performance of SAFs varies enormously by feedstock used to produce the fuel.**

Aircraft refueling[5]

Policies and targets — at both the international and state levels — drive the increase in demand for SAF.

- In November 2023, **the International Civil Aviation Organization agreed to a global framework to promote SAF production in all geographies.**[1]
- IEA forecasts that biojet fuel use will grow to 5 billion liters, or **1% of global jet fuel supply**, by 2028.[4]
- The Biden administration's Sustainable Aviation Fuel (SAF) Grand Challenge calls for expanding **domestic production of SAF to 35 billion gallons per year in 2050.**[2] ICCT estimates only a third of that goal (12.2 gallons) can be met without adverse market or environmental consequences.[3]

Sources: 1) IATA, 2024, 2) US Department of Energy, 2021, 3) ICCT, 2023, 4) IEA, 2024, 5) WRI, 2024.

Increased focus on and resourcing of the "bioeconomy" may have devastating impacts on people, nature, and climate

The total value of the global bioeconomy is currently $4 trillion USD. **Experts project its value could rise to $30 trillion USD by 2050.[1]**

Several new bioeconomy-related subsidies are being introduced globally. **Without safeguards, there is a risk that a bioeconomy push could entrench badly designed subsidy regimes that would end up harming, rather than helping, people, nature, and climate.**

Given Brazil's G20 Initiative on Bioeconomy and upcoming COP30 in Belém, it will be important to coordinate messaging related to commitments for socially just and ecologically sustainable bioeconomy development.

President Lula speaking at the opening session of COP28 to announce COP30 in Belém[2]

Sources: 1) Climate Policy Initiative, 2024, 2) Government of Brazil, 2023.

Recommendations

Lessons from the David and Lucile Packard Foundation's Beyond Bioenergy Strategy

Strategies		Issue areas	
Movement-building	Communications	Weakening industry influence	Energy alternatives
"*Building power is essential…at this point the information is well-established. If that was enough to persuade policymakers to do the right thing, they would have done so already."*	"*[Communications] is critical to flatten the complexity of the issues so that the public and decision-makers can understand."*	"*The sheer volume of noise coming from the industry has been exceptionally difficult to combat with effective science, communication, and public engagement."*	"*The most powerful rhetorical strategy to combat the spread of bioenergy is to build greater alignment around alternative energy sources."*

Recommendations for Funders

Target Outcomes
1) Phase out subsidies for bioenergy producers.
2) Change the classification of bioenergy in renewable energy policies so it is not treated as renewable or carbon neutral.
3) Change IPCC accounting protocols so that bioenergy is consistently accounted for in the energy sector.
4) Support grassroots communities that are at risk of land grabbing and/or pollution from wood pellet production.
5) Increase investments into alternative solutions for heating.
6) Shift global attention to demand reduction and energy efficiency.

Recommended Strategies and Tactics
1) Analysis to demonstrate and communicate that bioenergy is a poor public investment.
2) Support for frontline communities and movements that are defending their land and resources.
3) Support for shareholder and investor advocacy campaigns.
4) Broad strategic communications campaign to shift public and political sentiment on bioenergy.
5) Targeted policy advocacy aimed at removing renewable energy status from bioenergy.

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Section 2

Bioenergy 101: A false climate solution

Photo source: Oregon Department of Forestry via Flickr.

Workers transfer harvested palm fruits to a transport truck before processing into crude palm oil at a palm plantation in Pekanbaru, Indonesia. Photo source: WAHYUDI / AFP, 2022.

What is bioenergy?

Bioenergy is burning plants, trees, and other organic matter for energy (power, heat, and transportation fuels).

Modern bioenergy includes **biomass**, **biofuels**, and **biogas.**

Biomass: Combustion of organic material (usually wood chips or wood pellets) for heat and power at the utility scale.

Biofuels: Conversion of food crops, used cooking oils, algae, or energy crops into liquid fuels for use in the transportation sector (e.g., "biodiesel" and "bioethanol").

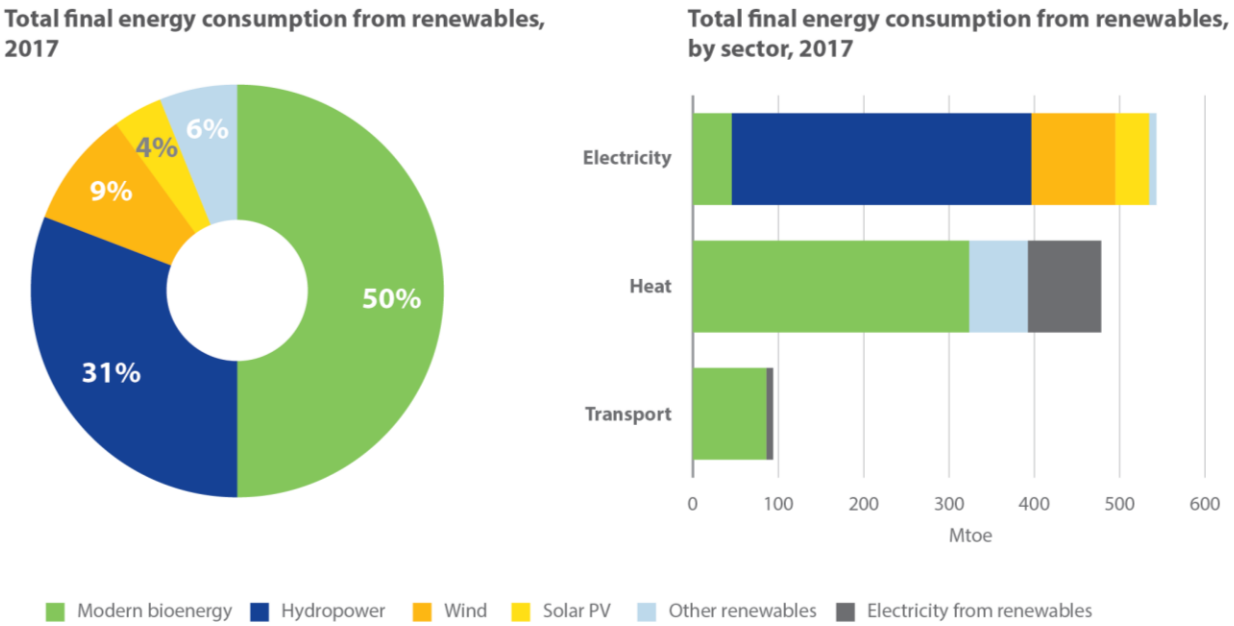
Biogas: The conversion of a variety of organic materials, including food crops and wood pellets, into natural gas for heat and power.

Traditional Bioenergy is the combustion of organic materials (typically firewood, wood chips, or dung) for household scale cooking and heating. Globally, traditional bioenergy accounts for more than half of all bioenergy use, but it is not the subject of this report.

Bioenergy is the hidden story of renewable energy.

Globally, **modern bioenergy accounts for about 50% of all renewable energy**, including electricity, heat, and transport. *(IEA reports that bioenergy accounts for 55% of renewable energy in 2023.)*

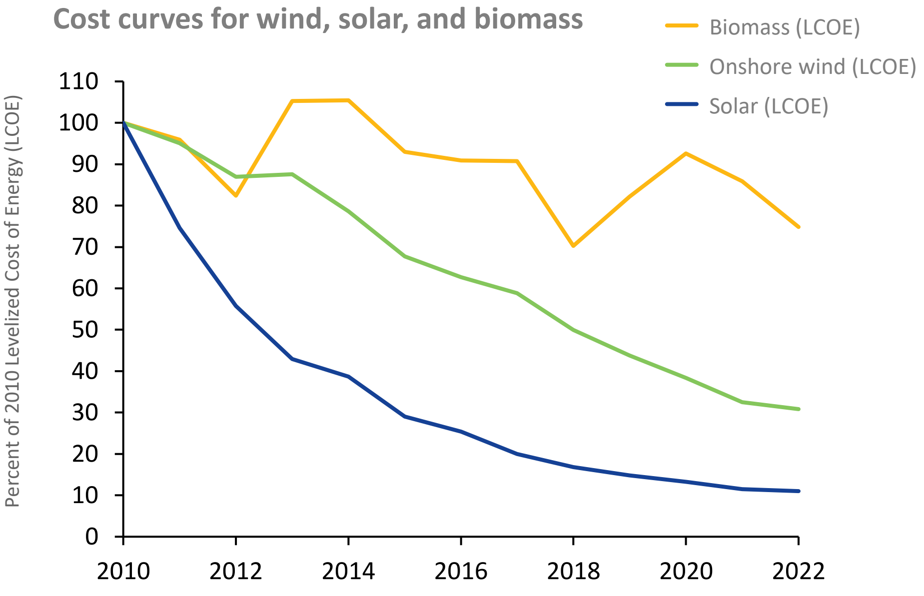
This is **almost four times** the contribution of solar and wind combined.



Total final energy consumption from renewables in 2017 (left) and broken down by sector (right).
Source: International Energy Agency, 2018.

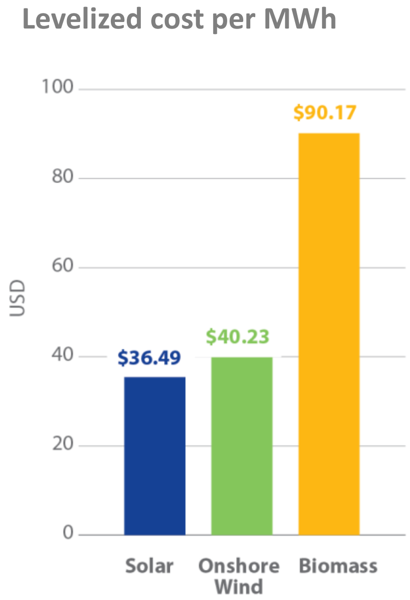
Bioenergy is not cost competitive with wind and solar, requiring heavy subsidies

The cost of biomass energy production has not dropped significantly in the last decade, while the cost of wind and solar have.



Source: IRENA, 2023.

Biomass is not cost-competitive with other sources of renewable energy without massive subsidies.



Source: US Energy Information Administration, 2022.

The bioenergy industry receives generous public subsidies, at the cost of renewable alternatives.

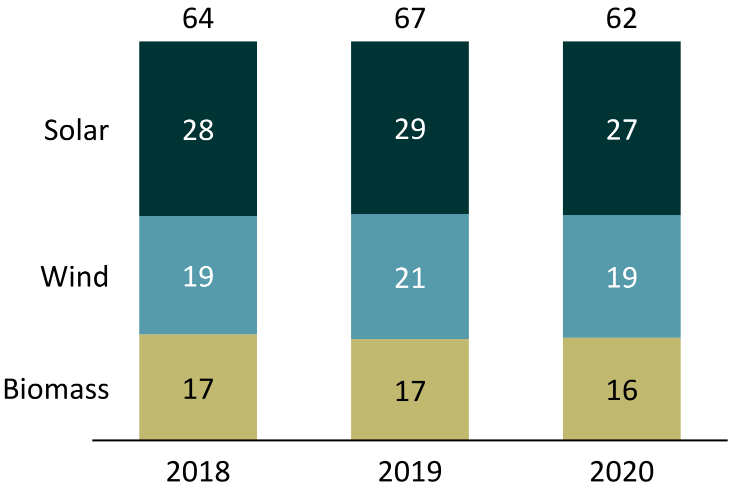
Between 2015 and 2023, Indonesian companies involved in biodiesel production received approximately $11.5 billion in subsidies. This total was split between 16 corporate groups representing 29 companies (Clean Transition Coalition).

As part of the US Inflation Reduction Act, the Section 45 tax credit for biomass production **would extend $54.9 billion worth of subsidies to industry between 2022 and 2026**. (Taxpayers for Common Sense 2022).

If the UK agrees to fund the installation of carbon capture and storage (CCS) at Drax Power Station, **the subsidies to pay for it could add £3.8 billion to homeowners' energy bills over 15 years**. If this money was instead spent on home insulation, it could insulate more than **2.5 million homes in the UK**, ultimately making them more efficient and actually saving them money by reducing their energy bills. **It would also cut the UK's greenhouse gas emissions by 1.1 million tonnes *per year***. (NRDC 2022)

In 2018, via the RPS Implementation Cost Settlement, **biomass utilities in South Korea received $1.5 billion**; and were issued almost 40% of all renewable energy certificates issued between 2014 and 2017 (Solutions for Our Climate 2018).

EU renewable energy subsidies by technology
(2018-2020; in EUR billions)



Source: European Commission, 2023.

Biomass extraction and combustion creates a carbon debt that the planet cannot afford.

Biomass was originally thought to be “renewable” and carbon neutral because trees grow back and recoup the emissions from burning them.

In reality, biomass extraction and combustion emit more carbon than fossil fuels and trees take a long time to grow back, if they ever do, creating a carbon debt.

