Research Paper

Environment and Society Centre

Sustainability Accelerator

October 2024

How strategic collaboration on the bioeconomy can boost climate and nature action

Ana Yang, Henry Throp and Suzannah Sherman

CHATHAM HOUSE

Chatham House, the Royal Institute of International Affairs, is a world-leading policy institute based in London. Our mission is to help governments and societies build a sustainably secure, prosperous and just world.

Contents

Summary

- Phasing out the use of fossil fuels in energy, food and material supply chains is an essential step in the climate transition. An increased role for circular and sustainable bio-based products (made from biological resources such as plants, animals and microorganisms) and services (such as carbon sequestration or water cycle regulation) in the global economy could provide an opportunity to address multiple environmental and socio-economic challenges.
- However, good social and environmental outcomes of these national and regional transitions to 'bioeconomies' are not guaranteed and require the establishment of robust regulatory guardrails. Policies for the protection, restoration and management of both ecosystems and bioresources are necessary to ensure that these transitions also boost the broader nature-positive development agenda, particularly in nature-rich tropical countries.
- Consensus is building among public and private sector actors on the important role of bio-based sectors to address environmental and economic development challenges. There has been an abundance of new country and regional bioeconomy strategies, and new bio-based innovations are emerging. At the same time, increasing volatility and geopolitical tension continue to impede effective governance of global issues.
- There are interdependencies between core bioeconomy innovations, which mean that their implementation must be carefully timed to achieve key environmental and social goals across value chains. For example, 'land-sparing' innovations – like alternative proteins that can reduce the amount of land required for crops – can help to enable other opportunities like bioplastics or cross-laminated timber (used in construction) at scale. To demonstrate this, the paper includes an exploratory analysis that assesses how these innovations are reliant on each other to be deployable at scale, how they compete for key resources (including land) and the importance of sequencing their roll-out.
- Despite the political, research and commercial energy being put into bioeconomy transitions, rapid progress in switching to bio-based value chains remains hampered by fragmentation between sectors, as well as differences both in governance and how innovations get to market.
- Transitioning towards national and regional bioeconomies is likely to create a shift in geopolitical dynamics and could give rise to dominant global leaders with rich natural resource endowments, established investments in R&D and processing capacities, such as Brazil and China.

- Three pragmatic steps to improve collaboration and coordination on the bioeconomy include:
  - Fostering clubs of countries with complementary roles across bioeconomies to drive a sustainable transition. These could be strengthened by platforms for international collaboration in a similar way to how the International Renewable Energy Agency (IRENA) supports the energy transition;
  - Facilitating pre-competitive initiatives and peer-led collaborations between large private sector organizations that shape supply chains across bioeconomy sectors, lessons could be drawn from initiatives such as RE100 or SteelZero; and
  - Creating decision-making frameworks that combine policy and technology evidence, potentially through existing groups like the International Resource Panel.
- Collaboration on national and regional bioeconomies is more difficult in an increasingly fragmented geopolitical environment. But there are opportunities to make progress, such as at the G20 – which agreed the High-level Principles on the Bioeconomy in 2024 – as well as at the COP30 climate summit, where host Brazil is uniquely placed to shape these discussions.

01 Introduction

The transition away from economies reliant on fossil fuels to circular and sustainable bioeconomies offers an opportunity to address multiple environmental and socio-economic challenges. However, collaboration between public and private sectors is critical to navigate the resulting trade-offs.

One of the key drivers of climate change and nature degradation is an overreliance on fossil fuels and other forms of non-renewable resource extraction in the production of energy, materials and food.

Alternative economic transition pathways are needed that can reverse the damage done to the global environment, but also robustly support international and national socio-economic development goals.

'Bioeconomies' – where the resources, innovations and principles that underpin economic activity are fully or partly derived from biological systems (as defined in Table 1) – could provide an opportunity to release the global economy from its fossil fuel dependency.[1] At the same time, the coordination and alignment of policies, investors and businesses operating in bioeconomy sectors could create stability and provide more reliable sources of cashflow to support nature-based solutions – which are activities that restore, conserve and manage ecosystems for biodiversity and local development.[2]

But badly managed transitions to bioeconomies could risk negative environmental and social outcomes through poor and extractive land-use practices. Care needs to be taken to ensure policy incentives, investments and innovations materially benefit the social and environmental fabric – with guarantees and protections for land rights – as well as empower local communities to play a central role in their area's development, through free, prior and informed consent. [3]

---

1 In this paper, we use the term 'bioeconomies' to describe the diverse range of different local, national or regional bio-based economies that are possible in different contexts, rather than a homogenic global bioeconomy.
2 Throp, H., Yang, A., Sherman, S. and Waack, R. (2023), *How forest bioeconomies can support nature-based solutions*, Briefing Paper, London: Royal Institute of International Affairs, https://doi.org/10.55317/9781784135539.
3 Ibid.

Table 1. Key concepts and definitions

Bioeconomy	A grouping of activities, defined by the European Commission as 'all sectors and systems that rely on biological resources – animals, plants, micro-organisms and derived biomass, including organic waste – as well as their functions and principles'.[4] This paper considers only land-based bioeconomy activities.
Materials	Materials are 'substances or compounds... used as inputs to production or manufacturing because of their properties. A material can be defined at different stages of its life cycle: unprocessed (or raw) materials, intermediate materials and finished materials.'[5]
Bio-based materials	Materials or products that 'mainly consist of a substance (or substances) derived from living matter (biomass) and either occur naturally or are synthesized, or it may refer to products made by processes that use biomass'.[6]
Transition	Transition is defined as the act of shifting one state (economic, environmental or social) to another. In this paper, the bioeconomy transition is used to describe a shift from a fossil fuel-based production and economic system to a bio-based one in a manner that has an overall positive impact for the environment or society.
Innovation	The act of introducing new methods, ideas or processes into established ways of doing something. It includes both technological innovation and social innovation.[7]
Circular economy	'The circular economy is a system where materials never become waste and nature is regenerated. In a circular economy, products and materials are kept in circulation through processes like maintenance, reuse, refurbishment, remanufacture, recycling, and composting.'[8]

Source: Compiled by the authors.

A transition to a bioeconomic model could have massive consequences for the global labour market, trade and geopolitics, as countries with large biological resources operate with more influence in the global economy and private sector actors pivot to bio-based business models.

If the global economy shifts away from fossil fuels, the political power of major oil-producing countries could wane and re-emerge in a different group of countries endowed with land, nature and other types of natural resources.

But little is known about the range of environmental or social impacts that are possible should countries and policymakers pursue bioeconomies to different extents, or if there is even enough land or other natural resources available to support a bio-based economic transition globally and in contained geographies.

4 European Commission, Directorate-General for Research and Innovation (2019), *Bioeconomy – the European way to use our natural resources: action plan 2018*, Brussels: Publications Office, https://data.europa.eu/doi/10.2777/79401.
5 International Resource Panel (2024), 'Glossary', https://www.resourcepanel.org/glossary.
6 EPA (2009), *'Volatile organic compound (VOC) removal by electropermeabilization: process analysis and modeling'*, https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NRMRL&dirEntryId=231873.
7 Young Foundation (2012), *The Open Book of Social Innovation*, https://youngfoundation.org/wp-content/uploads/2012/10/The-Open-Book-of-Social-Innovationg.pdf.
8 Ellen MacArthur Foundation (2021), 'What is a circular economy?', https://www.ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview.

The potential for strategic decision-making by policymakers and industry leaders within and across bioeconomy sectors is currently hampered by poor knowledge flows, siloed approaches to innovations within energy, food and material systems, and fragmented platforms to debate these issues.

At this early stage of transition, there is an onus on leaders in business and policy to create the conditions for bioeconomies to grow that materially reduce emissions, protect biodiversity and do not perpetuate extractive resource models. Poor decision-making and investment planning could lead to a transition that drives further resource extraction and competition, negative environmental impacts as well as social economic disparity, instead of a socio-economic pathway based on renewable, circular and bio-based principles.

This paper highlights how collaboration could aid decision-making in policy and business circles, focusing on sectors of the bioeconomy that impact supply chains of materials as an under-investigated area of research with a large climate impact.[9]

The paper examines trends that could affect the trajectory of bioeconomies, it then provides recommendations on ways forward. The paper includes a theoretical preliminary analysis that models three archetypal bioeconomy innovations – alternative proteins, bioplastics and cross-laminated timber (CLT) – to highlight the emerging synergies, resource competition and potential trade-offs between these innovations, and to identify gaps in strategic decision-making capacity.

9 For this paper, health and life sciences are not considered within the bioeconomy.

02
Trend spotting

Momentum is building behind the transition to bioeconomies and there is growing consensus among public and private sector actors on the potential role of bio-based sectors in addressing environmental and economic development. However, increasing volatility and geopolitical tension has introduced significant challenges to this approach.

The potential benefits of bioeconomies emerged from technological developments that enhanced biological processes to create products more efficiently and at scale. The EU Commission first brought the bioeconomy to prominence as a concept aligned with national development priorities, and international organizations such as the OECD have a long track record of identifying and analysing different bioeconomy archetypes.

In the last couple of years, the bioeconomy has gained renewed interest, and the concept has been expanded to also encompass a wider range of activities.

Initial bioeconomy innovations were mostly centred around first-generation bioenergy solutions, but there were some negative reactions to these due to adverse impacts on water, biodiversity and land-use competition. In the last couple of years, the bioeconomy has gained renewed interest, and the concept has been expanded, sometimes confusingly, to also encompass a wider range of activities, different aspects of the circular economy and sustainability, and some areas with limited direct impact on land use, such as industrial biotechnology. Interest has also been partly driven by the ever-expanding portfolio of new bio-based materials in construction, packaging and emerging climate solutions such as aviation fuels.

To understand the potential shape of the transition and what responses are needed to achieve environmental and social objectives, the next section of this paper looks at global demand drivers for land, the range of regional bioeconomy characteristics, the diversity of sub-sectors, the directions set by national strategies, rising volatility and geopolitical tensions, and new bio-based goods and services.

Increasing demand for land

Changing demands for biological resources in the coming decades will necessitate strategic decisions over the management of productive landscapes. Economic and demographic transitions will be two of the major drivers of demand for land, others include evolving uses of landscapes to tackle both climate change and biodiversity loss.[10] The following elements will all have an impact on how land use may change.

- **Nature-based solutions to socio-environmental issues –** How land is used will be an essential part of efforts to limit global warming to 1.5°C, as well as to protect and restore biodiversity. As of 2023, 142 countries included quantifiable land-based carbon dioxide removals (CDR) in their climate pledges.[11] Current approaches of afforestation, reforestation and bioenergy with carbon capture and storage (BECCS) all require land.[12] Alongside this, in 2022, 196 countries ratified the Kunming-Montreal Global Biodiversity Framework, which promises restoration and conservation of 30 per cent of suitable land by 2030.[13]
- **Agriculture and food production –** Global agriculture has intensified over the past six decades. Faced with rising food consumption and stagnating crop yields, by 2050 farming could require large increases in land area for both food production and non-food products.[14]
- **Energy –** Global energy demand is rising. This includes growing demand for bioenergy, which accounts for 6 per cent of the current total energy supply.[15] Expansion of other forms of energy such as solar and onshore wind also require land.
- **Urbanization –** The International Energy Agency (IEA) estimates that the current building stock will almost double from 223,000 square kilometres (km^2) to 415,000 km^2 by 2050.[16] Four-fifths of this growth is expected to be in emerging markets in Asia and Africa, driven by increasing populations and rapid urbanization.[17] In Africa, up to 80 per cent of the buildings required in 2050 are yet to be built.[18]

---

10 King, R. et al. (2023), *The emerging global crisis of land use,* Research Paper, London: Royal Institute of International Affairs, https://doi.org/10.55317/9781784135430.
11 Land Gap (2023), '2023 Update', https://landgap.org/2023/update.
12 King et al. (2023), *The emerging global crisis of land use*.
13 Convention on Biological Diversity (2022), 'COP15: Nations Adopt Four Goals, 23 Targets for 2030 In Landmark UN Biodiversity Agreement', https://www.cbd.int/article/cop15-cbd-press-release-final-19dec2022.
14 King et al. (2023), *The emerging global crisis of land use*.
15 Ibid.; International Energy Agency (IEA) (2023), 'Bioenergy', https://www.iea.org/energy-system/renewables/bioenergy.
16 World Green Building Council (2023), 'Every building on the planet must be net zero carbon by 2050 to keep global warming below 2°C: new report', https://worldgbc.org/article/every-building-on-the-planet-must-be-net-zero-carbon-by-2050-to-keep-global-warming-below-2c-new-report.
17 Ibid.
18 Ellen MacArthur Foundation (2021), 'Circular economy in Africa: built environment', https://www.ellenmacarthurfoundation.org/circular-economy-in-africa-built-environment.

— **Materials –** Material extraction has tripled in the last 50 years, based on research by the International Resource Panel. Production has increased at a similar rate for biomass, fossil fuels, metal ores and non-metallic minerals. If these historical trends continue, global resource use is expected to grow strongly until 2050 before stabilizing.[19] Another driver of increasing resource use is shifting consumption habits associated with a rise in living standards and wealth. Plastics pose a clear issue with mounting resource consumption and pollution (Box 1).

Box 1. Global plastic demand

— In 1950, annual global production of plastics was 2 million tonnes. By 2019, this figure had increased by almost 230 times, totalling 460 million tonnes.[20]

— The packaging sector is the most intensive user of plastic, accounting for 31 per cent (143 million tonnes) of plastic use in 2019. Closely followed by the buildings and construction sector, which consumed 17 per cent (77 million tonnes) of the plastic produced in 2019.[21] The OECD expects the use of plastics to more than double between 2019 and 2060, mainly driven by economic growth.[22]

Diverse bioeconomy goals and sectors

There is no one shape of the bioeconomy. The types of bioeconomy strategies that countries choose to deploy depend largely on local factors and constraints, such as the availability of natural resources, feedstocks, access to biotechnology, or natural endowments of biodiversity. While country strategies reflect their local contexts, they tend to incorporate three broad elements: bioresources, biotech and bioecology.[23]

— **Bioresources** – Some countries view the potential of the bioeconomy as a way to boost economic growth and resource security through the production and trade of biological resources distributed across sectors, like bioplastics, energy, construction, and pulp and paper.

— **Biotech** – Certain countries base their bioeconomy strategy on advances in technology, such as artificial intelligence, synthetic biology or novel industrial processes. Gaining a foothold in this area may provide an opportunity for market predominance and for private sector actors to become key players in the research, design and implementation of new technologies.

19 International Resource Panel (2024), 'Global Resources Outlook 2024', https://www.resourcepanel.org/reports/global-resources-outlook-2024.
20 Our World in Data (2018), 'FAQ on plastics', https://ourworldindata.org/faq-on-plastics.
21 OECD data processed by Our World in Data (2022), 'Annual global plastic use, 2019', https://ourworldindata.org/grapher/plastic-waste-by-sector.
22 OECD (2022), 'Global Plastics Outlook: Policy scenarios to 2060', https://www.oecd-ilibrary.org/environment/global-plastics-outlook_aa1edf33-en.
23 Johnson, F. X. et al. (2022), 'A comparative analysis of bioeconomy visions and pathways based on stakeholder dialogues in Colombia, Rwanda, Sweden, and Thailand', *Journal of Environmental Policy & Planning*, 24(6), pp. 680–700, https://doi.org/10.1080/1523908X.2022.2037412.

— **Bioecology** – Strategies that focus on bioecology place sustainability front and centre. A typical bioecology strategy includes an emphasis on the restoration and conservation of biodiversity and support for healthy ecosystems. Countries with natural endowments of biological diversity may look to improve the circularity of their bio-based industries, as well as implement policies and markets that are aligned with biodiversity targets.

The number of sector-specific bioeconomy strategies is also on the rise. There are common long-standing sectors of the bioeconomy, such as agriculture and forestry, where dedicated strategies have been commonplace for a while. Of the strategies assessed for this paper, across all levels of maturity, over 60 per cent had a focus on agriculture, followed by biomass, and then forestry.[24]

Commitments across national strategies are beginning to be targeted at traditionally non-bio-based sectors such as energy, construction and chemicals (notably plastics).

There are also emergent new sectors and sub-sectors of the bioeconomy. Commitments across national strategies are beginning to be targeted at traditionally non-bio-based sectors such as energy, construction and chemicals (notably plastics). These sectors made up around 20 per cent of the national strategies assessed for this research paper. [25]

Increasing number of national and regional bioeconomy strategies

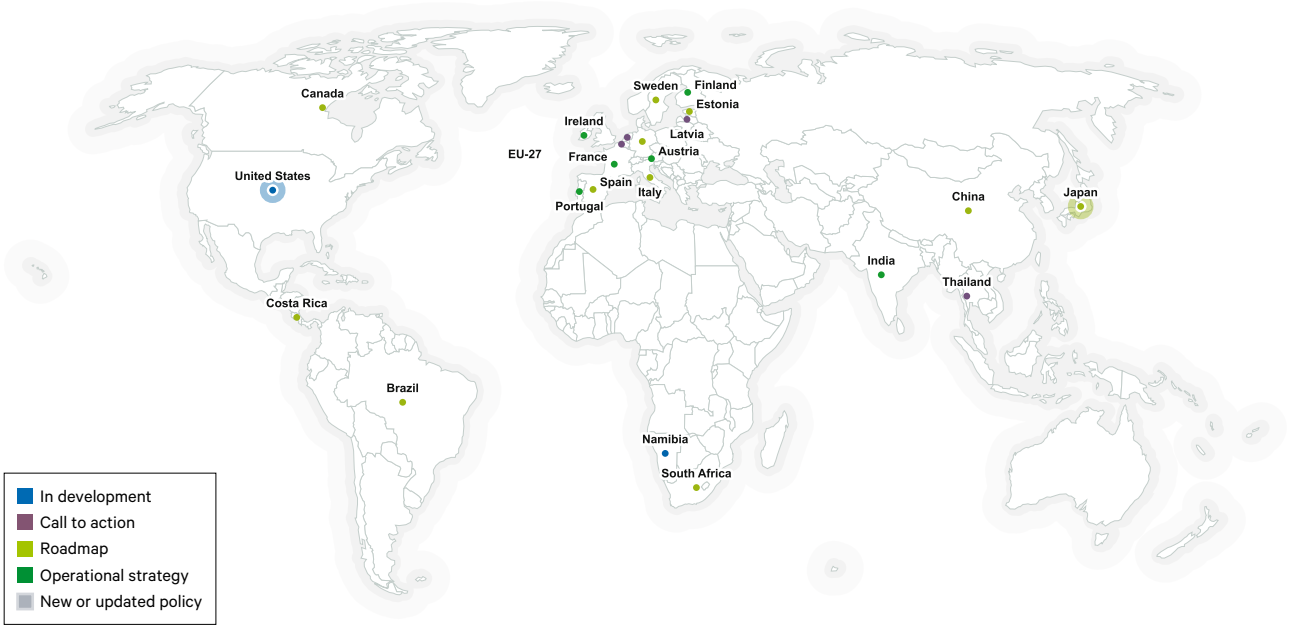
There is significant momentum behind the bioeconomy across a growing number of countries, as demonstrated by an increase in dedicated bioeconomy strategies.

There are over 50 countries that now have some level of national bioeconomy strategy in place, but the high-level goals of these vary depending on different visions and political priorities.

Regional bioeconomy strategies are also growing in number and scale. Driven by common resource endowments, demand centres or development strategies, such as the EU Bioeconomy Strategy, the Nordic Bioeconomy Programme and the East Africa Regional Bioeconomy Strategy (Box 2).

24 Chatham House (2024), 'Policies', https://circulareconomy.earth.
25 Ibid.

Figure 1. A map of assessed bioeconomy strategies included in Chatham House research to date



Source: Circulareconomy.earth (undated), 'National bioeconomy roadmaps and strategies', https://circulareconomy.earth/?policy=be-rs.

Box 2. East African Regional Bioeconomy Strategy

- The East African Regional Bioeconomy Strategy facilitates collaboration between countries including Kenya, Tanzania, Uganda, South Sudan, Rwanda and Burundi.
- The goals of the strategy are to support sustainable development in the region through the bioeconomy, focusing on themes like food, fuels and bio-based industries, as well as health and well-being for local communities.
- One pillar of the strategy is to better use waste streams from agriculture and forests to improve resource efficiency.
- The strategy also aims to encourage trade within the participating countries.

The current national and regional bioeconomy strategies set a direction of travel but often lack clear implementation steps that connect the whole value chain. Of the 23 national bioeconomy roadmaps assessed in the summer 2024 for this paper, there are only six operational strategies that outline time-dependent actions, specified action owners, a governance strategy including monitoring and evaluation, or financing where possible.[26]

26 Ibid.

Increasing volatility and geopolitical tension

Recent decades have seen a weakening of multilateral institutions, and a proliferation of informal and regional arrangements across many areas.

Since 2008, and after decades of accelerated expansion, the global integration of trade, markets and finance has slowed down. Trade conflicts between China and the US, Brexit and the effects of the COVID-19 pandemic on global value chains have exposed and accelerated these changes.[27]

There has been a shift to a more multipolar world, with a wider distribution of wealth and the willingness of states to assert themselves. China and Russia have emerged as global powers that shape both international laws and expected norms and conduct.[28]

This dynamic of increased volatility and uncertainty presents a challenge of how to address global public issues, when the international systems become more based on bilateral deals rather than global rules.

Accelerating private sector innovations

Understanding the types and extent of emerging bioeconomy innovations can indicate how current human and financial capital is allocated and the potential future shape of bioeconomy transitions.

Private sector innovation, research and development with public policy support are central to many national and regional bioeconomy strategies. This demonstrates that policymakers recognize the need to find new ways of shifting from fossil fuel-based goods and services.

Innovation in the bioeconomy can take many forms across the supply chain, including how raw materials are grown, managed and processed. For this research paper, a targeted desk-based horizon scan of innovations in material production and supply systems – with stakeholder input from private sector organizations – revealed a range of new possibilities within the bioeconomy.[29]

This mapping exercise revealed five broad groups of bioeconomy innovation:

— **Substitute products** – such as conversion of atmospheric carbon and energy into microbial protein for use in the food sector.

— **New (bio-based) processes and efficiency gains** – for example, new fermentation processes such as dark fermentation for bio-hydrogen production.

---

27 GIS Reports (2022), 'Multilateralism in crisis: What's next for global governance?', https://www.gisreportsonline.com/r/multilateralism-crisis.
28 European External Action Service (2023), 'Multipolarity without multilateralism', https://www.eeas.europa.eu/eeas/multipolarity-without-multilateralism_en.
29 The innovation horizon-scan was carried out between September 2023 and March 2024. A variety of sources were used to identify bioeconomy innovations, including news articles, academic papers and patents. A stakeholder engagement process was attended by around 30 industry experts from sectors including plastics, construction, chemicals, pulp and paper and agriculture.