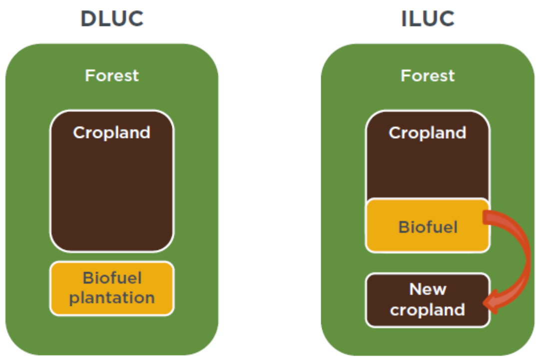
Climate Problem 1: Forest Loss
Cutting down trees damages forests, which absorb 30% of our annual carbon emissions for free.

Climate Problem 2: High Carbon Emissions
Burned biomass emits more carbon into the atmosphere than coal, the most polluting of fossil fuels.

Result = Carbon Debt
Regrowing a forest to absorb the carbon emitted takes half a century to a century. By that time, the fate of the climate crisis will already have been decided.

After accounting for land use change, biofuels produce more emissions than fossil fuels and pose threats to forests.

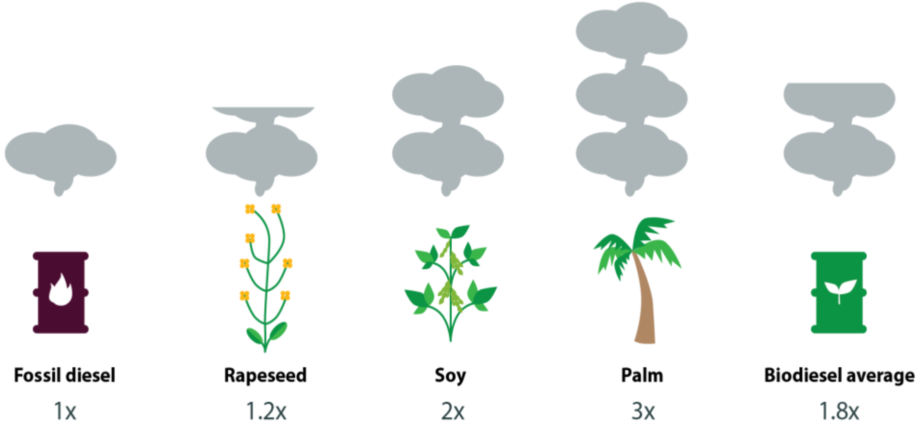
Biofuel crops cause direct and indirect land use change. Both can contribute to deforestation and the loss of carbon-rich ecosystems.



Direct Land Use Change (DLUC)
New cropland is created to produce biofuel feedstocks.

Indirect Land Use Change (ILUC)
Existing cropland is used for biofuel, forcing other agricultural products to be produced on new cropland.

When accounting for land use changes and competition with agricultural crops, biodiesel (including from rapeseed, soy, and palm feedstocks) produce more carbon emissions than fossil diesel.



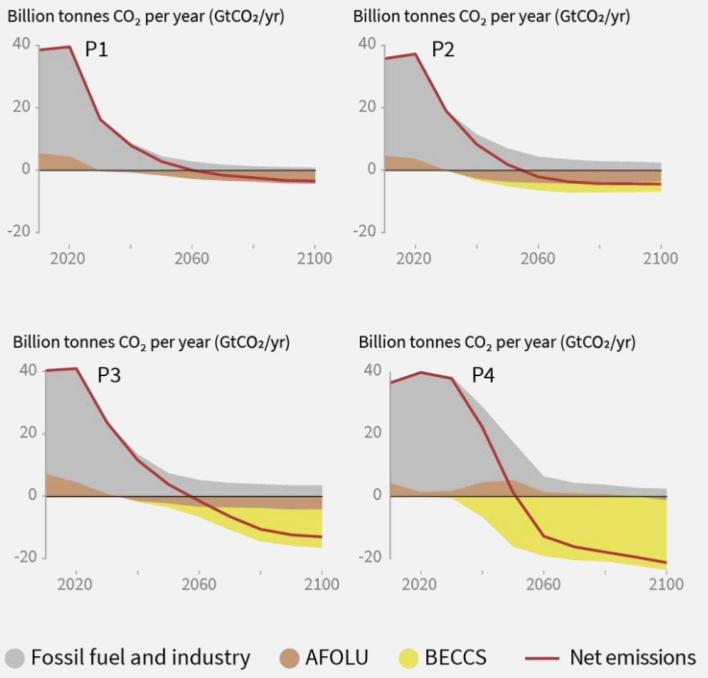
Source: Left: Takriti, Malines, and Searle, 2016. Right: Transport and Environment, 2016.

Many countries are relying on BECCS to reach net zero by 2050, but it is a false solution.

Bioenergy with Carbon Capture and Sequestration (BECCS) refers to energy generated by burning organic material (bioenergy) and then capturing and sequestering the associated carbon emissions. The logic of BECCS as a climate solution relies on the false assumptions that bioenergy is a carbon neutral energy source and that there will be abundant land upon which to grow bioenergy feedstocks. BECCS features prominently in most recent scenarios for addressing climate change, ignoring impacts of development at scale.

Of the climate models that provide the best chance of limiting warming to below 2ºC, the median commitment to BECCS is 12 GT CO_2 per year. **That requires 0.4 to 1.2 billion hectares, or 25% to 80% of current agricultural land. An area 1–2x the size of India would be necessary to grow crops for BECCS.**

Source: IPCC, 2018. Field and Mach, 2017.



Source: IPCC, 2018.

Bioenergy emissions are often not captured due to flawed international GHG accounting standards.

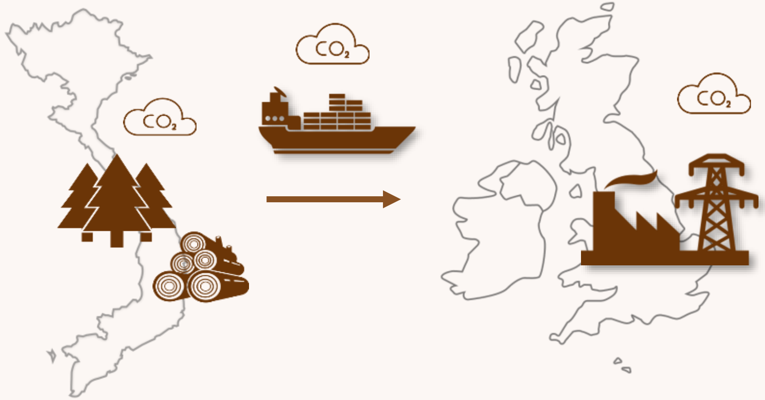
Inaccurate GHG accounting creates the false perception that biomass is a zero-carbon energy source at the point of combustion.

International accounting rules stipulate that bioenergy emissions should be reported only within the land-use sector to avoid double counting between the **energy sector** (where biomass is *burned*) and the **land-use sector** (where biomass is *harvested*). However, protocols for land use accounting mean that **biomass-related emissions are often not accounted for in the land-use sector either**.

Many of the largest forest biomass exporters, such as the US, Canada, and Russia, are not party to the Kyoto Protocol, one of the main ways to account for GHG emissions—leaving these land use emissions unreported.

Country A
(land-use sector)

Country B
(energy sector)

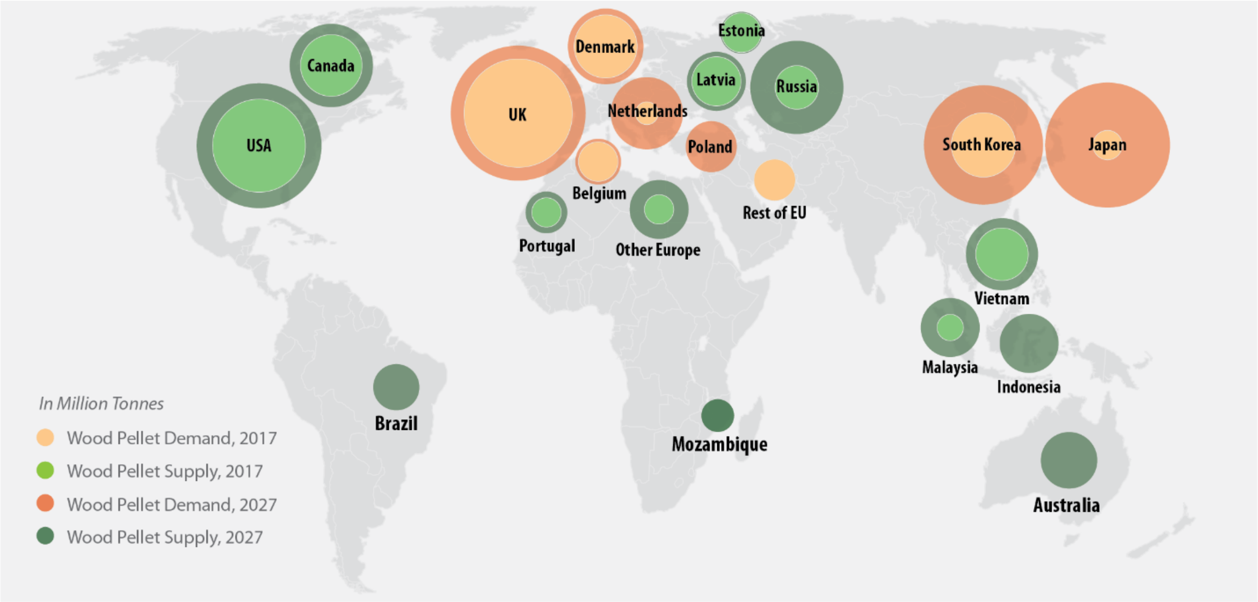


Country A **may not report** emissions from biomass harvesting.

Country B **does not report** emissions from biomass combustion or account for these emissions in climate targets.

Global demand for wood pellets has skyrocketed, a trend projected to continue.

Currently, Europe is the dominant importer of wood pellets, particularly the UK which is the largest consumer and importer of biomass in the world. However, increasing demand from Japan and South Korea could soon rival European demand for wood pellets.



The global wood pellet **trade** is expected to increase by 250% between 2017 and 2027.

Global wood pellet **demand** has increased nearly fourfold in less than a decade.

Source: Environmental Paper Network, 2018.

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Section 3

Bioenergy Emissions Accounting

Photo source: Fábio Nascimento via Mongabay.

Executive Summary

INTRODUCTION

- The greenhouse gas emissions footprint of bioenergy is not well understood.
- Data on the use of biomass for heat, power, and the trade of wood pellets is limited. Modeling of direct and indirect land use change associated with biofuels is challenging and contentious.
- Policymakers must rely on bespoke assessments and a modeling community that lacks alignment and is heavily backed by industry.
- Bioenergy is complex and technical, not well understood by the public, and highly susceptible to greenwashing.
- Bioenergy has received little attention from philanthropic funders and larger international non-governmental organizations.

FINDINGS

- Between 2019 and 2022, burning wood pellets and residues for biomass energy generated 561 million metric tons of carbon, equivalent to the annual CO_2 emissions from 561 coal-fired power plants. (Slide 46)
- In 2023, carbon emissions from biofuel production from key countries totaled between 176 to 213 million metrics tons of carbon. (Slide 57)
- Woody biomass is considered renewable because it can grow back. However, published estimates on the carbon debt of woody biomass for heat and power vary from 5 to over 300 years. Estimates are highly dependent on modeling approaches and the source of the feedstock (e.g., plantation vs. native habitat). (Slide 44)
- The leading model used to assess the carbon intensities of biofuels feedstocks for US biofuels policy, GTAP-BIO, appears to be heavily supported by industry. Published reviews have criticized the model as fundamentally unable to evaluate land use change. (Slide 55)

Executive Summary

FINDINGS (cont.)

- There is widespread academic consensus that biofuels contribute significantly to rising food prices and thus food insecurity. (Slide 64-66)
- Several assessments and CEA's modeling demonstrate that relying on bioenergy as a pathway in the energy transition is an inefficient use of both land and public funds compared with other options (e.g., solar and forest conservation and restoration), even if it were carbon neutral. (Slides 61-63)

RECOMMENDATIONS

- For biomass, greater attention should focus on the risk of large carbon debts, the value of irrecoverable carbon, and the risks of human rights abuses, land grabbing, and biodiversity loss.
- More broadly, for biofuels, the experience of the last decade of policy debate suggests that more attention should focus on the competition between biofuels and food and that simple policy measures (e.g., eliminate food crops as a biofuels feedstock) are more effective and less subject to industry influence than approaches that rely on technical modeling (e.g., carbon intensity thresholds).
- Overall, the unattractive features of bioenergy as a tool in the energy transition compared with other options ought to be elevated in policy and funder fora.

Introduction

CONTEXT

- In 2023, CEA conducted a midterm review of the David and Lucile Packard Foundation's Beyond Bioenergy program.
- Throughout the review of field-level publications and expert interviews, it became apparent that there were not widely available current estimates on the carbon emissions associated with biomass or biofuels.
- Estimates from reviewed literature found the emissions impact from bioenergy to be much smaller, compared to fossil fuels.

PURPOSE

- To conduct a landscape assessment of peer-reviewed literature quantifying the carbon emissions impact of bioenergy.[1]
- To generate a preliminary calculation of the carbon emissions impact of biomass and biofuels.
- To develop an opportunity cost analysis to understand the carbon trade-offs of investing in bioenergy versus forest conservation and restoration.
- To identify i) areas for further research and ii) organizations and/or individuals well-positioned to execute the research agenda.
- To surface broader challenges affecting the field's ability to quantify the emissions impact of bioenergy.

FUNDING

- The David and Lucile Packard Foundation's Beyond Bioenergy program commissioned CEA Consulting to conduct this analysis in the first half of 2024.

[1] The Beyond Bioenergy program is focused on modern biomass (used for industrial energy production) and biofuels. While traditional biomass and biogas are important drivers of bioenergy emissions, they are not a focus of the strategy, and as a result, were not included in the scope of this analysis.

Methodology

INPUTS

- For this analysis, CEA Consulting conducted a literature review of recently published academic and government papers and reports that quantify the emissions from biomass and biofuels consumed for heat, power, and transportation.
- CEA utilized data from the literature review to develop a preliminary calculation of global carbon emissions from biomass and biofuels.
- CEA supplemented this analysis with 11 interviews with experts in the field.

RESEARCH QUESTIONS

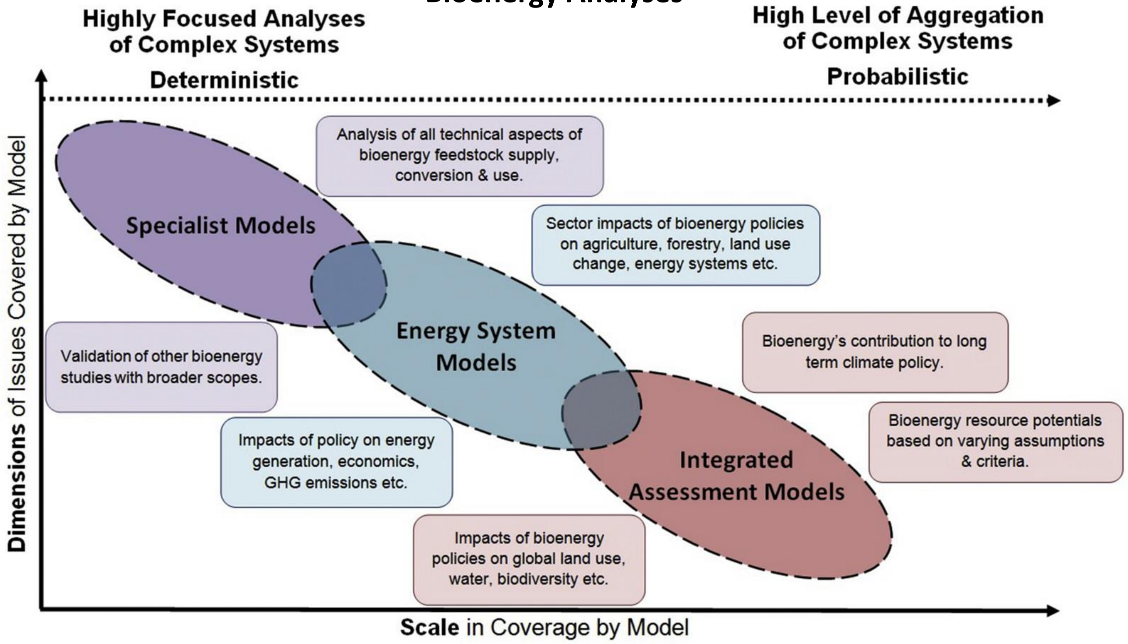
- What is the state of available scholarship on carbon emissions from modern bioenergy?
- Does the field find the lack of harmonized estimates quantifying the carbon emissions impact of modern bioenergy an important gap?
- What data gaps exist in the literature? How might these gaps be filled? Who is well-positioned to conduct this research?
- What is important about the story of bioenergy emissions that is often missed that might compel other energy and climate funders to support this field, even if the total emissions are in fact relatively small?

Biomass

- Current state of biomass modeling
- Differences between available models
- Overview of calculations and findings
- Novel empirical analyses
- Synthetic takeaways

Modelling and methodologies to quantify the carbon emissions from biomass burning vary significantly; 99.5% of available models use a bespoke approach.

Energy Modelling Categories and their Approaches and Capability for Bioenergy Analyses



Source: Welfe, Thornley, and Order, 2020.

Available biomass emissions modelling efforts vary significantly, by:

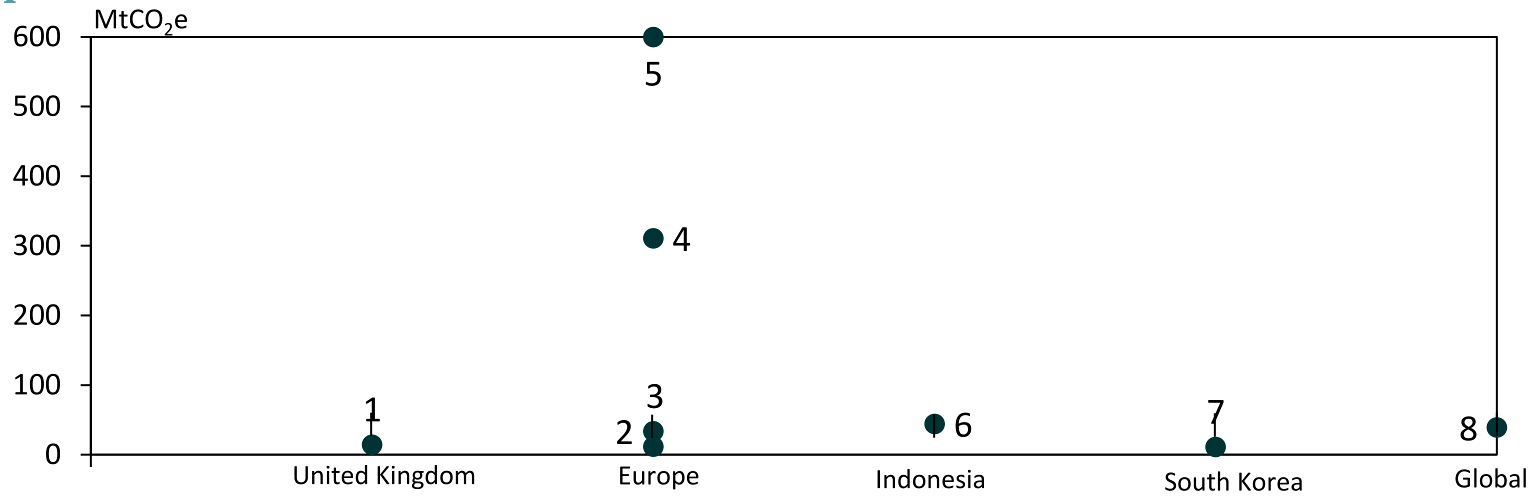
- **Geography:** The majority of analyses included in this review focus on the US Southeast, the greater United States, and the United Kingdom.
- **Feedstocks:** The majority of analyses included in this literature review considered the impact of wood pellets on select forests. Others also included the combustion of mill residues, forest residues, and roundwood.
- **Scope**: Some analyses just quantify emissions from combustion, while others aim for a full accounting of the supply chain (harvesting, pelletizing, transport), in addition to measuring foregone removals.

The wide range of methodological frameworks explains the wide range of estimates on emissions from biomass modeling.

	Description & scope	Advantages	Disadvantages
Integrated Assessment Models	Compiled from distinct sectoral models across physical and social sciences.	Enables user to explore different future pathways and model scenarios.	Heavily driven by simplified assumptions in key input data (e.g., economic growth, regulatory change).
Energy Systems Models	Focused on bioenergy processes, technologies, and feedstocks.	Can analyze detailed aspects of energy systems and allows for the evaluation of multiple technologies and/or scenarios. Prevailing model used by the IPCC.	Does not consider social, environmental, or policy feedback loops.

Bespoke models	Description & methodology
Funk et al (2022)	Uses the GLOBIOM-MESSAGE model to develop estimates of the production of biomass feedstocks in different regions of the world. Downscales GLOBIOM harvest estimates to the U.S. Southeast to quantify the impact to the land sink.
Aguilar et al (2022)	Uses a post-matching difference-in-difference approach to assess whether an industry pelletizing woody biomass affects total carbon stocks in national forest inventory plots.
Manomet study (2010)	Employs a carbon accounting framework to compare fossil fuel scenarios with biomass scenarios producing equivalent amounts of energy, specific to Massachusetts.
Sterman et al (2018)	Develops a dynamic lifecycle analysis tracking carbon stocks and fluxes among the atmosphere, biomass, and soils. Simulates the substitution of wood for coal power, leverages available data on forest carbon fluxes in the eastern US, and uses estimates on supply chain emissions.
Favero et al (2020)	Uses a dynamic global timber model to assess how bioenergy demand affects the forestry sector, forestland, and carbon sequestration.
UK Department of Environment and Climate Change (2014)	Constructs scenarios to represent North American woody feedstocks currently used for the production of pellets and uses a Biomass Emissions and Counterfactual simulation to investigate the GHG intensity and counterfactual land use for each scenario. Used by the UK government.
Chatham House (2021)	Uses estimates from Drax annual reports and forest inventory data to quantify the full lifecycle emissions of US wood pellet imports to the UK.

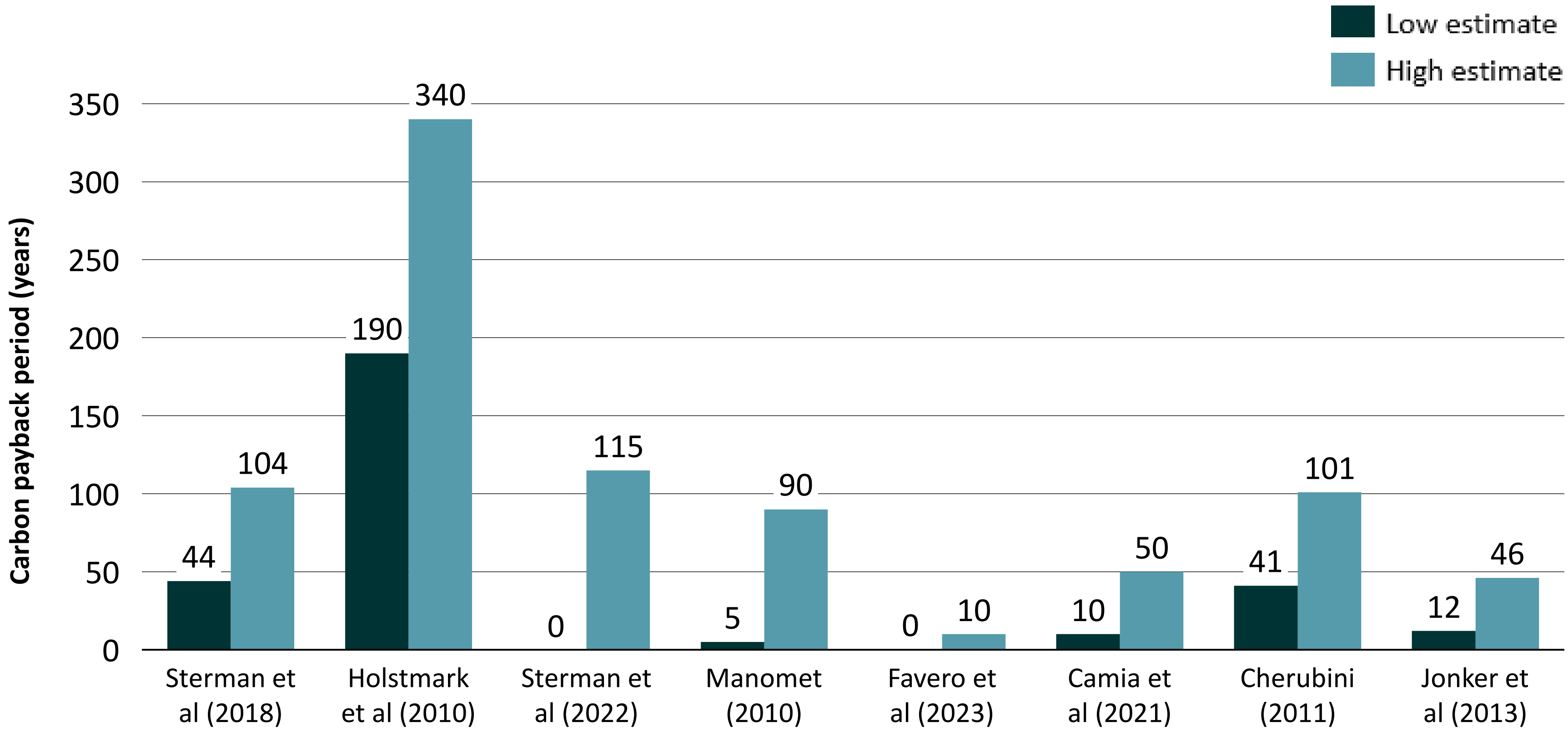
Fieldwide estimates on emissions from biomass combustion vary significantly due to different methodologies, data sources, and scopes.*



Label	Source	Year(s)	Notes/ scope
1	Chatham House	2019	Estimate of emissions of US-sourced wood pellets burnt in the UK
2	Funk et al 2022	2030	Estimate of emissions of US-sourced wood pellets burnt in Europe
3	Funk et al 2022	2050	Estimate of emissions of US-sourced wood pellets burnt in Europe
4	Forest Defenders Alliance	N/A	Annual estimate of emissions from biomass combustion in Europe
5	European Environment Agency	2022	Estimate of emissions from biomass combustion from the EU
6	Trend Asia	2024	Estimate of emissions from biomass production and combustion for 52 coal-fired plants in Indonesia
7	Solutions for Our Climate	2022	Estimate of emissions from biomass combustion for electricity in South Korea
8	CEA Consulting	2015	Estimate of emissions from global wood pellet combustion

**The estimates included on this slide are empirical analyses that have been generated either through modelling or have been compiled from official emissions reporting sources.*

Available modelling presents a wide range of numbers to represent the "carbon payback period" of biomass.