- **New (bio-based) products** – including blending of bio- and fossil fuel-based materials, e.g. reinforcing bio-based or traditional products with nano-scale cellulose for use in construction.
- **New behaviours** – such as cultivating landscapes to promote the provision of ecosystem services, greater uptake of sharing approaches for products, changes in diets, or new combinations of cascading use and re-use of biomass.
- **Reducing negative externalities** – a frontier of innovation in the bioeconomy that seeks to address environmental improvements such as genetically modified trees for restoration, satellite imagery to monitor deforestation, or new land management practices that contribute to ecosystem services.

Beyond these specific bioeconomy innovation types, there is also the transformational potential of advances in other fields and general-purpose technologies to shape the trajectory of bioeconomy development. The impact of advances in artificial intelligence are highly uncertain but potentially game changing.

03
Making sense of bioeconomy trends

Despite the political, research and commercial energy being put into the bioeconomy, the switch to bio-based value chains is hampered by fragmentation between bioeconomy sectors, policies and how innovations are rolled out.

The bioeconomy is multi-sectoral and complex. While the strong upswell in emerging bioeconomy innovations points to possible achievable transformation pathways to a more sustainable future, public and private sector approaches to the bioeconomy are fragmented and focused on relatively isolated dimensions of the transition.

A significant challenge for public and private sector actors in supporting the transition is the lack of standardized systems for determining legal rights to, and ownership of, land – which is compounded by weak enforcement of existing regulations in this space. Land rights are needed to both protect the rights of local landowners, communities and indigenous groups as well as to identify those perpetrating detrimental land-use practices – such as land grabbing, the sale of ineffectual carbon credits as well as ecosystem degradation – that can worsen social and environmental outcomes.

Beyond this core issue, there are three types of fragmentation that are further impeding effective management of a bioeconomy transition that could deliver for sustainable societies.

Fragmented bioeconomy sectors

Four key systems – food, energy, materials and nature – will shape the future supply and demand profiles for different sectors of the bioeconomy.

Research and actions have been progressing at various speeds across these sectors, mostly on separate tracks. Organizations like the IEA and the Intergovernmental Panel on Climate Change (IPCC) have conducted deep work on potential ways that bio-based applications across the energy and food systems could transform land-use and impact nature.[30]

Yet, the materials sector – which typically includes the industries of chemicals, metals and mining, and forestry products – is underexplored in terms of bioeconomy innovations. It is a group of industries for which demand is set to increase, but that are typically hard to abate and are not on track for reaching net zero. Material extraction has tripled in the last 50 years, and the International Resource Panel expects this rate of resource extraction to continue up to 2060, driven by population growth and rising living standards and wealth.[31]

There is also renewed demand to put aside land for restoration and conservation of natural ecosystems, as demonstrated by initiatives such as the Global Biodiversity Framework and the UN Decade on Ecosystem Restoration.[32] But there is no framework to address how, when and where it is appropriate to combine productive lands for food, energy and materials, with restoration objectives for natural systems. Critically, no bio-based value chain operates within just one of these four systems. Bioeconomy innovations are complex because each has a reliance and interdependency on available bio-based resources and the future mix of end products.[33] For example, forest biomass, sourced from plantations, is commonly used and re-used within highly complex and connected value chains. Industrially transforming wood creates opportunities for by-products that also can be used as inputs for other products or for the generation of energy.[34]

However, there are currently few cross-sectoral strategic bioeconomy collaborations at scale. This can result in resource competition and a failure to capitalize on opportunities for industrial collaboration.

— **Risks of resource competition:** A purely vertical and sectoral approach makes it challenging to fully consider the impacts of bioresource competition across the bioeconomy, which is compounded by a current lack of integrated national land-use planning across sectors. If sectors pursue vertical integration this can introduce competition for upstream bio-based resources that are productive and ecologically valuable.

---

30 IEA (undated), 'Bioenergy', https://www.iea.org/energy-system/renewables/bioenergy; Shukla, P. R. et al. (eds) (2019), 'Summary for Policymakers', in *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems,* IPCC, https://www.ipcc.ch/site/assets/uploads/2019/11/SRCCL-Full-Report-Compiled-191128.pdf.
31 International Resource Panel (2024), *Global Resources Outlook 2024,* https://www.resourcepanel.org/reports/global-resources-outlook-2024.
32 United Nations Environment Programme (undated), 'About the UN decade', https://www.decadeonrestoration.org/about-un-decade.
33 Philp, J. and Winickoff, D. (2019), *Innovation ecosystems in the bioeconomy*, OECD Science, Technology and Industry Policy Papers, No. 76, Paris: OECD Publishing, https://doi.org/10.1787/e2e3d8a1-en.
34 Gurria P. et al. (2022), *EU Biomass Flows*, Publications Office of the EU: Luxembourg, doi:10.2760/082220.

— **Missed collaboration opportunities:** Sector-focused approaches can also fail to capitalize on 'economies of scope' for bio-based goods and industrial cooperation. 'Economies of scope' are where a diverse range of bio-based resources can be used to create more cost-effective goods and services outside the boundary of traditionally organized operations. Integrated biorefineries offer one mechanism for this but require a supportive ecosystem (Box 3).

Policymakers need to take an ambitious cross-sectoral approach to be able to make effective decisions on how to manage land for nature, biodiversity, food, materials and energy production. Moving from siloes to greater industrial collaboration could help drive energy optimization and support the interplay between multiple applications of the same feedstock, reducing resource use across the supply chain.[35]

Policymakers need to take an ambitious cross-sectoral approach to be able to make effective decisions on how to manage land for nature, biodiversity, food, materials and energy production.

There are many possibilities for new cross-sectoral infrastructure. For example, feasibility studies have been conducted on biorefineries that transform spent coffee grounds into biodiesel and high-value chemicals.[36]

Box 3. Case study: Integrated biorefinery

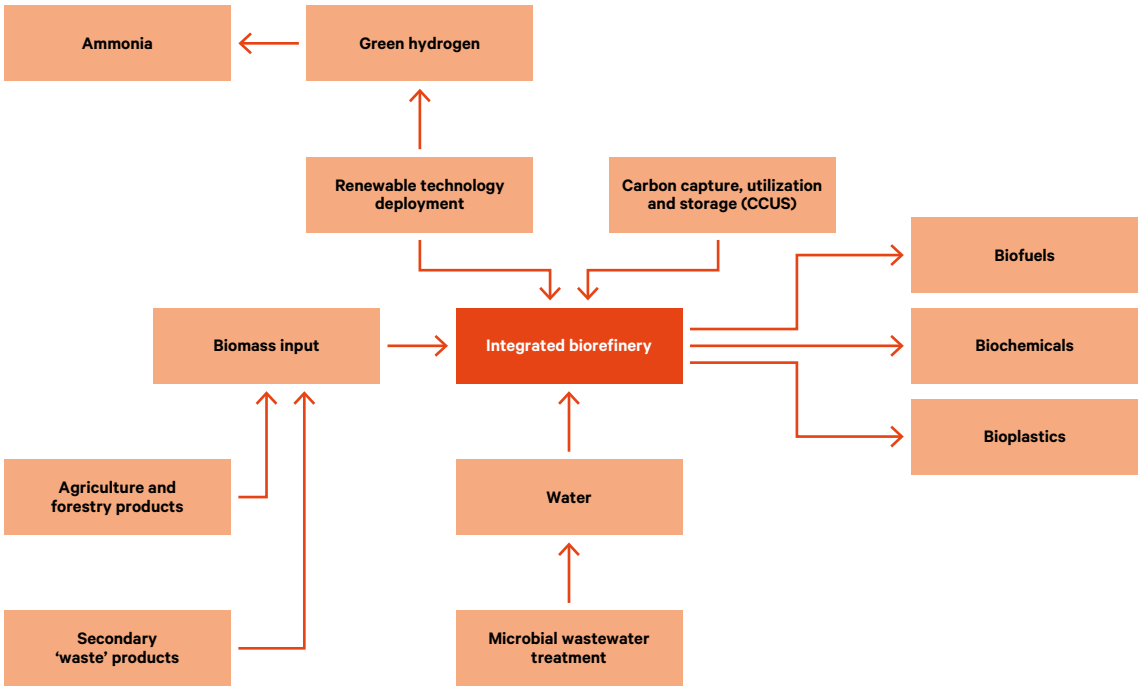
— Biorefineries are resource intensive – requiring energy, water and sources of carbon – in order to produce high-value bio-based products, such as biochemicals and biocosmetics.

— The next generation of integrated biorefineries are designed to be more effective by diversifying their pool of inputs, relying on a range of alternative technologies.[37] Energy can be sourced from renewable technologies, water and feedstock from urban or agricultural waste, and carbon from atmospheric carbon, capture, utilization and storage, as shown in Figure 2.

— The roll-out – and effectiveness – of each innovation is highly dynamic, depending on a number of technological, market and policy factors. For example, costs for the addition of carbon capture storage to biorefineries are highly variable and uncertain.[38] Already, however, many integrated biorefineries are online. For example, the US Department of Energy has funded eight integrated biorefineries that are currently operating at commercial scale.[39]

35 OECD (2023), *Carbon Management: Bioeconomy and Beyond*.
36 Yeoh, L. and Ng, K. (2022), 'Future Prospects of Spent Coffee Ground Valorisation Using a Biorefinery Approach', *Resources, Conservation and Recycling*, 179, https://doi.org/10.1016/jzresconrec.2021.106123.
37 Ibid.
38 IEAGHG (2021), *Biorefineries with CCS*, https://ieaghg.org/publications/biorefineries-with-ccs.
39 Office of Energy Efficiency and Renewable Energy (undated), 'Integrated biorefineries', https://www.energy.gov/eere/bioenergy/integrated-biorefineries.

Figure 2. A schematic to show the range of innovations and resource flows that could impact the design and efficacy of an integrated biorefinery



Source: Compiled by authors based on workshop.

Fragmented governance and policymaking

Sectors of the bioeconomy are varied and amorphous. A myriad of actors across institutional and social settings are involved, with no single actor holding the power to steer the transition alone.[40]

This introduces challenges for how to design and target effective policies. While bioeconomy strategies are emerging, there is currently limited international policy harmonization and coordination.[41] Broadly there is a lack of coherent public policy measures such as clear investment plans, coordinated delivery agencies and monitoring.

Nationally

Within national governments, sometimes even different ministries are pursuing divergent goals depending on their mandate.

Explicit and outcome-oriented integration of broader societal goals into bioeconomy strategies, and vice versa, remains limited or only at the initial stages. Strategies tend to be developed in isolation from each other, with each belonging to a different branch of government and holding its own distinct set of objectives.

40 Dietz, T. et al. (2023), 'Towards effective national and international governance for a sustainable bioeconomy: A global expert perspective', *EFB Bioeconomy Journal*, 3, 100058, https://doi.org/10.1016/j.bioeco.2023.100058.
41 Ibid.

For example, the current bioeconomy debate taking place in Brazil has various ministries leading the discussion from different perspectives, focusing on different outcomes with impacts for different industry sectors.

Internationally

There is a lack of a unified global framework for governing bioeconomies, which hampers effective decision-making over the international impacts of a transition from fossil fuel-based economies to bio-based economies. Currently, regulation is mainly country-specific and aligned with each national development pathway and strategy. This creates numerous overlapping institutional arrangements for the global governance of bioeconomies – coupled with a lack of binding international laws and regulations – and does not provide mechanisms for both funding and capacity transfer.[42]

There is a lack of a unified global framework for governing bioeconomies, which hampers effective decision-making over the international impacts of a transition from fossil fuel-based economies to bio-based economies.

In the absence of an appetite for international cooperation, there are some emerging factors that could enable governments to better join up policies that affect the bioeconomy. These include the mutual benefits of trade in bio-based feedstocks and products, the possibility of accelerated innovation development through research partnerships, and an international understanding – based on the link between zoonotic diseases and nature degradation, demonstrated by the COVID-19 pandemic – that global collaboration can be mutually beneficial. These themes are explored in Chapter 5.

Fragmented innovation systems

A horizon scan conducted by the authors identified a diverse range of potential bio-based applications that could significantly affect current production and consumption models. Whether in a positive or negative way depends on when, how and where they are taken up. The diversity reflects the heterogeneity of international bioeconomies and demonstrates the importance of more joined-up development approaches.

The horizon scan found a concentration of visible innovations in new processes, such as fermentation advances and diversification of feedstocks for, and products from, biorefineries.

42 Ibid.

Many of the more transformative innovations are only enabled when rolled-out in combination with other new advances. For example, there are critical linchpin technologies required for numerous bioeconomy innovations, such as carbon capture and utilization and the harnessing of hydrogen, which would help in implementing innovations like protein from air.

There are many ways that innovations could be adopted simultaneously – for example, at different stages of the value chain, as well as part of an industrial cluster, like integrating carbon capture storage within a biorefinery.

Critically, many identified innovations are technologically possible but not yet commercially viable. Even mature bio-based applications or technologies can lack market readiness or market opportunities due to the low cost of fossil fuel-based alternatives, as demonstrated by the struggle of bioplastics to compete with traditional plastics.[43] This presents significant problems for investment and scaling.

Another area to consider is the landscapes on which many land-intensive technologies depend. Parcels of land provide opportunities to deliver multiple societal and environmental functions – through nature-based solutions. For example, through innovative management practices, like polyculture planting, mosaic forestry or agroforestry.[44]

More importantly, because there are no 'silver bullet' bioeconomy innovations, but rather a suite of useful interventions, strategic decisions need to be made about national industrial policy – such as where the innovation should be and who is trained to work with it – and how it is aligned with landscape policy (e.g. how is the feedstock integrated with cattle schemes and how does it align with plans for conservation set-aside policies).

This is because if innovations are supported on a case-by-case basis, some of the benefits, trade-offs or negative consequences that might occur once innovations are implemented at scale simultaneously may not be known about. This is the case, for example, when planning a landscape policy to grow feedstock for a particular bio-based product, without considering the land spared or used by other bio-based innovations.

43 Rosenboom, J., Langer, R. and Traverso, G. (2022), 'Bioplastics for a circular economy', *Nature Materials*, 7, pp. 117–137, https://doi.org/10.1038/s41578-021-00407-8.
44 Throp, Yang, Sherman and Waack (2023), *How forest bioeconomies can support nature-based solutions*.

04 Innovation systems: Land-use constraints, synergies and trade-offs

This paper's exploratory analysis of three innovations – alternative proteins, bioplastics and cross-laminated timber – demonstrates how these new technologies are reliant on each other to be deployable at scale, how they compete for key resources (including land) and that the sequencing of innovation roll-out is essential.

A lack of investigation into the land-use resource constraints, synergies and trade-offs of rolling out multiple bioeconomy innovations has created uncertainty about which policies and innovations are of merit. In addition, there is no clarity on when bioeconomy transition pathways should be phased out, for example, if they lead to negative outcomes such as landscape degradation.

With the aim of highlighting some of the land-use constraints, trade-offs and opportunities that might play out with the simultaneous introduction of multiple bioeconomy innovations, a basic model was created to simulate the dynamics of three innovation systems.

The analysis was designed to identify the types of opportunities and risks related to land use that decision-makers across government ministries – such as those overseeing the environment, economy and industry – and large supply-chain businesses must navigate.

The focus of the analysis was to investigate two strategic land-use questions related to bioeconomy innovations, which can require large amounts of land to grow feedstocks:

- What are the land footprint and system dynamics of introducing multiple innovations?
- What land-use dependencies are there between these innovations?

Establishing exploratory future innovation case studies

Bioeconomy innovation systems are complex – requiring a web of connected innovations supplying renewable energy, feedstocks and other resources (such as water or hydrogen).

Three illustrative bioeconomy innovations with diverse requirements for land (Table 2) were chosen to illuminate potential interactions between such emerging technologies.

Table 2. Innovations included in the analysis

Innovation	Description	Interaction with land-use system
Alternative proteins	Substitute food-grade proteins sourced from plants, genetic fermentation or lab-grown cultured meats, without the need for rearing livestock and poultry.	Replacing a land-extensive agricultural model for pastureland with a land imprint based on crop production.
Bioplastics	Chemical polymers derived from bio-based feedstocks rather than traditional fossil fuel inputs.	Switching from a fossil fuel plastics production model to an agricultural model that requires additional land.
Cross-laminated timber (CLT)	An engineered timber product that is produced by arranging structural grade lumber crosswise, providing a feasible alternative to concrete building materials.	Produced currently on managed forests.

Source: Compiled by the authors.

Two exploratory scenarios were developed for the analysis to test the speed and extent of roll-out for each individual innovation and as a collective, both to 2050 and 2100.

The first scenario – Far-reaching Transition – simulated a world largely dependent on bio-based products. The second – Limited Transition – simulated a future in which bio-based products play an important role in the market but have not displaced the dominant traditional fossil fuel or heavy emitting products

or technologies. The indicators and variables used for each scenario are shown in Annex B. The results should be interpreted with care. The case studies are not associated with any probabilistic roll-out of these bioeconomy innovations.

Instead, they are presented because they illustrate some of the critical land-footprint dynamics that may emerge if bioeconomies were to play a more significant role in the global economy.[45]

Understanding limitations

The purpose of the analysis is to flag some of the potential land-use synergies and trade-offs that emerge when bioeconomy technologies that require land are rolled out. The methodology is listed in Annex A. The limitations of the experiment demonstrate some of the large uncertainties that exist as innovations are introduced, including the pace of adoption and how and where they are used. The analysis should be interpreted within the context of a number of caveats, listed below in Box 4.

Box 4. Assumptions and caveats

- The analysis is global in scope. It ignores local factors including the location of infrastructure, policies in place and trading relationships.
- The analysis runs to 2100. While some assumptions have been made about the productivity of feedstocks, the relative use of technologies and population changes over this period, the analysis otherwise excludes the roll-out of other technologies during this time.
- Global GDP is adjusted to reflect a hit due to climate change, which will have a negative impact on productivity and cause physical damage associated with global warming. The analysis uses the methodologies and results generated by Burke et al. that correlate changes to global GDP to temperature changes due to global warming.[46]
- The analysis ignores multipurpose uses of land – such as agroforestry or agrivoltaics – instead simplifying this to pastureland, crop land and forest land.
- The interplay of future demand changes is complex. The analysis balances future increases in the demands of larger, wealthier populations with the behaviours that tell us about how those people are consuming. There are some assumptions about demand for each innovation, which are listed in Annex A. The analysis is limited to land footprint and land-use change. Further research would be required to provide full assessments of the social, environmental and economic impacts of each innovation.
- Further research is needed to provide geographical and local context.

45 The case studies were developed based on a storytelling session at a workshop with around 30 key bioeconomy industry players hosted at Chatham House.
46 Burke, M., Zahid, M., Diffenbaugh, N. and Hsiang, S. (2023), *Quantifying climate change loss and damage consistent with a social cost of greenhouse gases*, NBER Working Paper 31658, DOI 10.3386/w31658.

Steady and consistent development is uncommon in successful technological transitions, as exemplified by the growth trends of renewable energy capacity.[47] Equally, external events – either unexpected or predicted – for example, due to conflict, new medicines, climate change or antimicrobial resistant organisms, can change market dynamics in novel ways.

The analysis accounts for some significant increases in variables – such as the non-linear rise in plastic use or the impact of climate change damage on the global economy. Meanwhile, some non-linear possible futures have been ignored: like the adoption of novel technologies towards the end of the century.

Emerging land-use dynamics and their implications

The transition towards bio-based economies is highly uncertain and complex. This analysis does not include a wide range of possible futures, instead it draws out key interactions between innovations within a constrained system to highlight further dynamics to explore.

Policymakers, investors, scientists and entrepreneurs have some capacity to shape the transition. By flagging the dynamics, limitations and trade-offs of available technologies, it is possible to draw out some of their potential implications or identify priority areas for action.

Table 3. Examples of land-use change based on innovation roll-out in the 'Limited Transition' and the 'Far-reaching Transition' scenarios

Results		Reference point	Limited Transition		Far-reaching Transition	
		2023	2050	2100	2050	2100
Grassland for meat production (million hectares)		755	815	473	710	235
Area harvested (million hectares)	Grain	705	725	434	682	242
	Other crops (like sugarcane for bioplastics)	303	406	747	453	1040
Additional cross-laminated timber harvest (additional harvest from 2023 in million hectares)	Forest plantation	0	0.15	0.72	2.26	10.1
	Pastureland	0	1.33	6.25	2.11	9.42
	Agricultural land	0	1.4	6.6	2.53	11.3

Source: Results from authors analysis.
Notes: The scenarios are not associated with any probabilistic roll-out of these bioeconomy innovations. These are not predicted results but are used to show the interplay between the innovations. For example, the changes to grassland for meat production and area harvested for grain relate to the land-use changes from moving from meat to alternative protein diets. The increase in area harvested for other crops relates mostly to sugarcane for bioplastics and some other crops for alternative proteins. New cross-laminated timber plantations are shown as additional to ones already established in 2023.

47 International Energy Agency (2024), 'Renewable Energy Progress Tracker', https://www.iea.org/data-and-statistics/data-tools/renewable-energy-progress-tracker; Roser, M., Ritchie, H. and Mathieu, E. (2023), 'What is Moore's Law?', Our World in Data, https://ourworldindata.org/moores-law.

The two scenarios are not predictions for future bioeconomies but instead show a range of potential impacts on global land footprint associated with rolling out the innovations together at scale. Results for land footprint change are shown in Table 3.

The analysis provided three important insights for these innovations in the context of global trends, like technology adoption and future demand, when adopted simultaneously.

Insight 1. Land-sparing innovations – like alternative proteins – are needed to enable those that require more land – such as cross-laminated timber or bioplastics.

Dynamic: Innovations have various impacts on the land footprint. Alternative proteins can free up grassland used for livestock, which allows for innovations like CLT plantations to be located on released lands.	**Implication:** New demand for bio-based products – and the added land footprint needed to supply them – is only possible at really large scales when in combination with innovations that can spare land, like alternative proteins.

Alternative proteins were the only innovation in the analysis with a clear capacity to reduce land use. In the Limited Transition scenario, this technology reduced the requirement for grasslands by 37 per cent between 2023 and 2100, while the Far-reaching Transition scenario repurposed 69 per cent of grasslands in the same timeframe.

The significant land-sparing potential of alternative proteins is due to the fact that the technology disrupts the livestock industry, which is currently responsible for the largest use of productive lands.[48]

Successful land-sparing innovations such as alternative proteins are essential for diverse bioeconomy transitions. For example, the land-change requirement for CLT is much lower than the pastureland freed up by alternative proteins. Therefore CLT's limited use of land allows other landscape functions to be pursued.