While there is a standard framework to calculate smokestack emissions from biomass, determining lifecycle emissions requires additional analysis that cause the final estimates to vary.

To assess smokestack emissions from biomass, the standard framework is to multiply the following inputs:

1. Data on the volume of biomass feedstocks burnt for energy (e.g., wood pellets, wood residues, black liquor); and
2. An emission factor model to translate how those shifts in land use may affect the amount of GHG emissions being released

Determining the full lifecycle of emissions requires insight into additional components of the biomass production process (e.g., harvest, transport, pelletization), as well as the foregone carbon removals if the forests used for feedstock were still intact.

Indirect emissions

1. Harvest, transport, pelletization, foregone carbon removals

Process-based emissions across fuel supply chain and foregone removals

+

Emissions from combustion

2. Consumption volume from chosen feedstock (e.g., wood pellets, wood residues, black liquor)

Net change in global land use in response to biofuel demand

×

3. Emission factor model (e.g., EPA, IPCC)

CO_2e emissions from changes in land use and land management

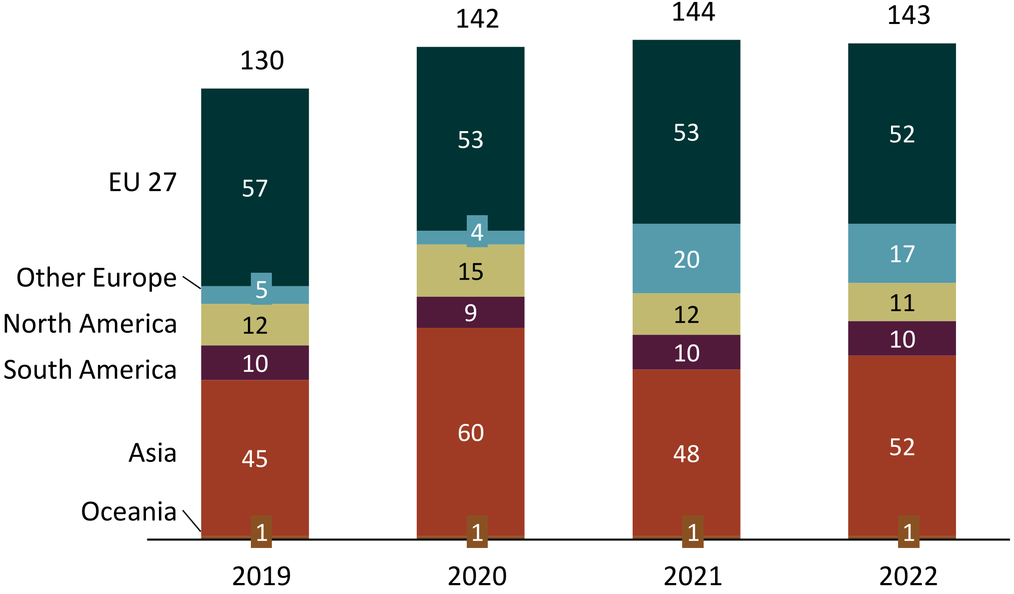
CEA's analysis found that between 2019 and 2022, burning wood pellets and wood residues for energy produced approximately 561 million metric tons of carbon, roughly equivalent to the annual CO_2 emissions of 551 coal-fired power plants.

To generate carbon emissions estimates from biomass, the emissions factor for wood and wood residuals[1] was multiplied by the consumption numbers for wood pellets[2] and wood residues[3], and then summed together.

Our model relies on several assumptions, including:

- Emissions factors between regions are negligible, and a blanket emissions factor from the US EPA can be employed across regions.
- 30% of wood residue production is for energy consumption.

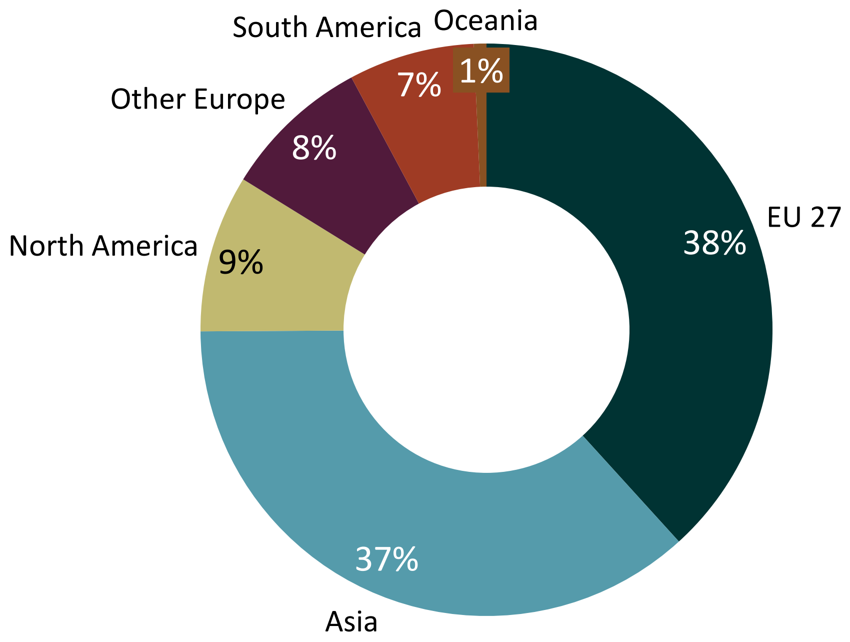
Estimated carbon emissions from wood combustion for biomass energy, 2019 – 2022 *$MtCO_2e$*



Sources:
[1] EPA GHG Emission Factors Hub.
[2] Bioenergy Europe (2020 – 2023) reports.
[3] FAOStat data.

CEA's analysis found that the EU-27 and Asia generated 75% of the carbon emissions associated with biomass energy.

Regional breakdown of carbon emissions (2019-2022)

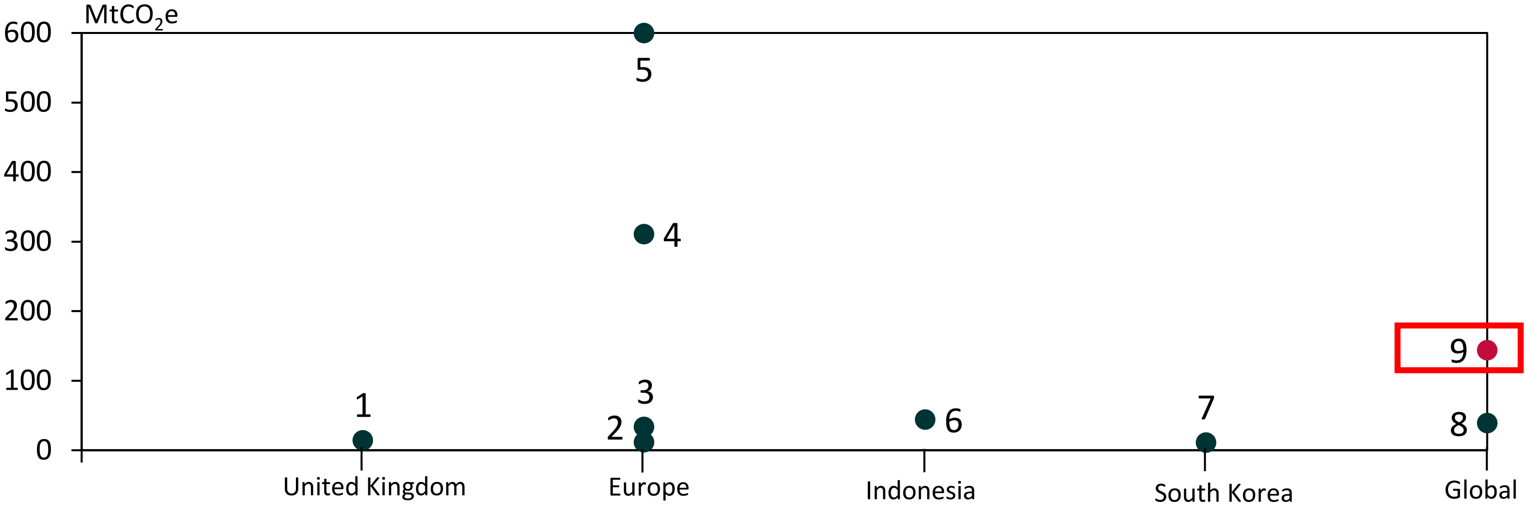


Regional carbon emissions associated with wood pellet and wood residue combustion for biomass energy (2019-2022)

$MtCO_2e$

	Wood pellets	Wood residues	Total
EU 27	150	64	215
Asia	55	150	206
North America	19	30	50
Other Europe	31	15	47
South America	3	35	40
Oceania	0.65	3	4

CEA's 2022 estimate of carbon emissions likely undercounts the total global estimate of biomass combustion emissions.*



Label	Source	Year(s)	Notes/ scope
1	Brack et al 2021	2019	Estimate of emissions of US-sourced wood pellets burnt in the UK
2	Funk et al 2022	2030	Estimate of emissions of US-sourced wood pellets burnt in Europe
3	Funk et al 2022	2050	Estimate of emissions of US-sourced wood pellets burnt in Europe
4	Forest Defenders Alliance	N/A	Annual estimate of emissions from biomass combustion in Europe
5	European Environment Agency	2022	Estimate of emissions from biomass combustion from the EU
6	Trend Asia	2024	Estimate of emissions from biomass production and combustion for 52 coal-fired plants in Indonesia
7	Solutions for Our Climate	2022	Estimate of emissions from biomass combustion for electricity in South Korea
8	CEA Consulting	2015	Estimate of emissions from global wood pellet combustion
9	CEA Consulting	2022	Estimate of emissions from global wood pellet and wood residue combustion

**CEA's analysis included the emissions from wood pellets and wood residues, which are just two of the feedstocks used to generate biomass energy. This analysis does not account for emissions generated from other feedstock types, such as wood chips.*

Lack of available data disaggregated by region and feedstock type present challenges to biomass modelling efforts.

Data insights

- **Disaggregation:** Biomass feedstocks, such as wood pellets, may be used for other purposes (e.g., paper and pulp products). There isn't available data to disaggregate feedstocks by use. For this reason, it can be challenging to quantify the impact of biomass energy on deforestation and forest degradation due to competing uses for wood, such as logging for pulp and paper, furniture, and construction materials.
- **Data availability**: While some countries (e.g., Annex I) regularly report wood residue usage to the IPCC, other countries of interest do not.

Fieldwide insights

- **The specter of co-firing:** Several countries, including Indonesia, South Korea, and Japan support co-firing biomass with coal power as a form of carbon abatement. This trend threatens to entrench coal power and infrastructure and could result in further underreporting of biomass emissions.
- **Carbon payback period**: While estimates on the carbon payback period of biomass are varied, the literature generally agrees that even if bioenergy can pay back the "carbon debt", significant impacts on the carbon sink, biodiversity and human health will have occurred in that timeframe.

Biofuels

- Current state of biofuel modeling
- Differences between models available
- Overview of calculations and findings
- Novel empirical analyses
- Synthetic takeaways

There continues to be substantial uncertainty and a wide range of estimates of the carbon emissions impact of biofuels.

Corn fields of Northwest Iowa

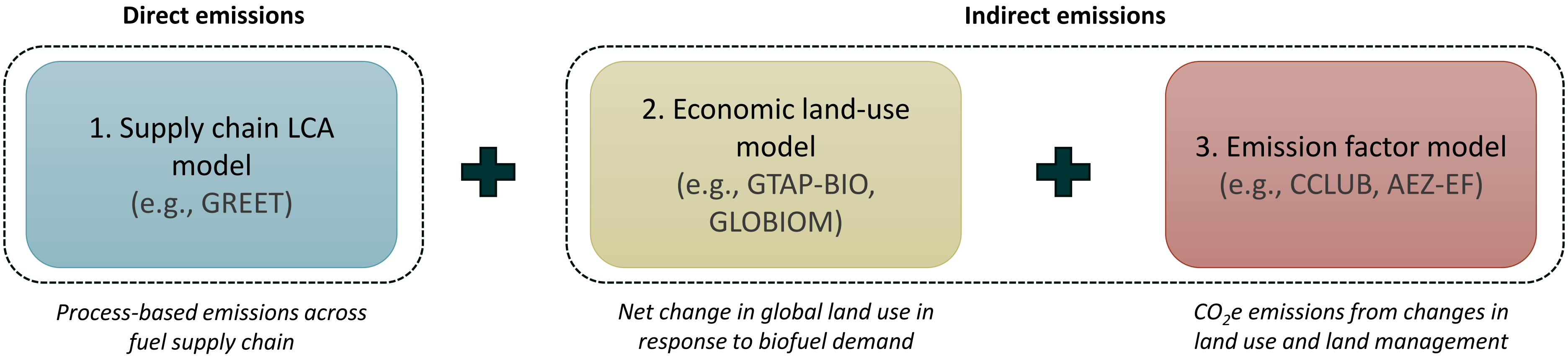
Source: Don Graham via Flickr.

- The majority of emissions accounting for biofuels is related to assessing or developing policies, like sustainable aviation fuel (SAF) criteria or low-carbon fuel standards (LCFS).
- Although there is a standardized framework for evaluating lifecycle emissions from biofuel production (both direct and indirect), there is debate surrounding the individual model components that go into that framework.
- Different regulatory bodies utilize different models, and the models themselves are often heavily influenced and funded by industry/vested interests.
- These dynamics have contributed to continued uncertainty and a wide range of estimates on the climate effects of biofuels. The range of findings even suggests lack of certainty around the direction of impact.

There is a standardized framework for modeling life-cycle emissions from biofuels, but the individual components differ, particularly for economic land-use modeling.

To assess the lifecycle of emissions from biofuel production, the standard modeling framework is to combine the outputs from three different types of models.

1. A supply chain LCA model to calculate direct emissions;
2. An economic model to assess shifts in land use in response to biofuel demand; and
3. An emission factor model to translate how those shifts in land use may affect the amount of GHG emissions being released.



Standard biofuel LCA modeling framework, adapted from ICCT, 2023a

Recent biofuel emissions assessments and leading underlying economic models

Greenhouse gas accounting assessments/methodologies	
40BSAF-GREET 2024	Developed by Argonne National Laboratory and released in April 2024, 40BSAF-GREET 2024 is used to characterize life cycle emissions from SAF production explicitly for the purpose of the 40B SAF tax credit in the US. The model relies on GTAP-BIO to assess indirect land-use change.
California Low Carbon Fuel Standard (LCFS)	Developed by the California Air Resources Board and implemented from 2011 onwards, California's LCFS program incentivizes the adoption of low-carbon transportation fuels based on lifecycle emissions. The policy sets an average carbon intensity that all regulated parties must achieve across fuels they provide for use in California and was last updated in 2020. The model relies on GTAP-BIO to assess indirect land-use change.
Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)	Developed by the International Civil Aviation Organization (ICAO) implemented from 2021 onwards, CORSIA is a voluntary, international carbon offset and reduction scheme for member states of the ICAO. The methodology relies on a harmonization of GTAP-BIO and GLOBIOM to assess indirect land-use change.

Economic models	Description	Advantages	Disadvantages
The Global Trade Analysis Project (GTAP) Model (GTAP-BIO)	Computable general equilibrium model developed by GTAP at Purdue University.	Uses the open-source GTAP database.	Less detailed regional coverage and land representation.
The Global Biosphere Management Model (GLOBIOM)	Partial-equilibrium model developed by International Institute for Applied Systems Analysis (IIASA).	Detailed representation of agricultural sector (regional coverage and land representation).	Does not have feedback from labor, capital, or other parts of the economy.

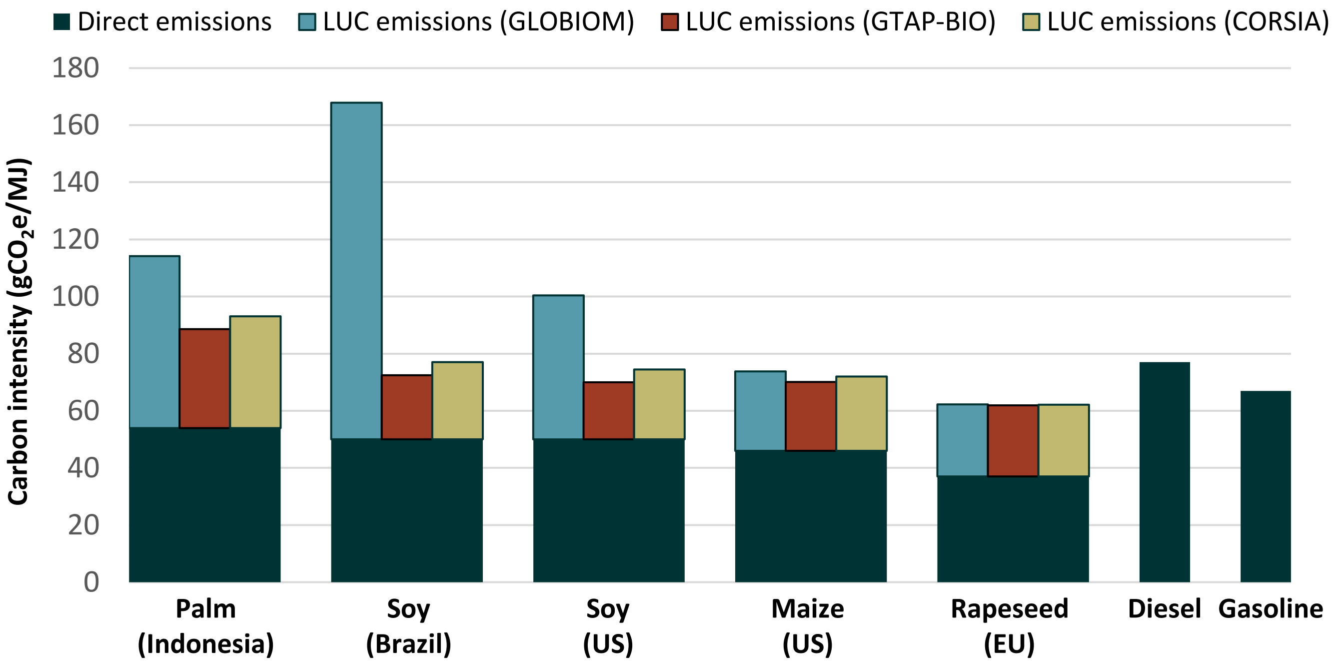
Source: EPA, 2023.

Carbon intensity of biofuels differs based on which economic models are used (e.g., GLOBIOM, GTAP-BIO).

Carbon intensity of different feedstocks related to land-use change (LUC) modeling is the **key difference between the different economic models that feed into the GHG accounting assessments for biofuel production.**

GLOBIOM uses higher, more conservative estimates for emissions from LUC than GTAP-BIO. The CORSIA methodology harmonizes the LUC values from both GLOBIOM and GTAP-BIO, leading to lower overall carbon intensity values.

Carbon intensity, or the sum of direct and land-use change (LUC) emissions, per 1G of biofuel production as described by GLOBIOM, GTAP-BIO, and CORSIA[1]



Source: [1] Table 95, ICAO, 2022.

The contentious GTAP-BIO model plays a dominant role in regulatory analysis for biofuels in the US.

In the US, the dominant economic model for assessing land use change related to biofuel consumption is GTAP-BIO. The model, produced by Purdue University's Center for Global Trade Analysis, is used for regulatory analysis by the California Air Resources Board, International Civil Aviation Organization, and the EPA (EPA, 2023).

Despite its popularity within the US regulatory sphere, **researchers find the model lacks an economic foundation and is particularly unable to evaluate land use changes.** (Berry et al., 2024; Malins et al., 2019) GTAP-BIO's limitations include the following.

1. Lack of empirical basis for its economic parameters
2. Fundamental treatment of land as a resource is inaccurate and grossly underestimates the risk of land conversion (e.g., adjustments to the model have strengthened the assumed role of productivity increases compared with land use changes in meeting feedstock demands without compelling justification)
3. Structure only accounts for actively managed land for timber, excluding the unmanaged land that makes up most of the world's carbon rich land
4. Outdated trade modeling, limiting the predicted effects of US policy on world land use
5. Additional empirically unsupported updates to the model, including unjustified pure assumptions that ensure that to the extent the model claims the need for more cropping area, it does not result in additional land conversion to meet that need

Industry plays a dominant role in biofuel policy globally. Strong trade interests (US, Brazil, Argentina - all members of the Global Biofuels Alliance) seem to be the biggest obstacle to phasing out soy biofuels in the EU Renewable Energy Directive (Transport & Environment, 2023).

In lieu of literature estimating the sector-wide footprint of biofuels, CEA sought to estimate lifecycle emissions for 2023.

2023 biofuel production volume by country

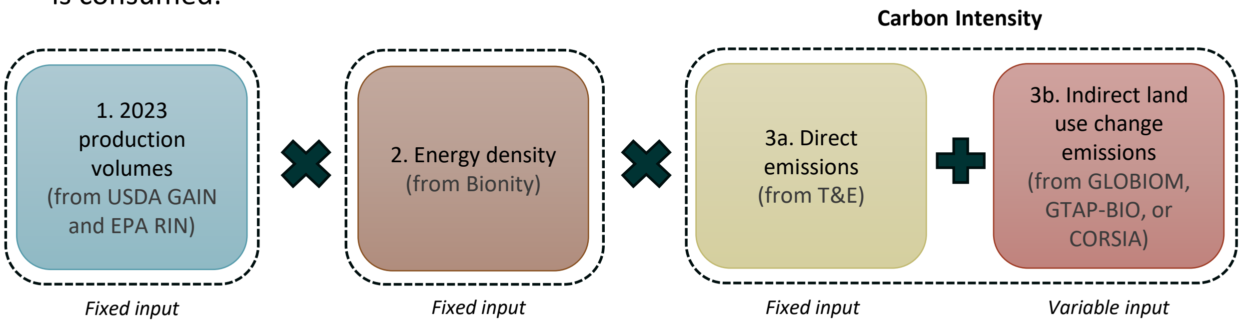
Biofuel by country	2023 production (million liters)
Indonesia biodiesel [1]	13,650
Brazil biodiesel [1]	4,828
Brazil bioethanol [1]	32,950
EU biodiesel [1]	16,200
EU bioethanol [1]	5,570
US biodiesel [2]	6,306
US bioethanol [2]	55,503

Source: [1] USDA GAIN reports. [2] EPA RIN data.
See "Appendix A: Biofuel production details" for feedstock mix.

CEA's literature review and expert consultation found no publications that explicitly calculate the total emissions profile of the biofuel sector. To estimate lifecycle emissions from 2023 biofuel production, CEA combined:

1. 2023 production volumes for each country
2. Energy density
3. Carbon intensity, based on both direct emissions (3a) and indirect land use change emissions (3b)

This methodology relies on assumptions, namely that all biofuel volume produced is consumed.