48 Ritchie, H. and Roser, M. (2024), 'Land use', Our World in Data, https://ourworldindata.org/land-use.

Insight 2. Incremental improvements in available innovations – including the production of bioplastics – still require too much land to meet the demand for products across bioeconomies. Such a transition will require the adoption of novel, perhaps yet-to-be-conceived or scaled, land-sparing innovations.

Dynamic: Despite the analysis including productivity and efficiency increases per unit of land, based on previous trends, extra demand for bio-based products like bioplastics still result in large increases of the land footprint.

Implication: There is an innovation gap. Efficiency improvements that go beyond current trends in the productivity of lands or new technologies are required to limit the overall land footprint of bioplastics.

The current suite of innovations is not sufficient to deliver a sustainable global bioeconomy across multiple sectors. It is imperative that the innovation gap is addressed in the coming decades.

The current generation of bioplastic solutions consumes significant resources. To meet future demand for non-grain crops – like sugarcane for bioplastics – the land footprint would need to expand by 444 million hectares or 737 million hectares between 2023 and 2100 (for the Limited and Far-reaching cases, respectively). The sector could take up a significant share of the land made available through other innovations, such as alternative proteins.

However, the analysis ignores many of the more revolutionary innovations and approaches that could play a role in this timeframe. Some of which have the potential to substantially disrupt existing supply chains. Instead, the analysis includes incremental technology changes that follow trends on yield and productivity of agricultural landscapes.

But more breakthrough technologies are possible. 'Landless' food production methods that use a mixture of microbial growth and captured carbon for protein growth, eliminating a reliance on land-extensive crops (those that require large amounts of land to produce in high quantity) as feedstocks, are already beginning to be sold in markets in Singapore.[49] Alternatively, there are new innovations that seek to produce plastics from different feedstocks, including seaweed.[50]

Recognition that the pool of innovations will change can be useful in defining strategies to support needed innovations that can relieve land use. However, technocratic solutions focused on land-management should not solely be relied upon. This is because unintended consequences for emissions or job creation may emerge from adoption of new innovations. Additionally, fledgling technologies do not always prove technologically feasible at scale nor cheap enough to penetrate markets.

---

49 London Stock Exchange Group (2024), 'Solar Foods Launch New Solein-Powered Products', https://www.londonstockexchange.com/news-article/ANIC/solar-foods-launch-new-solein-powered-products/16623861.
50 Ayala, M., Thomsen, M. and Pizzol, M. (2023), *Life cycle assessment of pilot scale production of seaweed-based bioplastic*, Algal Research, 71, https://doi.org/10.1016/j.algal.2023.103036.

Insight 3. It is critical that competing sectors use spared land efficiently to reduce their impact, and research is needed into how best to distribute this land.

Dynamic: Some spared land can be used for new purposes – including through the restoration of degraded land – but there is limited research into how best to distribute land among competing sectors.

Implication: Multipurpose landscapes and demand-side policies are a priority to reduce the land footprint of bio-based products.

In both case studies, demand for construction materials and plastics increased, driven by population and GDP growth. The model apportioned parcels of crop, pasture or forest land to meet this demand for all innovations. Pursuing the current generation of bioplastic technology would be highly land extensive, with the potential for land requirements to exceed availability, whereas land required for CLT can be accommodated by that freed up by alternative proteins. At the same time, there is also a need for the restoration of natural ecosystems – for example repairing degraded lands and soils – on appropriate freed-up land, which would be split between plantation and natural forest restoration.

Policymakers and landowners must navigate trade-offs in order to best manage land to meet society's needs.

Policymakers and landowners must navigate trade-offs in order to best manage land to meet society's needs. For example, little else is possible from a sustainable land-use perspective if bioplastics, in their current form, are pursued. However, it is possible to do more with limited land.

Firstly, one limitation of the analysis is that it assumes landscapes have a single purpose. Landscapes can be designed to serve many functions. In practice, more multipurpose and integrated land management, including with agroforestry and agrivoltaics, can help supply multiple demands for goods and services on the same parcels of land.

Secondly, the analysis underappreciates – and reaffirms – the need for effective innovations, policies and behaviours that reduce consumer demand for products that use virgin raw materials.

Demand-side measures to reduce consumption remain limited, and in some cases, targets are not being met. In the plastics sector, recycled plastic only makes up about 6 per cent of plastic feedstock.[51] Only 15 per cent of waste wood is recycled.[52] In some

51 OECD (2022), *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options*, Paris: OECD Publishing, https://doi.org/10.1787/de747aef-en.
52 Business Waste (undated), 'Wood recycling facts and statistics', https://www.businesswaste.co.uk/your-waste/waste-wood-collection/wood-recycling-facts-and-statistics/#:~:text=Only%20about%2015%25%20of%20waste,of%20wood%20waste%20every%20year.

key markets, circular economy policy targets are also not being met – for example, in the EU, a target to recycle up to 50 per cent of plastic in 2025 will likely not be met by 19 member states.[53]

Government measures to reduce demand for certain products can be politically controversial, because of the potential for industry and societal backlash. But there are established policy routes that can be used. These include mandates and targets, as well as procurement of, and investment in, innovations that enable a more circular infrastructure.

Some of the most promising opportunities lay in redesigning the purpose and function of current assets. For example, within the built environment, there are opportunities to design buildings for their eventual deconstruction so that materials such as wood can be repurposed when the building reaches the end of its life. In the bioplastics sector, there are opportunities to incorporate agricultural waste streams as well as recycled plastics into recycling facilities.

The power of behaviour change – based on cultural customs, costs and consumer preferences – is underrepresented in the analysis, and such change could be a major disrupter of future demand to 2100.[54]

Ensuring environmental and social benefits

The analysis identified some of the land-use resource constraints, trade-offs and synergies of rolling out multiple innovations in the bioeconomy. But making choices over innovation deployment will be based on a much wider range of environmental and societal goals.

The scale of the challenge is large. To limit global warming to 1.5°C by 2050, greenhouse gas emission levels will have to decrease by 84 per cent compared to 2019 levels.[55] The bioeconomy has an important role to play in this objective. However, over a billion people work in the global agricultural sector, which is likely to be most impacted by bioeconomy innovations. These workers must be part of the consideration behind these new technologies – whether that be in protecting certain jobs or creating new roles.[56]

Geographical and political realities will determine where exactly bioeconomy solutions are most suitable both at the local, national and regional levels. Identifying where, how and when elements of the bioeconomy are appropriate requires significant collaboration between the private, public and third sectors.

---

53 European Environment Agency (2023), 'Many EU Member States not on track to meet recycling targets for municipal waste and packaging waste', https://www.eea.europa.eu/publications/many-eu-member-states.
54 Schroder, P. et al. (2021), 'What is the circular economy?', Chatham House, https://www.chathamhouse.org/2021/06/what-circular-economy.
55 Intergovernmental Panel on Climate Change (2023), 'AR6: Climate Change 2023: Synthesis Report: Summary for Policymakers', https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf.
56 Food and Agriculture Organization (2023), 'Almost half the world's population lives in households linked to agrifood systems', https://www.fao.org/newsroom/detail/almost-half-the-world-s-population-lives-in-households-linked-to-agrifood-systems/en.

05
The emerging geopolitics of the transitions to bioeconomies

Transitioning towards bio-based economies brings a new set of geopolitical dynamics and could give rise to new dominant players with natural resource endowments, R&D and innovation investments, and processing capacities.

The Russian invasion of Ukraine has highlighted the dynamic connection between climate and geopolitics. This has been further exacerbated by increasing tension between the West and China. At the same time, climate change impacts will affect natural resource availability such as water, which will negatively impact crop yields and reduce food production, further changing global dynamics.

A transition from a fossil fuel-based economy to a bio-based one brings a different set of geopolitical implications. The dominance and power that comes with ownership, control and access to in-demand resources would shift from current large oil majors to new players with different bio-related endowments.

This shift is set against a backdrop of turbulence and uncertainty. Sustainable technological advancements are proceeding at a great pace and rapidly altering businesses, societies and national priorities. The extent of climate impacts is also likely to affect the abilities of nations to transition to a bioeconomy.

We have highlighted here four emerging geopolitical dynamics that are shaping bioeconomy transitions.

Nature in a 'Paris moment'

At a time when international negotiations on climate are running up against geopolitical and supply chain barriers, there have been recent successes on multilateral agreements to protect nature.

Momentum is growing behind the concept of considering nature in international legal frameworks and development pathways. Countries – including Brazil, Indonesia, China and the US, among others – with large natural resource endowments, such as land and water, are emerging in a unique position on the world stage.

By May 2023, an analysis of 101 developing countries – that submitted their updated nationally determined contributions as part of the Paris Agreement – showed that over 95 per cent had included in some way nature-based solutions for mitigation or adaptation.[57] The link between COVID-19 and the encroachment on natural habitats has also helped reinforce the need for collective action on nature protection.[58]

This momentum culminated in 196 countries signing up to the ambitious 2022 Kunming-Montreal Global Biodiversity Framework.[59] One of the centrepieces of the agreement is a target to restore 30 per cent of all degraded ecosystems and conserve equal amounts of land, water and seascapes.[60]

Nature-based solutions – which are actions to restore, manage or conserve natural ecosystems to provide environmental, biodiversity and social benefits – gained significant support in recent years.[61] While international negotiations on nature might be going through a 'Paris moment', as some frame it, there are many issues to resolve.[62]

Dialogue continues on fairly sharing the benefits and proceeds from the use of digital sequence information (DSI) technologies, which can advance innovation by sharing access to online genetic data and thus replace the need to access and assess physical biological materials. But the rules for accessing DSI remain generally unclear, with some biodiverse nations believing their sovereign rights

---

57 NDC Partnership (2024), *Working with nature-based solutions to address climate change: Trends in NDC Partnership Support*, Insight Brief, https://ndcpartnership.org/sites/default/files/2024-05/nature-based-solutions-insight-brief.pdf.
58 Ray, A. S. and Bhattacharya, K. (2024), 'An Overview on the Zoonotic Aspects of COVID-19', *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences*, 94(1), pp. 9–13, https://doi.org/10.1007/s40011-023-01445-8.
59 Convention on Biological Diversity (2022), 'The Biodiversity Plan', https://www.cbd.int/gbf.
60 Convention on Biological Diversity (2023), '2030 Targets (with Guidance Notes)', https://www.cbd.int/gbf/targets.
61 Throp, H. and Yang, A. (2021), 'Ensuring Investment in Nature Delivers Benefits for All', Chatham House Sustainability Accelerator, https://accelerator.chathamhouse.org/article/delivering-benefits-for-all-when-investing-in-nature.
62 Lacerda, A. (2022), 'It's Time for Biodiversity's Paris Moment', The Nature Conservancy, https://www.nature.org/en-us/what-we-do/our-insights/perspectives/time-biodiversity-paris-moment-lacerda.

and potential monetary gains have been undermined by the commercialization of the technology.[63] This will be a core focus at the United Nations Biodiversity Conference (CBD COP16).[64]

Another challenge will be to align how global conservation and restoration ambitions relate to the development pathways of emerging economies that rely on the extraction of natural resources, like Indonesia, Brazil and India. In 2020, international flows of conservation finance – comprised of different approaches to reallocate financial capital in ways that benefit nature – amounted to between $124 billion and $143 billion. This pales in comparison to the revenues of the extractives sector. For example, the 2023 revenue for the top 40 mining companies was $845 billion globally.[65]

Unfair competition from fossil fuels

There is a current lack of level playing field for bio-based innovations, exacerbated by large-scale fossil fuel subsidies. Such subsidies artificially lower the price of fossil fuels, at either production or consumption, and make the cost of bio-based alternatives relatively higher. Production subsidies can take the form of tax breaks or direct payments, while consumption subsidies include government policy to guarantee cuts to fuel prices for consumers.[66]

There is a current lack of level playing field for bio-based innovations, exacerbated by large-scale fossil fuel subsidies.

Russia, Iran, China, Saudi Arabia and Egypt are the top five subsidizers of fossil fuels, based on share of GDP.[67]

Fossil fuel subsidy reform is a way to encourage investment in renewable carbon use and bio-based options. Repurposing a fraction of this to bio-based innovation could alter the cost-profile of these innovations, bringing them to market more rapidly.

Yet while there is political rhetoric behind removing 'inefficient' fossil fuel subsidies, the vagueness and the intractability of other priorities and industrial policies make their elimination difficult.

---

63 Scholz, A. H. et al. (2022), 'Multilateral benefit-sharing from digital sequence information will support both science and biodiversity conservation', *Nature Communications*, 13(1), p. 1086, https://doi.org/10.1038/s41467-022-28594-0.
64 Convention on Biological Diversity (2024), 'Ad Hoc Open-ended Working Group on Benefit-sharing from the Use of Digital Sequence Information (DSI) on Genetic Resources', https://www.cbd.int/conferences/wgdsi-2.
65 CPIC (2021), 'Conservation Finance 2021: An unfolding opportunity', https://www.cpicfinance.com/news/new-report-conservation-finance-2021-an-unfolding-opportunity; PwC (2024), 'Mine 2024: Preparing for impact', https://www.pwc.com/gx/en/industries/energy-utilities-resources/publications/mine.html.
66 Timperley, J. (2021), 'Why fossil fuel subsidies are so hard to kill', *Nature*, 598(7881), pp. 403–5, https://doi.org/10.1038/d41586-021-02847-2.
67 International Energy Agency (2023), 'Value of fossil fuel subsidies by fuel in the top 25 countries, 2022', https://www.iea.org/data-and-statistics/charts/value-of-fossil-fuel-subsidies-by-fuel-in-the-top-25-countries-2022.

Countries in the G7 and G20 have agreed to remove 'inefficient fossil fuel subsidies', but there is a lack of clarity over what this means or in what timeframe.[68] Indeed, explicit annual subsidies have more than doubled from $500 billion in 2020 to $1.3 trillion in 2022.[69]

Individual countries attempting fossil fuel reform have often faced economic reverberations and a social backlash. For example, Kazakhstan, which is in the top 25 countries for fossil fuel subsidies, erupted into violence in 2022, sparked by a sharp increase in national fuel prices due to the formal end of subsidies for domestic liquefied petroleum gas (LPG).[70]

But this is not inevitable and there are emerging efforts by country alliances to manage fossil fuel subsidy reform. Initiatives like the Beyond Oil and Gas Alliance (BOGA) are increasing their membership while other countries, including Indonesia, the Philippines, Ghana and Morocco, have each introduced policies, such as cash transfers and social support, to compensate for reduction or removal of fossil fuel subsidies.

A transition away from fossil fuels stands to transform global power relations as new value chains are created that introduce different resource powerhouses and potential technology leadership.

New and expanded value chains can shift geopolitical power

The concentration of resources gives economic and political leverage to the countries that possess these assets. As this power shifts away from fossil fuel producers, different national capabilities and dynamics will emerge.

Bioresource endowments

Countries with large bio-based resource endowments stand to drive and shape the configuration of existing and potentially new global production and value chains.

Biomass can come from many sources, including from land dedicated to its growth (such as woody biomass), waste and residual pools. Current concentrations illuminate potential global dynamics of bio-based production across food, energy and materials.

— Asia has the largest area for grazing (10 million square kilometres – km^2), dominated by China (4 million km^2). Followed by Australia (3 million km^2), the US (2 million km^2), Brazil (2 million km^2) and Kazakhstan (2 million km^2).[71]

---

68 Timperley (2021), 'Why fossil fuel subsidies are so hard to kill'.
69 Black, S., Liu, A., Parry, I. and Vernon, N. (2023), 'IMF Fossil Fuel Subsidies Data: 2023 Update', Working paper, IMF: Washington, DC, https://www.imf.org/en/Publications/WP/Issues/2023/08/22/IMF-Fossil-Fuel-Subsidies-Data-2023-Update-537281.
70 Capalla, E. L. (2022), '2022 Crisis in Kazakhstan', CERES, https://ceres.georgetown.edu/research/student-projects/2022-crisis-in-kazakhstan/.
71 HYDE with minor processing by Our World in Data (2023), 'Land use over the long term, world', figure, https://ourworldindata.org/land-use.

- Asia also has the largest area for cropland (6 million km^2), led by India (2 million km^2). Followed by the US (2 million km^2), China (2 million km^2), Russia (1 million km^2) and Indonesia (1 million km^2).[72]
- The greatest area of forest is in Europe, dominated by Russia (8 million km^2). Followed by Brazil (5 million km^2), Canada (3 million km^2) and the US (3 million km^2).[73]

Value-adding capabilities

The potential geopolitical power shift is not just about the location of physical resources. To realize a high-value bioeconomy, production capabilities need to be matched by processing capabilities.

At present, these exist only in a few concentrated locations. Biorefinery capacity is strongly dominated by the US, European Union and China. India and Brazil have large pockets of existing industry and global value chain players that could provide a head start in processing bio-based products.[74]

Converting existing oil refineries so that they utilize bio-based feedstocks – including both forest products and crops, like maize and sugar cane – to produce a variety of bio-based chemicals, plastics and fuels is an emerging opportunity to increase the global production capacity, which could provide a broader base of refineries with a role to play in the transitions to bioeconomies in regions like the Middle East, Southeast Asia and in resource and processing rich countries.[75] Currently, the cost of updating oil refinery technology – especially for hydrotreating, which is required when using bio-based feedstocks rather than those derived from fossil fuels – is a barrier to transitioning existing infrastructure.[76] But the balance could tip in the favour of converting to bio-based feedstock if the cost of fossil fuels increases compared to its market value.[77]

Technology development

Countries that are identifying and investing in key innovations and technologies stand to be at the forefront of bioeconomy transitions.

---

72 Ibid.
73 UN Food and Agriculture Organization (FAO) processed by Our World in Data (2021), 'Forest Resources Assessment: Share of global forest area', https://ourworldindata.org/forest-area#:~:text=This%20visualization%20shows%20the%20breakdown,one%2Dfifth%20of%20forest%20area.
74 Annevelink, B., Chavez, L. G., van Ree, R. and Gursel, I. V. (2022), *Global Biorefinery Status Report 2022*, IEA Bioenergy, https://task42.ieabioenergy.com/publications/global-biorefinery-status-report-2022.
75 FracTracker Alliance (2022), 'Global oil refinery complex, daily capacity, CO2 emissions, and various ancillary products produced', https://maps.fractracker.org/3.13/?appid=8e72a974af4c4fe9ba6875cee03078ee.
76 Fitzgibbon, T., Narimanl, K. and Rot, B. (2023), 'Converting refineries to renewable fuels: no simple switch', McKinsey & Company, https://www.mckinsey.com/industries/oil-and-gas/our-insights/converting-refineries-to-renewable-fuels-no-simple-switch.
77 Su, J., van Dyk, S. and Saddler, J. (2022), 'Repurposing oil refineries to "stand-alone units" that refine lipids/oleochemicals to produce low-carbon intensive, drop-in biofuels', *Journal of Cleaner Production*, 376, p. 134335, https://doi.org/10.1016/j.jclepro.2022.134335.

A transition to a bio-based economy offers emergent high-tech opportunities to establish new markets for products and new methods of production that are not necessarily reliant on existing land endowments. For example:

- The US has focused on harnessing capabilities for bio-manufacturing and biotechnology innovation, commercialization and trade across numerous sectors including chemicals, food, climate change solutions and health.[78]
- New technology allows the controlled growth of bio-feedstocks from microbial sources and atmospheric CO_2 or fungi.[79]
- Countries can also integrate other technology advancements with existing bio-based sectors. For example, Finland is pursuing strengthened knowledge and technology bases, in preparation for the 'next digital leap' in the bioeconomy in which data is used to automate processes and add value.[80]
- Global value chain players across key sectors, such as pulp and paper, consumer goods and biosolutions are all experimenting with bioeconomy innovations in production, feedstock blending, processing and consumer products, which are disrupting fossil fuel-based energy, food and material products.

Realizing the value of potential bioeconomy innovations requires commensurate skills and capacities to develop, deploy and scale-up. In recognition of this, some countries are putting their strategic focus on future bio-based industries. India is creating a skilled workforce for the bioeconomy by expanding activities in strategic areas including synthetic biology and quantum biology.

There are also parallel critical linchpin technologies, dominated by the US and China, which are required for numerous bioeconomy innovations:

- Carbon capture, utilization and storage (CCUS) is still nascent but dominated by the US. These technologies are needed to implement certain bioeconomy advances such as protein production from air. But the future feasibility of CCUS is highly uncertain. Currently, this technology only captures around 50 million tonnes of CO_2 (Mt CO_2) annually. By 2030, the IEA estimates that operational, under-construction and planned CCUS capacity will total 435 Mt CO_2 each year, which is still tiny compared to total energy emissions today, which total 37.4 billion gigatonnes of CO_2 in 2023.[81] The widespread use of CCUS is still hampered by technological, efficiency and cost barriers. Currently, only 1.3 Mt CO_2 are used in the biofuels industry. The US is dominant in this field, with a share of nearly half of operational global CCUS.

---

78 The White House Office of Science and Technology Policy (2023), *Bold Goals for U.S Biotechnology and Biomanufacturing*, https://www.whitehouse.gov/wp-content/uploads/2023/03/Bold-Goals-for-U.S.-Biotechnology-and-Biomanufacturing-Harnessing-Research-and-Development-To-Further-Societal-Goals-FINAL.pdf.
79 Zhang, C., Ottenheim, C., Weingarten, M. and Ji, L. (2022), 'Microbial utilization of next-generation feedstocks for the biomanufacturing of value-added chemicals and food ingredients', *Frontiers in Bioengineering and Biotechnology*, volume 10, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9035589.
80 Ministry of Economic Affairs and Employment, Ministry of Agriculture and Forestry, Ministry of the Environment (2022), 'Bioeconomy Strategy 2022–2023 – Sustainably towards higher value added', https://www.bioeconomy.fi/bioeconomy-strategy-2022-2035-sustainably-towards-higher-value-added.
81 International Energy Agency (2024), 'CCUS Projects Explorer', https://www.iea.org/data-and-statistics/data-tools/ccus-projects-explorer; International Energy Agency (2024), 'CO2 Emissions in 2023: Executive Summary', https://www.iea.org/reports/co2-emissions-in-2023/executive-summary.

— Abundant renewable energy is needed for the bioeconomy transition and China will play a leading role. In principle, renewable energy resources are available in one form or another in most countries, but some countries, namely China, have raced ahead in deploying capacity. China has a leading position in manufacturing, but also in innovation and deployment of renewable energy technologies. The country is also the biggest investor in renewable energy.[82]

Crucially, countries that do not control key biotechnologies may become heavily dependent on the few countries and companies that do. Countries, regions and organizations that have conditions conducive to R&D, including access to early stage capital, protected intellectual property rights and established markets, already have a comparative advantage.

Collaboration in the context of alliances and competition

Competition – and shifting alliances – have become a key narrative when it comes to trade.