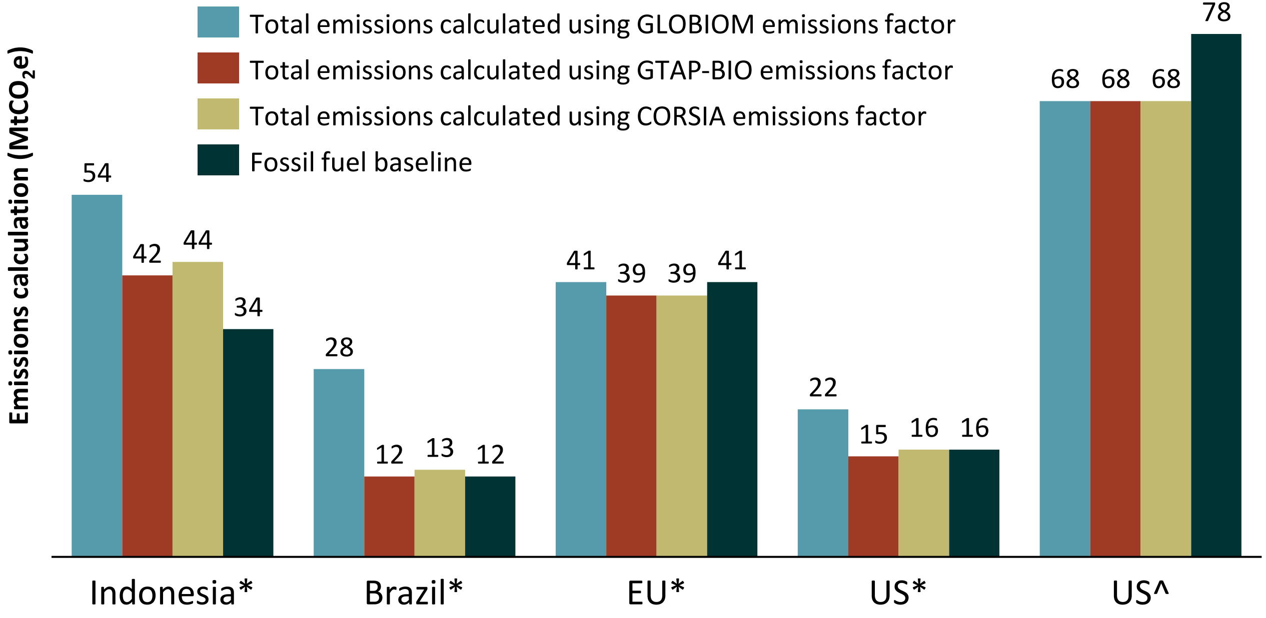


CEA's lifecycle emissions calculation inputs

Using different ILUC values, CEA estimated life cycle emissions from 2023 biofuel production at the country level.

Consistently, emissions from biodiesel are either roughly equal to or greater than the fossil fuel baseline for the same production volume.

Total emissions from 2023 biofuel production per country/region using GLOBIOM, GTAP-BIO, and CORSIA



See "Appendix A: Biofuel production details" for feedstock mix. * = Biodiesel ^ = Bioethanol

Total emissions ($MtCO_2e$) in 2023 from select countries in CEA's analysis

Scenario	Total emissions
GLOBIOM	213
GTAP-BIO	176
CORSIA	180
Fossil fuel baseline	181

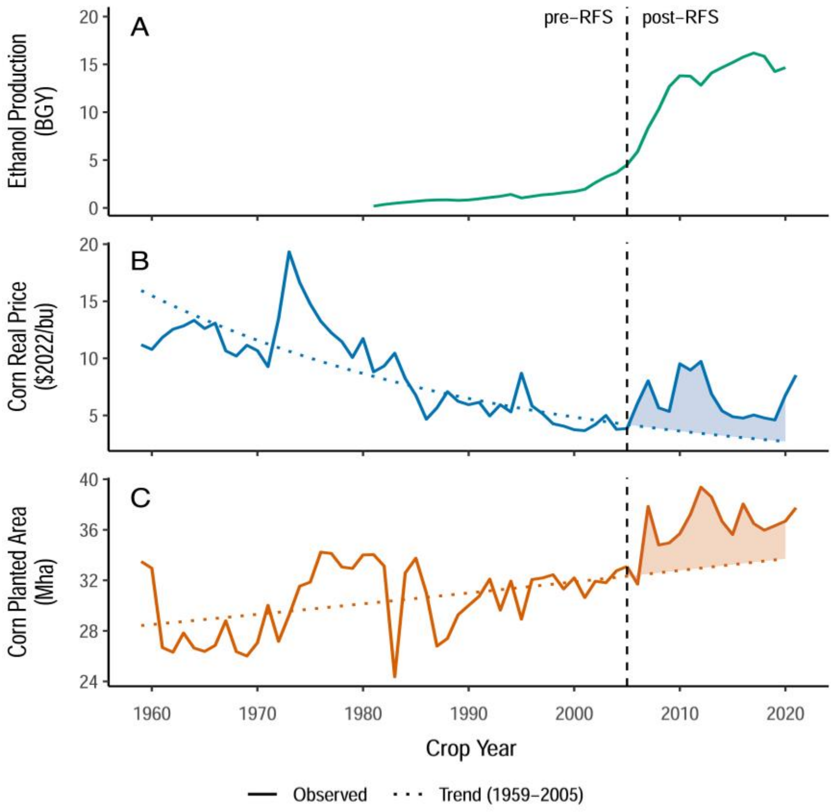
A recent retrospective study assessed the impact of the US Renewable Fuel Standard (RFS).

A 2022 empirical study by Lark et al. combined econometric analyses, land use observations, and biophysical models to retrospectively estimate the effects of the RFS on pricing, cropland, and land use change emissions in the US.

Lark found that, from 2008 to 2016, the RFS:

- **Increased corn prices by 30%** and prices of other crops by 20%
- **Expanded US corn cultivation by 2.8 Mha** and total cropland by 2.1 Mha
- Increased **annual nationwide fertilizer use by 3 to 8%** and **water quality degradants by 3 to 5%**
- Contributed to **320.4 $MtCO_2e$** via conversion to cropland – **24% above the gasoline baseline**

Ethanol production, corn price, and corn planted area pre- and post-RFS



Source: Lark et al., 2022.

Lifecycle emissions of biofuels are almost impossible to model. A diversity of approaches are needed.

Data insights

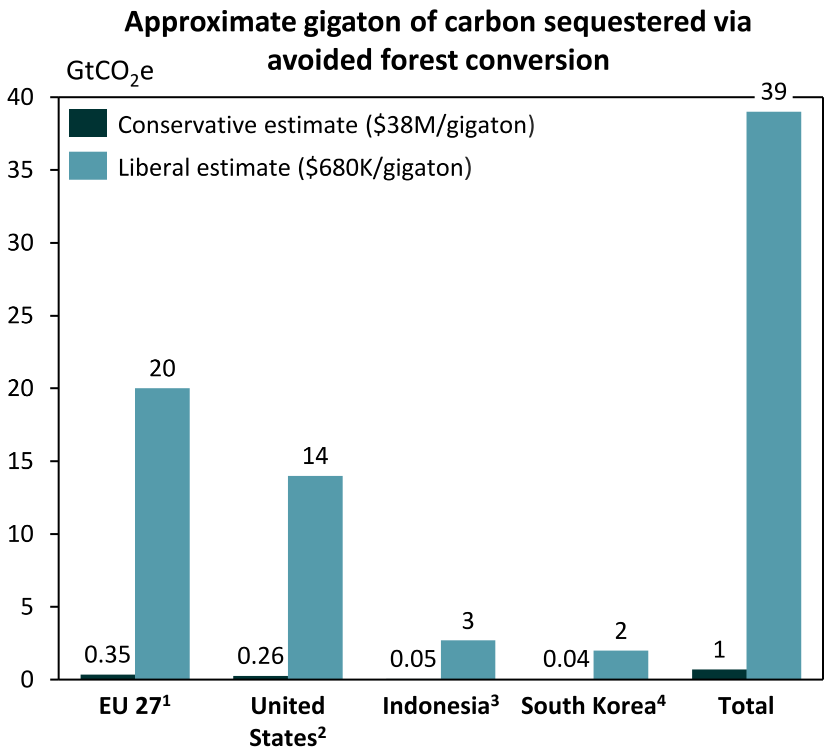
- **Variable emissions estimates:** CEA's calculations exemplify the wide range of estimates you can get for the climate impact of biofuels using different modeling approaches.
- **Assumptions are key:** Despite years of ILUC modeling efforts, the field hasn't come to a consensus on a single number or approach to indirect emissions from biofuels. Industry can influence modeling efforts by funding research that utilizes assumptions that work in their favor (i.e., return ILUC emissions values lower than fossil fuel alternatives).

Fieldwide insights

- **GTAP-BIO controversy:** Despite its popularity within the US regulatory sphere, researchers find the industry-backed GTAP-BIO model lacks an economic foundation and is particularly unable to evaluate land use changes.
- **Empirical analyses:** Novel empirical methods contrast traditional biofuel modeling and highlight policy-driven increases in prices and subsequent increases in cropland expansion, fertilizer use, and water quality degradation.
- **Increasing attention on SAF**: Interviewees cited heightened interest and concern regarding the impact of SAF mandates.

Opportunity Costs

If bioenergy subsidies were reallocated to support avoided forest conversion, at least 1 gigaton of carbon could be sequestered.

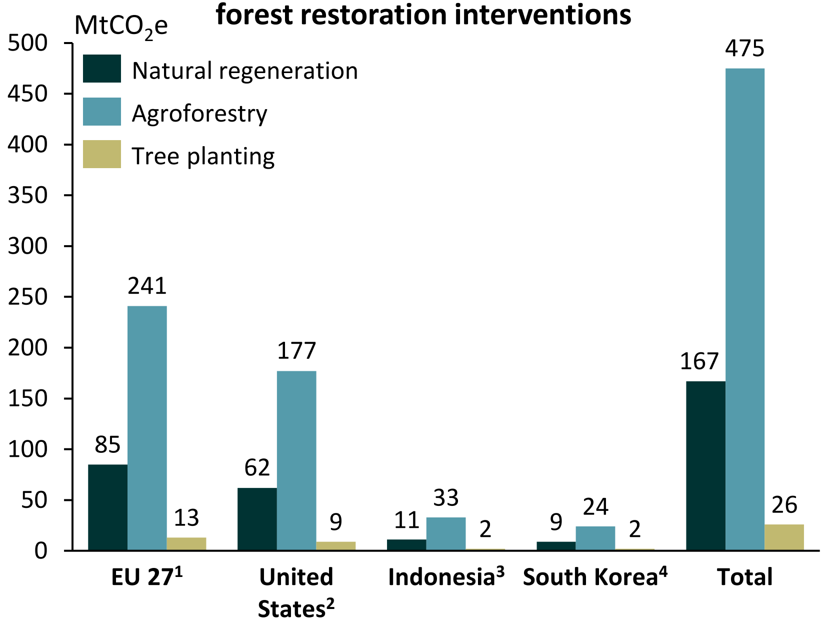


- Griscom et al (2017) provides two estimates on the cost to conserve 1 gigaton of forest carbon: $38M/gigaton (high estimate), $680K/gigaton (low estimate).
- The figure to the left models the approximate gigatons of carbon that would be sequestered if bioenergy subsidies were reallocated to forest conservation via avoided conversion, using the cost factors presented in Griscom et al (2017).
- **The four selected countries could sequester at least 1 gigaton according to conservative estimates,** equivalent to the emissions produced from the entire aviation industry in 2019.[5]

[1] 2022 subsidy estimate: $15 billion. Source: European Commission, 2023.
[2] Average 2022 subsidy estimate: $10.98 billion. Source: Taxpayers for Common Sense, 2022.
[3] Projected 2023 subsidy estimate: $2.02 billion. Source: Reuters, 2023.
[4] 2018 subsidy estimate: $1.5 billion. Source: Solutions for Our Climate, 2020.
5 BloombergNEF, 2022.

Reallocating bioenergy subsidies to forest restoration would generate meaningful carbon sequestration benefits as well (albeit less than avoided conversion because restoration is more expensive).

Approximate amount of carbon sequestered via forest restoration interventions



[1] 2022 subsidy estimate: $15 billion. Source: European Commission, 2023.

[2] Average 2022 subsidy estimate: $10.98 billion. Source: Taxpayers for Common Sense, 2022.

[3] Projected 2023 subsidy estimate: $2.02 billion. Source: Reuters, 2023.

[4] 2018 subsidy estimate: $1.5 billion. Source: Solutions for Our Climate, 2020.

- Trillion Trees (2022) provides estimates on the cost per hectare for three types of forest restoration interventions: natural regeneration ($1,946/ha), agroforestry ($683/ha), and tree planting ($12,968/ha).

- The figure to the left models the approximate million metric tons of carbon sequestered if bioenergy subsidies were reallocated to the different forest restoration interventions. To calculate carbon sequestered per hectare, CEA used an estimate assuming that at peak productivity, 1 hectare can sequester 11 tons of carbon.

- Forest restoration is generally more expensive than conservation efforts (e.g., avoided conversion) and achieves significantly fewer sequestration benefits. Nevertheless, reallocating subsidies to any one of these interventions by country results in significant sequestration benefits – **if all four selected countries immediately reallocated their subsidies to agroforestry, 475 $MtCO_2eq$ would be sequestered, equivalent to the emissions from 122 coal-fired power plants in one year.**

Dedicating crop and forestland to bioenergy is also a poor use of land.

Use for biofuel crops

Rewilding on an area of the same size

Replacing biofuels with solar power and rewilding the remaining area

Source: Transport & Environment, 2023.

Because the planet is inherently land-constrained, bioenergy competes with other land-dependent priorities such as **enhancing forest carbon sinks, conserving and restoring biodiversity, and ensuring food security.**

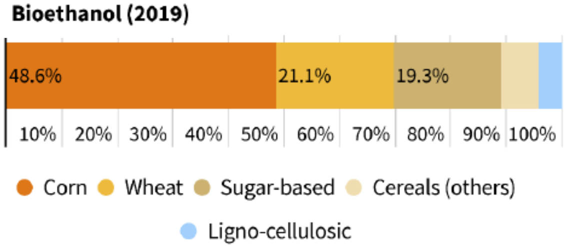
Forests and other vegetation regrowing on an area equivalent to what is currently used just for biofuel crops in the EU (5.3 Mha), **could absorb 64.7 million tonnes of CO_2** from the atmosphere - **nearly twice the officially reported net CO_2 savings from biofuels replacing fossil fuels** (32.9 Mt of CO_2eq). **40 times more land is needed to power a car using biofuels versus a solar-powered vehicle.** Using just 2.5% of the land area currently dedicated to biofuels for solar panels instead would produce the same amount of energy (Transport & Environment, 2023a).

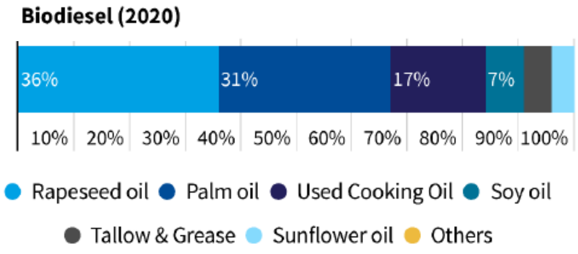
In Indonesia, under the 10% biomass co-firing plan, **up to 1.05 million hectares of forest could be cleared for acacia and eucalyptus plantations to provide wood pellets**. This would result in up to **489 million metric tons of emissions** — a vastly greater amount than the 1 million tons in reduced emissions that co-firing is expected to achieve (Trend Asia, 2022).

The carbon debt from bioenergy could result in the loss of irreplaceable carbon reserves that are critical to avoiding the worst impacts of global warming by 2050. **Since 2010, agriculture, logging, and wildfire have caused emissions of at least 4 gigatons of this irrecoverable carbon.** The world's remaining 139.1 ± 443.6 Gt of irrecoverable carbon faces risks from land-use conversion and climate change (Goldstein et al., 2020).

Globally, the vast majority of biofuels come from food crops.

In Europe, oils derived from rapeseed, palm, soy, and sunflower crops make up 78% of total biodiesel feedstocks. For bioethanol, corn, wheat, sugar-based crops, and other cereals make up 96% of the feedstocks.





Source: Transport & Environment 2022a. *Note: biodiesel data are EU27, bioethanol data are EU27 and UK.*

In the US, although the Renewable Fuel Standard was initially designed to incentivize non-food feedstocks, 94% of US ethanol is derived from corn[1] and ~40% of corn produced is used for ethanol.[2] Biodiesel has been growing in the US for the last decade, with soy as the leading feedstock.

In other major biofuel producing countries, food crops are the leading feedstocks as well.[3]

- In Indonesia, virtually all of the biofuels produced are derived from oil palm
- In Brazil, 97% of ethanol is derived from sugarcane and 68% of biodiesel is derived from soybeans.
- In India, sugarcane is the leading feedstock.
- In Argentina, corn and soy are leading feedstocks.

18% of the world's vegetable oil production goes to biodiesel and 10% of all grains produced globally are used for ethanol.[4]

Source: [1] Center for Sustainable Systems, University of Michigan 2023. [2] USDA 2023. [3] USDA Biofuels Annual Reports 2023. [4] Transport & Environment 2022b.

Biofuels clearly contribute to rising food prices.

A meta review of the economic literature on the effects of biofuels found that "there is a wide consensus that **increasing biofuel demand increases food prices**, with significant impacts seen at the global level" (Malins 2017).

Additionally:

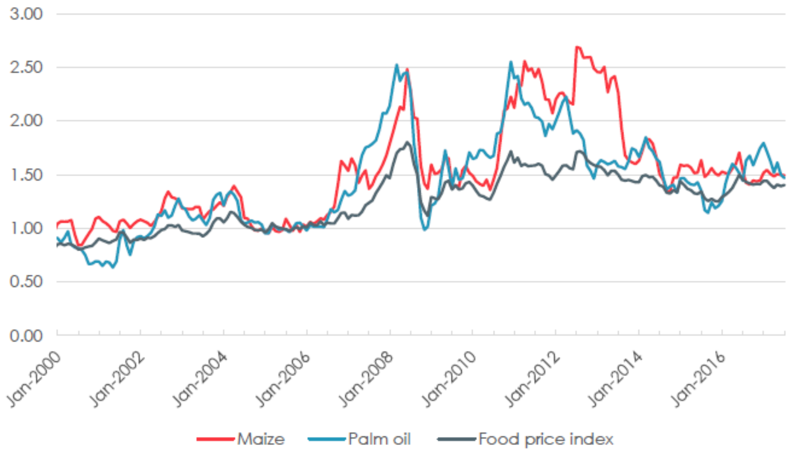
- Food consumption of poor households in the developing world is more sensitive to food commodity prices than those in the developed world, and thus **poorer households will be disproportionately affected** by food price increases caused by biofuel demand (Malins 2017).
- A review of the impacts of the US RFS from 2008 to 2016 found that it increased corn prices by 30% and the prices of other crops by 20% (Lark et al., 2022).
- In Europe, 5.3 Mha of land is fully dedicated to biofuels. If instead, that land was used to grow wheat, **it could provide for the caloric needs of 120M people**, ¼ of Europe's population (Transport & Environment, Oxfam 2023b).
- There is consensus among studies that use of maize ethanol in the U.S. made a **large contribution (20-70%) to increases in maize prices in 2006-2008, during the "food price crisis"** (Malins 2017).
- Devoting food crops to biofuels makes global food markets less resilient to shocks such as the war in Ukraine. T&E estimates that **Europe uses 10,000 tonnes of wheat for ethanol every day (enough for 15M loaves of bread)** and that reducing the use of wheat in EU biofuels to zero would compensate for 20% of Ukraine's wheat exports. (Transport & Environment 2022a).

"Every year we burn millions of tonnes of wheat and other vital grains to power our cars. This is unacceptable in the face of a global food crisis."

Maik Marahrens, biofuels manager at T&E

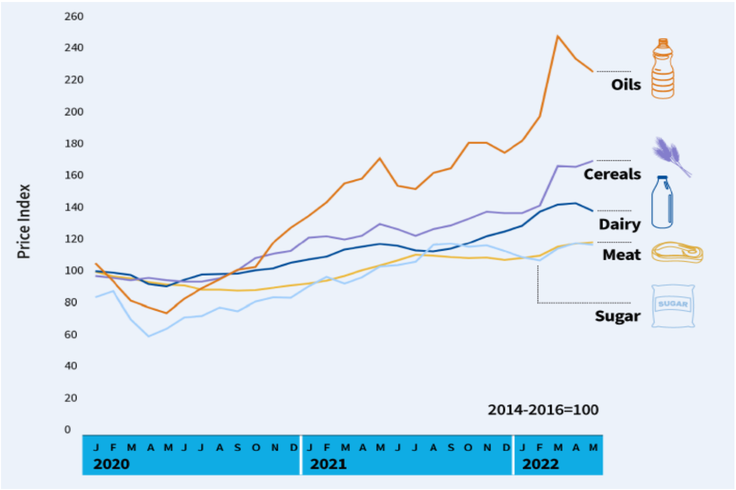
Biofuels make food prices less resilient to other supply shocks and increase food insecurity.

Establishment of the RFS in 2005 (expanded in 2007) is widely thought to have been a significant driver of the food price "crisis" of 2006-2008.



Variation in inflation adjusted price of maize, palm oil, and a food price index[1]

Biofuels demand has contributed to the rising prices of vegetable oils, particularly with the shock of the Ukraine war in early 2022. Ukraine accounts for over 40% of global exports of sunflower oil and is also Europe's largest external supplier of rapeseed oil.[2]



Price increases across key food categories[2]

Source: [1] World Bank Global Economic Monitor Commodities in Malins 2017. [2] FAO Food Price Index, in Transport & Environment 2022b.

Conclusion

Challenges

The industry influences the science.
Bioenergy is a highly technical topic. General audiences and policymakers must rely on technical assessments to understand the climate and land use impacts of bioenergy.

- **Biofuels** – The assessment of climate benefits of biofuel feedstocks depends on ILUC modeling. ILUC modeling requires many assumptions which can lead to a wide range of outcomes. There are only a few models that can be used to analyze ILUC in biofuels and only a few experts globally who are equipped to run them. This concentrates the findings into a few models and research groups, which can be problematic both because it limits the number of voices who can influence the technical debates and because the modeling is susceptible to industry funding and influence.
- **Biomass** – The climate benefits, and lack thereof, of biomass are highly susceptible to green washing. Industry commonly hides blatant deforestation of old growth forests behind a veneer of "sustainable forest management." Activists and climate scientists have been engaged in a battle of competing evidence with the industry for over a decade.

Bioenergy is a convenient, but ultimately ineffective 'quick fix.'
Though bioenergy is viewed as critical to advancing global goals towards net zero, its associated carbon emissions, land use effects, and human rights implications mitigate any benefits.

- **The 2022 Land Gap Report** examines the area of land required to meet projected biological carbon removal (including BECCS) in national climate pledges and commitments submitted by Parties to the UNFCCC. It finds that these pledges rely on almost 1.2 billion hectares of land – close to the amount of current global cropland.
- Although **dependence on BECCS** in Integrated Assessment Models has subsided in the last few years (thanks to some academic critiques, e.g., Field and Mach, 2017), there is still an overreliance on BECCS in 1.5 degree scenarios, leading to questionable policy support. *"If you give a model a cheap answer, it will use it." – Interviewee*
- **Sustainable Aviation Fuels (SAF)** – According to the ICCT, the US has the potential to produce 12.2B gallons of SAF that avoid adverse market or environmental consequences. This is roughly 1/3 of the US's 2050 SAF target (35B gallons). (ICCT, 2023b) An industry-wide focus on SAF has major environmental risks and distracts from the much harder discussion of the need to fly less.

Bioenergy has fallen between the cracks of philanthropic interest.
Despite being a major driver of deforestation and the leading source of renewable energy globally, bioenergy has not received significant attention from either forest, land use, and agriculture funders or from climate and energy funders.

Recommendations for further research

Biomass

Research questions

- What is the full lifecycle of emissions from biomass consumption for energy, globally? If factored into country net zero plans, how far away are these countries from achieving net zero?
- What is the impact of biomass production on the carbon sinks of various geographies (e.g., South Korea, Japan, Indonesia), akin to the analysis from the Funk 2022 analysis?
- What is the opportunity cost, both in terms of production capacity and in terms of climate mitigation to supporting biomass instead of alternatives (e.g., wind, solar, energy efficiency)?
- What is the current extent of land grabbing due to bioenergy?

Research contacts

- Atsushi Yoshimoto, The Graduate University for Adv. Studies
- Cholho Song, Korea University
- Griffith University
- Jason Funk, Conservation International
- Mary Booth, Partnership for Policy Integrity
- Nicklas Forsell, IASA
- Peg Putt, Environmental Paper Network
- Peter Riggs, Pivot Point
- Toby Ackroyd, Wild Europe

Biofuels

Research questions

- How much money is going into lobbying related to SAF tax credits in the US? How much revenue do industry associations have at stake? Research to demonstrate the relationship between industry and research groups publishing on ILUC/climate impact of biofuels.
- How much cropland expansion is expected related to SAF tax credits in the US?
- What is the 'food tax' of supporting biofuels (particularly SAFs)?
- How can retrospective analyses (e.g., Lark et al., 2022) be used to understand the impacts of biofuel mandates on land use change?
- How are existing policies and regulations in the US and EU supporting deforestation and land grabbing globally?