Imports of forestry and agricultural products has become increasingly dominated by two countries: the US and China. In 2022, they imported forestry products worth up to $32 billion and $42.3 billion, respectively, almost three times as much as their closest competitor, Germany ($11.7 billion). For agricultural products in 2022, China imported $223 billion and the US $139 billion (compared to Germany's $88.3 billion).[83] The US and China are still strongly bound by their bio-based dependencies. The US receives most of its agricultural imports from regional actors, Canada and Mexico, while China purchases significant amounts of agricultural goods from the US. Brazil is China's top agricultural products importer.[84]

In the last decade, trade of forestry and agricultural products has become increasingly dominated by two countries: the US and China.

Future political turmoil could see countries looking towards allies – or countries willing to trade with both the US and China – to meet their import needs.

Against this backdrop, countries and private sector actors recognize that there is much to gain from having a competitive advantage in the bioeconomy. There are many variables, but industry estimates suggest that biological production

82 International Renewable Energy Agency (2019), *A New World: The Geopolitics of Energy Transformation*, https://www.irena.org/publications/2019/Jan/A-New-World-The-Geopolitics-of-the-Energy-Transformation.
83 Chatham House (2022), 'Resource Trade Data Viewer', ResourceTrade.earth, https://resourcetrade.earth/?year=2022&category=1&units=value&autozoom=1.
84 Ibid.

applications could contribute to a significant economic impact over the next 10 to 20 years.[85] As a result, policies and agendas to foster domestic bioeconomy sectors often enjoy bipartisan political support in the US.[86]

The private sector will be a necessary conduit for research and design for the next generation of biotechnologies – as well as a beneficiary of the financial rewards.

At the same time, trade-offs are emerging. Addressing the biodiversity and climate crises requires collaboration on investment and technology-sharing. But countries also see advantages – from resource security and market opportunities – in protectionist policymaking. While in the private sector, international companies – which have the resources to test and roll-out technologies – have market incentives to grow their own business models.

85 Attal-Juncqua, A. et al. (2023), 'Shaping the future US bioeconomy through safety, security, sustainability, and social responsibility', *Trends in Biotechnology*, 42(6), pp. 671–673, https://doi.org/10.1016/j.tibtech.2023.11.015.
86 Ibid.

06 Navigating geopolitical collaboration across bioeconomies

In the absence of agreed global frameworks and forums, public and private partnerships to progress the bioeconomy will need to coalesce around policy approaches, pre-competitive partnerships and existing global gatherings to identify trade-offs and emerging solutions.

The current space for international dialogue and negotiations is fraught with many competing goals, priorities and capacities.

Given the interconnected nature and impacts of bio-based transitions across resources, trade and technology, there must be mechanisms in place to support strategic decision-making on the multiple trade-offs and pathways open to ensure that nations achieve sustainable goals.

Public and private sector actors will depend on each other's distinct capabilities to transition to a sustainable bioeconomy. Some private sector actors have transnational operations and can have longer investment cycles than the time frames of certain national policy decisions. These actors will play an instrumental role

in shaping global and local interconnected bio-based value chains through large R&D investments, the establishment of international operations, and the delivery of goods and services. Especially in areas where central government ambition may be lacking or slow, the private sector can demonstrate and begin to implement real steps towards sustainable bioeconomies.

However, these actors can also be driven by the profit motives of a limited group of shareholders and, as a result, exacerbate negative environmental and social outcomes. There must be progress on clear public policy signals and guardrails for a bioeconomy transition, and it is critical to establish incentives that drive action towards positive environmental and social outcomes.

A collaborative approach is needed to bring international, national, public and private sector actors together in a way that can negotiate trade-offs, adapt and respond to unexpected consequences, and capitalize on emerging issues and shifting social priorities.

Such an approach is particularly important in the short term as the world faces greater climate impacts. This would necessitate a broader understanding of the utility of circular and sustainable economies that rely on biological processes to maximize efficient resource use and reduce environmental footprints.

It will not be easy. Aspects of the climate transition are increasingly fragmented, and political support is weakening and lacks nuance. Yet, there are some promising emerging spaces for cooperation relating to bioeconomy transitions. This paper recommends three collaboration mechanisms to drive this shift, namely: cooperation between countries with similar bioresources or capabilities, peer-led initiatives, and policy and tech coherence.

Action area 1. Clubs of countries

In a current fraught environment for global dialogue, clubs of national action can connect countries with complementary roles to drive a sustainable transition.

The potential scale and certain dimensions of the bioeconomy transition – across trade, investment and knowledge – bring to the fore conflicting international power and political dynamics. However, current mechanisms for cooperative international problem-solving are not fit to resolve these issues.

Pathway

A collaborative effort across countries with private sector engagement can steer and accelerate bioeconomy transitions that deliver sustainable societies.

Different countries have distinct roles in production and demand, and their coordinated interplay has the potential to catalyse the bioeconomy transition at scale. This also matters both for how to organize infrastructure and connect production with value-adding capacity e.g. biorefineries. There are four key capability areas for the sustainable bioeconomy transition.

- **Production and resource endowments.** Countries with existing bioresource endowments, such as Brazil and the US, can play a role to improve sustainable production systems, advance alternative species with less harmful environmental impacts and expand into higher value-added uses of biomass.
- **Processing.** Advances in processing capabilities, such as biorefineries, through research and development can make a significant contribution to the transition. This can also occur through the creation of bio-industrial parks or clusters that draw together resources, relevant actors and businesses, as has occurred through the EU Bio-based Industries Joint Undertaking.
- **Demand centres.** Countries can put in place initiatives to strengthen demand for sustainable bio-based products at scale. For example, Canada and Thailand are both developing procurement programmes that influence markets and stimulate demand for sustainable products.
- **Technology and skills development.** Countries can promote international collaboration on knowledge creation, talent mobilization (as seen in Thailand) and technology transfer to enable adoption, where relevant, of innovations that drive environmental improvements.

While opportunities exist to integrate bioeconomy cooperation mechanisms into existing international forums, they are quite diffuse. See Table 4 for an overview.

Table 4. International institutions relevant for the governance of bioeconomy pathways

Market and economic	Knowledge (research and innovation)	Informational (labels, standards, verification)	Commitment and agenda
WTO	Biofuture Platform	Roundtable on Sustainable Biomaterials (RSB)	Convention on Biological Diversity (CBD)
OECD	Global Bioeconomy Council	The Global Bioenergy Partnership (GBEP)	UN Convention to Combat Desertification (UNCCD)
UN Conference on Trade and Development (UNCTAD)	Food and Agriculture Organization	International Organization for Standardization (ISO)	UN Framework Convention on Climate Change (UNFCCC)
G20, G7	UN Industrial Development Organization (UNIDO), UN Development Programme (UNDP), UN Environment Programme (UNEP)		
	World Intellectual Property Organization (WIPO)		
	International Bioeconomy Forum (IBF)		

Source: Bößner, S., Johnson, F. X. and Shawoo, Z. (2021), 'Governing the Bioeconomy: What Role for International Institutions?', *Sustainability*, 13(1), p. 286, https://doi.org/10.3390/su13010286. With UNIDO added by authors.

Immediate action

Pragmatic entry points need to be found in the current fragmented geopolitical climate to strengthen dialogues and joint commitments among key countries that can enlarge and then drive greater cooperation.

This could happen through different mechanisms, taking an approach to balance what is feasible in existing deliberation forums. For instance, an initial focus can be taken through 'market and economic' and 'knowledge' centred multilateral forums (see Table 4).

- **G7/G20:** Momentum from the growing presence of bioeconomy strategies among member countries could be strengthened in the G7 through economic governance and agenda-setting. This has already occurred within the G20, which adopted High Level Principles on the Bioeconomy in September 2024.[87] However, such an approach needs to be complemented by other governance models – as well as private sector involvement – because the G7/G20 forums cannot adopt collective binding rules, and their limited memberships would constrain their effectiveness for wider bioeconomy issues.
- **Country coalitions:** Looking to the International Renewable Energy Agency's (IRENA) function in the renewable energy transition, there is space for such an organization to play a similar role in the bioeconomy to act as a platform for international cooperation, and to provide leading analyses on available levers to support sustainable bioeconomy development. Existing efforts could hold promise, such as the Biofuture Platform, which is a 23-country initiative to promote an advanced low-carbon bioeconomy that is sustainable, innovative and scalable.
- **Bilateral and trilateral:** As a starting point, because many of the significant players with substantial bioresources are also part of the BRICS+ countries, it could be possible to harness some of the existing bilateral and/or trilateral relationships. These could include the current China–Brazil agriculture trade relationship or the forest-economy relationships between Nordic countries and Brazil.

Action area 2. Peer-led initiatives

Facilitate pre-competitive initiatives with large organizations that can shape supply chains across bioeconomy sectors and drive sustainability.

To realize the potential benefits of new means of production, products and uses in bioeconomy sectors that deliver positive environmental outcomes, leading centres for innovation need to come together to speed up discovery and adoption.

87 G20 Brasil 2024 (2024), 'G20 reaches consensus and establishes High-Level principles on Bioeconomy', 11 September 2024, https://www.g20.org/en/news/g20-reaches-consensus-and-establishes-high-level-principles-on-bioeconomy#:~:text=The%20agreed%20principles%20include%20promoting,business%20models%2C%20and%20decent%20jobs.

Bringing new innovations to scale requires capital and time – often around 25 years. The growth rates of feedstock or bio-based goods and services, such as CLT, can also be lengthy, ranging from seven years in warmer regions like Brazil to 30 plus years in colder temperate countries.

Experiments and innovations are happening within sectors, among different industry players, but stakeholders are not coming together to learn, discuss and understand the implications of this work.

Mixing knowledge and implementation capacity can increase the speed and impact of discoveries and improve the selection and testing process. Pre-competitive collaboration, where usually competing companies collaborate on a shared challenge or opportunity, can also enable risk-sharing that speeds up experimentation and development.[88] R&D and innovation is often competitive as the private sector invests to gain an advantage over rivals. Experiments and innovations are happening within sectors, among different industry players, but stakeholders are not coming together to learn, discuss and understand the implications of this work. These siloes can slow down the rate of distribution of innovations between sectors and may mean that negative impacts and trade-offs when new applications are deployed at scale are not foreseen.

Pathway

There is a requirement for initiatives and partnerships that encourage greater technological collaboration among existing and future private and public sector actors that will dictate the pace and direction of the bioeconomy transition.

Importantly, actors need to be able to collaborate on meeting shared goals without creating unfair competitive advantages or damaging business competitiveness.

There are a few archetypes for peer-led collaborations that could be effective for sustainable bioeconomies:

— **R&D and knowledge.** There is an opportunity for pre-competitive R&D across novel forest restoration approaches e.g. combining restoration with food production, protecting new species, as well as the development of environmental services markets and traceability. This will also have implications for intellectual property rights, for example over advances in genetic sequencing or development of new varieties of biomass.

88 Snow, T. (2018), 'Why and how does collaboration drive innovation in the public sector', Nesta, 20 August 2018, https://www.nesta.org.uk/blog/why-and-how-does-collaboration-drive-innovation-public-sector.

- **Financial standards and specifications.** Connecting natural capital to assets is at the frontier of bioeconomy approaches.[89] There is a lot of ongoing work on standards and specifications, such as through the Task-force for Nature-related Disclosures (TNFD). This is a market-led, science-based and government-supported global initiative that has set guidance for a disclosure framework to act on evolving nature-related dependencies, impacts, risks and opportunities.[90]
- **Cooperative business models between sectors.** For example, where industries come together to create a precision genetic engineering system to provide multiple ingredients, such as a genetically modified cocoa plant that could produce chocolate and medicines, and whose waste materials can be used for packaging.
- **Demand-side coalitions that lead by example and send strong policy signals of the intent to purchase sustainable bioeconomy goods and services.** Lessons can be drawn from initiatives across other sectors such as RE100 (the renewable energy initiative), SteelZero (an initiative for net zero steel industry) and the Global Salmon Initiative.[91]

Across potential new bioeconomy applications, there needs to be aligned investments of a scale large enough to help new technologies and approaches reach maturity and markets.