Research contacts

- Adam Smith, UC Davis
- Bhima Yudhistira, the Center of Economic and Law Studies
- Dan Sperling, UC Davis
- Jeremy Martin, UCS
- Professor Andri Gunawan Wibisana, Universitas Indonesia
- Satya Bumi (Indonesian civil society organization)
- Tyler Lark, University of Wisconsin

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Appendix A: Biofuel production details

Biofuel by country	Feedstock mix	2023 production volume (million liters)	2023 production capacity (million liters)	Source* * *Unless specified, source listed covers feedstock mix, production volume, and capacity.*
Indonesia biodiesel	Palm	13,650	16,565	USDA (2023). "Biofuels Annual." Report Number: ID2023-0018.
Brazil biodiesel	Soy (68%), Other (32%)	4,828	10,336	USDA (2023). "Biofuels Annual." Report Number: BR2023-0018.
Brazil bioethanol	Sugarcane (97%)	32,950	54,800	USDA (2023). "Biofuels Annual." Report Number: BR2023-0018.
EU biodiesel	Rapeseed (42%), UCO (24%), Palm (8.5%), Other (25.5%)	16,200	20,115	USDA (2023). "Biofuels Annual." Report Number: E42023-0033.
EU bioethanol	Mix	5,570	8,519	USDA (2023). "Biofuels Annual." Report Number: E42023-0033.
US biodiesel	Soy	6,306	7,896	*Production/feedstock mix*: EPA (2024). "RINs Generated Transactions.“ *Capacity*: EIA (2023). "U.S. Biodiesel Plant Production Capacity."
US bioethanol	Corn	55,503	66,995	*Production/feedstock mix*: EPA (2024). "RINs Generated Transactions.“ *Capacity*: EIA (2023). "Biofuels Explained: Ethanol."

Section 4

Beyond Bioenergy Mid-term Review

Photo credit: Jorge Franganillo/Unsplash.

Introduction and Methodology

Objectives

1) To **document major accomplishments and areas where less progress was made** from the first three years of the David and Lucile Foundation's five-year Beyond Bioenergy strategy (review covered 2020-2022).
2) To **inform internal learnings, future grantmaking, and decisions about the future of this program**, especially as the strategy folds into the Foundation's Global Climate Initiative.
3) To **provide a synthesis of learnings from the last three years** to the program's grantees to help inform their on-going strategies.

Guiding questions

1) In what ways has the strategy managed to achieve the goals set by its 2025 targets?
2) Where did the strategy fall short in achieving its intended objectives?
3) What has the grantee community learned from its work over the last three years?
4) As the Beyond Bioenergy program transitions into GCI, what strategies and geographies ought to be a priority?

Inputs

1) Literature review
2) Three focus groups (Europe, North America, and Asia) including 31 individuals representing 27 organizations.
3) Interviews with experts in the field, including 9 grantees and an independent expert.
4) A strategy-wide grantee survey (44 responses)

Objective 1: Stopping Forests from Becoming the new Coal

2025 Target	Progress rating
Target 1. Projections of coal plant conversions to biomass and new biomass plants are halved by 2025 across the EU and Asia.	Medium
Target 2. Several first mover countries eliminate the zero emissions rating of biomass against climate targets and begin to reduce subsidies to bioenergy.	Medium
Target 3. Low-carbon alternatives to biomass and fossil fuels in heat networks are expanding across Europe.	High
Target 4. Effective protections, including rights and legal protections, are in place to safeguard frontline communities from the public health and climate impacts of the wood pellet industry.	Low

Highlights

- **Elevated public awareness** – e.g., Greta Thunberg’s advocacy, progress with EU Parliament, “toxifying” Drax in UK.
- **Some high-profile wins** vs. individual biomass plans/conversions (e.g., Maizuru City plant cancellation in Japan).
- **The Netherlands** – pulled subsidies from green-washers; **Australia** – first country to excluded native forest biomass from definition of renewable energy; **Massachusetts** – first state to exclude biomass from their Renewable Portfolio Standard (RPS).
- **Commercialization of alternatives** – EU-wide adoption of heat pumps grew 70% in 2022.
- **Frontline and campaign wins** – Some success using public health protections to block the permitting process for a biomass plants and wood pellet mills, particularly in the US Southeast.

Lowlights

- **EU’s RED III** finalized with woody biomass still considered renewable energy (but some small wins in the regulation).
- **“Energy Forest Plantations” -** Indonesia’s potential energy transition through co-firing of wood biomass.
- **War in Ukraine** making campaigning vs. woody biomass very hard.

Objective 2: Reducing demand for high-carbon biofuels that drive deforestation

2025 Target	Progress rating
Target 5. Key EU member states end policy support for high-carbon biofuels, notably palm and soy biodiesel.	High
Target 6. Low-carbon fuel standards (LCFS) continue to gain traction at the state and (possibly) national level in the US.	Medium
Target 7. Large emerging markets in Indonesia and other key countries have enacted renewable energy policies that limit high-carbon biofuels and are increasing support for the transition to electric transportation systems. The growth rate of palm biodiesel consumption in Indonesia has slowed.	Low
Target 8. Both the aviation and maritime industries begin to decarbonize through electrofuels and other innovations and adopt robust sustainability and verification standards for their use of adv. biofuels.	Medium

Highlights

- **Food vs. fuel framing is powerful** – e.g., Pull-back of support for crop-based biofuels in EU after Ukraine war highlighted tension; China's suspension of E10 mandate.
- **EU Member State palm oil phase out** – Austria, Denmark, France, and Portugal have already phased out palm oil imports; Belgium, Germany, Italy, and the Netherlands have drafted measures with plans for phaseout (though loopholes and soy inclusion remain).

Lowlights

- **LCFS/SAF/EVs** – LCF have struggled to gain traction out of US Northwest; some concern that these are "false solutions" (e.g., CA LCFS is supporting expansion of biofuels refineries).
- **Indonesia's B50 target** – Indonesia plans to shift its palm oil supply largely for domestic uses, partially in response to export market constraints and controls. Slow progress toward transportation sector electrification despite strong targets.
- **Expansion of other markets** – Japan, South Korea, India, Brazil.
- **Risks of land-grabbing** - Demand for crop-based fuels – particularly palm oil – is anticipated to accelerate the rate of land-grabbing and dispossession currently facing Indigenous Peoples and other forest-dwelling communities; poor data on this trend.

Objective 3: Empowering Communities and Movements Advocating for Their Rights and for Forests

2025 Target	Progress rating
Target 9. The capacity of Indigenous peoples, community groups, and youth movements to engage in climate and bioenergy policy forums is significantly enhanced.	High
Target 10. National carbon emissions from bioenergy appear accurately and transparently in national accounts, are reflected in UNFCCC reporting and IPCC accounting guidelines, and are available to policymakers and investors.	Low
Target 11. Investors have the information they need to accurately assess risks to investing in bioenergy infrastructure.	Medium
Target 12. The international science community has ready access to the science pertaining to the climate impacts of bioenergy as a result, bioenergy becomes significantly less prominent in climate stabilization scenarios that look out to the end of the century.	Medium

Highlights

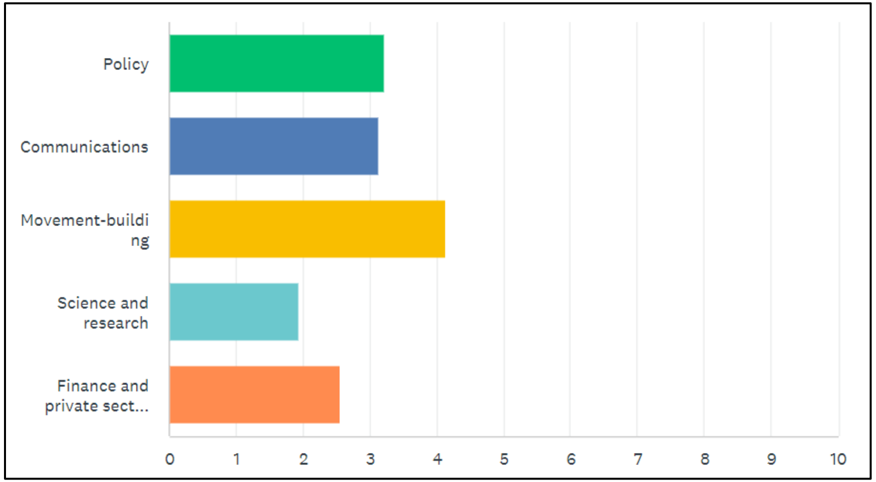
- **Expansion of support for civil society and IPLC** – e.g., Grassroots Organizing pilot program; Climate Justice Pavilion at COP 27.
- **Limited wins with IPCC** – climate models reduced reliance on BECCS; 2019 Special Report on Climate and Land Use acknowledged limited space for 'carbon removals'.
- **Shareholder activism** – e.g., delisting Drax from S&P Global Energy Index; Enviva and Drax's share price drop.

Lowlights

- **Battle of narratives** – increasing strength of the bioenergy industry and the complexity of the topic make greenwashing incredibly easy.
- **Expansion of "net zero" commitments** – Many country level commitments greatly over-rely on BECCS, highlighted in Land Gap Report.
- **Poor bioenergy standards among finance sector** – e.g., bioenergy's classification in EU's Sustainable Finance Taxonomy; BankTrack analysis showing inadequate lending policies for biomass across leading banks.
- **Little success in aligning with the anti-fossil fuel movement or developing strong alternative energy strategies** (e.g., reduced energy consumption and distributed, communally-governed systems).

Forward Looking: Strategy

Where has philanthropic investment failed to match the opportunity?



A survey was distributed to the grantees of Packard's Beyond Bioenergy program. Survey respondents (n=35) were asked to rank (1-5) the following strategies where philanthropic investment to date has failed to match the opportunity: Policy, Communications, Movement-building, Science and research, and Finance and private sector.

Movement-building

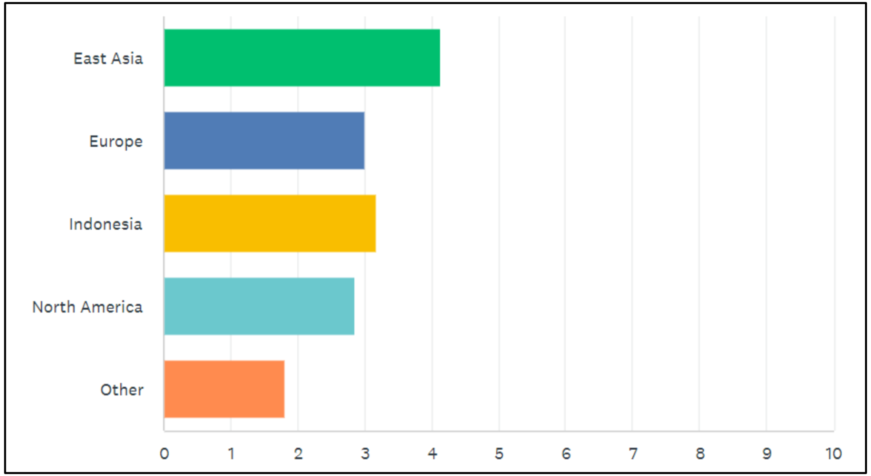
- **Catalytic to improving ground game for campaigners** – As one grantee noted, "building power is essential…at this point the information is well-established. If that was enough to persuade policymakers to do the right thing, they would have done so already."
- **Providing an opportunity for the strategy to operationalize its JEDI Action Plan** – Shifting power and resources to frontline, youth, IPLC, and grassroots organizations via flexible, core support.
- **Broad spectrum of "movement-building" activities** – Grantee and funder convenings, leadership incubators/fellowships, coalition-building with other climate/energy interest groups, security/personnel support.

Communications

- **Foundational to success on other fronts – I**mportant to "flatten the complexity [of the issues]" so that the public and decision-makers can understand.
- **Public engagement is still necessary –** Simplifying the narrative through strategic communications can help communicate the work of researchers and campaigners.

Forward Looking: Geography

Where has philanthropic investment failed to match the opportunity?



A survey was distributed to the grantees of Packard's Beyond Bioenergy program. Survey respondents (n=35) were asked to rank (1-5) the following geographies where philanthropic investment to date has failed to match the opportunity: East Asia, Europe, Indonesia, North America, and Other.

Asia

- **Challenges in Indonesia –** Indonesia's plans to convert its palm oil supply to meet domestic energy demand is concerning; its plan to create "Energy Plantation Forests" to generate additional feedstock for biomass co-firing is similarly troubling to grantees.
- **Growth of Vietnam as a supplier –** Vietnam is now the second largest supplier of wood pellets globally; there is shrinking space for civil society and activist/organizations are under threat by the government.
- **South Korea and Japan as new frontiers for expansion – A**s one grantee noted, South Korea and Japan are the two geographies where "the great preponderance of additional demand is coming from." There is an opportunity to galvanize and build greater alignment among CSOs there.

North America and Europe

- **Opportunities in North America –** The US Southeast and the British Columbia were highlighted as hotspots for wood pellet mill expansion; there is an opportunity to shift even greater resources to BIPOC communities and organizations.
- **Member-state level campaigning in the EU –** Closure of the RED III discussions will refocus attention on member-states.