Immediate actions

Existing initiatives from other sectors offer insight into potential ways to increase collaboration across the diverse sectors and activities of a sustainable bioeconomy:

- Learn from the experiences of the forest industry and its relationship with voluntary standards through movements like the Forest Stewardship Council (FSC) or Programme for the Endorsement of Forest Certification (PEFC). These multisectoral initiatives provide forums for negotiation on issues around innovation and industry practices related to social and environmental movements. These movements connect major players across supply chains and can help shape the direction of travel to sustainable bioeconomies.
- Enlarge coalitions of end-users of bio-based products to identify and negotiate potential upstream competition for bio-based resources. One possible approach is to build coalitions around specific emerging bio-based goods and services prior to their scale-up. In practice, this could mean bringing together downstream users of CLT, for example, to align on standards and demand robust production that does not exacerbate poor land management or social practices.

---

89 Natural capital can be defined as the world's stocks of natural assets, which include geology, soil, air, water and all living things.
90 Taskforce on Nature-related Financial Disclosures (2021), 'What is the TNFD?', https://tnfd.global/#what-is-the-TNFD.
91 Climate Group (2020), 'About RE100', https://www.theclimategroup.org/about_re100; World Wildlife Fund (2019), 'The Business Case for Pre-Competitive Collaboration: The Global Salmon Initiative (GSI)', https://www.worldwildlife.org/publications/the-business-case-for-pre-competitive-collaboration-the-global-salmon-initiative-gsi.

— Accelerate funding innovation to support critical technologies across the bioeconomy. The European Circular Bioeconomy Fund (ECBF) was the first venture fund investing in growth-stage companies in the European bioeconomy.[92] The model of supporting businesses with high potential, favourable returns and sustainable impact could be expanded to other regions.

In addition, a priority should be engagement with asset managers. This section of the financial system is beginning to drive financial product innovation in the bioeconomy in recognition of the potential opportunities.

Ultimately, bringing together actors against a backdrop of competitive business models requires trusted intermediaries. Creating global research initiatives that are transdisciplinary by nature but focused on the bioeconomy, which accomplish what the International Energy Agency does for the energy sector, can provide evidence-based analysis on the resource constraints, synergies and trade-offs of innovation adoption and bring together the needed governments, industries and research bodies to navigate these.

Action area 3. Policy and technology coherence

Develop and socialize fit-for-purpose decision-making frameworks that combine policy and technology evidence.

The emergence of new technologies and solutions for bioeconomies is accelerating, bringing with it a complex array of potential social and environmental policy implications.

This is happening at both the national and international levels, where technology advancements spread across borders and can influence – positively or negatively – deployment in other regions, supply chain organization and livelihoods.

Technology and social policy development need to happen together to manage these impacts. This will require decision-makers to combine and collate policy and technology evidence to mitigate risks and manage expectations. While there are good existing approaches that deliver a range of analysis (such as life cycle analyses and integrated assessment models), they do not enable exploration of uncertainties, sensitivities, transparent goals and stakeholder views on trade-offs.

Pathway

Effective policymaking requires consideration of changes to the workforce and environmental resource constraints, trade-offs and synergies in the development of a strategic decision-making process.

Platforms that can bring together international stakeholders – combined with relevant analysis and data that captures transnational impacts of the adoption of new bioeconomy-related technologies – are needed to enhance anticipatory policymaking that prioritizes environmental and social goals.

---

92 European Investment Bank (2022), 'European Circular Bioeconomy Fund', https://www.eib.org/en/products/equity/funds/european-circular-bioeconomy-fund.

The current use of analytical models can be strengthened through the input of experts. Principles of robust decision-making should play a key role in this process, where rounds of deliberation among experts inform the questions asked of analytical models as well as the interpretation of results.[93] These processes allow a range of future scenarios to be anticipated – and decision-making can then reflect these.

Strategic decision-makers in the private sector, such as R&D experts and strategy developers, and experts in the public sector, such as specialists in economic policy, must play a role in these deliberations.

Immediate action

Existing groups already working on issues of resource extraction and consumption could streamline the process for bringing evidence and analysis into collaborative decision-making, as occurs in the International Resource Panel.

There could also be an opportunity to improve joint consideration of technological development and social policy in other international forums. For example, the G20 track on the bioeconomy has a pillar on science, technology and innovation for the bioeconomy.[94] In future, these types of science and innovation focused tracks could also explicitly include joint dialogues on social policy.

Navigating and negotiating trade-offs

In the absence of a clear direction of travel and socio-environmental guardrails, bioeconomy transition processes will be patchy and messy, with potentially negative socio-economic and environmental impacts in both the short term and long term.

In the absence of a clear direction of travel and socio-environmental guardrails, bioeconomy transition processes will be patchy and messy, with potentially negative socio-economic and environmental impacts in both the short term and long term.

Identifying the trade-offs, as well as creating mechanisms to manage, negotiate and encourage societal agreements will be necessary so the bioeconomy transition can achieve socio-economic, climate and nature objectives. Navigating natural endowment (such as land and water) and budgetary constraints will be critical to ensure better allocation and distribution of limited resources.

---

93 Workman, M. et al. (2021), 'Climate policy decision making in contexts of deep uncertainty-from optimisation to robustness', *Environmental Science & Policy*, 120, pp. 127–137, https://doi.org/10.1016/j.envsci.2021.03.002.
94 G20 Brasil 2024 (2024), 'Initiative on Bioeconomy', https://www.g20.org/en/tracks/sherpa-track/bioeconomy-initiative#:~:text=The%20Initiative%20on%20Bioeconomy%20is,economy%20in%20promoting%20sustainable%20development.

There are already lessons to be learned from the winding down of the coal industry, particularly in relation to managing job losses, reskilling, and the mismatch in timing of renewable jobs and the phase-out of traditional jobs. There are existing mechanisms to minimize the dislocation by providing social protection for impacted workers to reduce livelihood insecurity. As countries implement their own bioeconomy strategies, engaging early and negotiating with the negatively affected industries and their workers will be critical for buy in.

At the same time, as highlighted by the three bioeconomy innovations in the analysis presented in this paper, as more bio-based materials are embedded into the economic system and compete for the same renewable energy, land and natural resources, the more critical it will be for the world to manage this competition to avoid environmental degradation. More importantly, it is vital to ensure that these new materials are in a circular supply chain, otherwise, there will just be more bio-based waste streams.

As countries face budgetary constraints, national governments will need to choose their investments strategically to ensure that their bio-based transition pathways will strengthen their geopolitical position. Having significant bioresources is a clear advantage, but it can still be squandered by ideological infighting or the political capture of governments by current powerful industries, such as fossil fuel sectors, that are in decline.

07 Bioeconomy pathways in a fragmented world

There is a very small window of opportunity to determine the shape and forms of different bio-based transition pathways. Key moments at the G20 and COP30 meetings – both of which will have Brazil as president – can act as a springboard for the sustainable bioeconomy transition.

Official, multilateral conversations about the future of bioeconomies may be nascent, but they are beginning to take root in the traditional forums for decision-making. Brazil – as the incumbent head of the G20 and incoming president of COP30 – has a unique opportunity to shape these bioeconomy discussions. Senior officials in Brazil have demonstrated their clear intention to do this.

For example, in December 2023, the country launched the first Global Bioeconomy Initiative. At that time, Ivan Oliveira, undersecretary of financing for sustainable development at the Ministry of Finance, argued that, 'the G20 is the right place to frame the discussion on bioeconomy… for relating technology, energy and other elements such as the need to take resources to where they are most needed, in contexts which the current financial model cannot reach'.[95] In September 2024, a communique with bioeconomy principles was agreed among members states, and South Africa has announced it will continue the discussion in 2025 when it becomes president of the G20.

95 G20 Brasil 2024 (2023), 'Now at the Helm of the G20, Brazil Launches its Global Bioeconomy Initiative', https://www.g20.org/en/news/now-at-helm-of-the-g20-brazil-launches-its-global-bioeconomy-initiative.

While these discussions will prioritize the bioeconomy in international forums, to bolster this approach, Brazil needs to define the roll of the bioeconomy when the country holds COP30. Through the climate troika – a diplomatic effort between the previous, current and future COP hosts – Brazil can support a continuous discussion about the bioeconomy at future climate COPs.

Equally, another pathway to aid collaboration on the bioeconomy internationally is through the Convention on Biological Diversity. This will be an essential lever to ensure bioeconomic activities do not drive nature degradation. In 2024, Colombia will assume the presidency. There is a significant opportunity for Colombia to work with its neighbour Brazil, as they share national boundaries in the Amazon basin and the challenges of both protecting nature and providing social economic development.

Global frontrunners in the bioeconomy need to provide credible leadership both internally and externally. In practice, this means addressing local challenges, including implementing existing policy frameworks relating to nature protection and completing their contributions to global targets, such as the Global Biodiversity Framework.

At a time of geopolitical fragmentation, there is an opportunity for emerging powers to use the bioeconomy to encourage a policy debate between the West, China and other countries in the BRICS+ community.

Effective partnerships between public bodies and large global private sector players that operate international value chains are important. Mobilizing public funding – from organizations like the Brazilian National Development Bank or Inter-American Development Bank – can help to crowd private capital into developing regions. More broadly, the concept of the bioeconomy ties together many of the most pressing issues of our time – nature, climate change and development policy – into the geopolitical arena. Its principal protagonists include emerging powers, like Brazil and India, endowed with large amounts of natural resources, in addition to traditional powers like the US, China and the EU. At a time of geopolitical fragmentation, there is an opportunity for emerging powers to use the bioeconomy to encourage a policy debate between the West, China and other countries in the BRICS+ community.

But the transition is complex – there are many policy levers to it, including land-use protection and management policies, fiscal incentives and subsidies, as well as industrial and innovation policies for processing and production of bio-based alternatives.

Identifying the likely trade-offs of the bio-based transition is critical so that authorities can manage any fallout. In order for countries to lean towards the bio-based transition to address climate and biodiversity challenges, national government will need to manage the negative socio-economic impacts with policies to ensure safety nets.

Navigating this complexity will require input and resources from a number of stakeholders in unusual alliances. From industry and academia working together to develop explorative modelling techniques to cross-government initiatives to align environmental, agricultural, business, economic and innovation departments.

A transition from fossil fuel economies to sustainable bioeconomies will not happen overnight, even if there is significant momentum behind it. Nor is it necessarily a good thing in all circumstances, unless the right guardrails and supports are put in place to avoid destruction of biodiversity or to our social fabric.

And so, a deliberate and intentional drive from nations, civil society and private sector players who have influence over the shape of a sustainable bioeconomy transition is needed to appropriately manage resource constraints, synergies and trade-offs.

Annex A. Analysis methodology

System dynamics models can simulate the behaviour of non-linear environmental, economic and social systems through time. In this paper we used the FeliX model.[96]

This model was chosen for a number of reasons. It has previously been used in academic literature to test the feasibility of bioeconomy innovations through the lens of land footprints, such as the use of microalgae as a feedstock for protein production.[97] The model is agile and provides near-instantaneous outputs, making it suitable as a tool to aid decision-making, as it is able to quickly provide analysis based on a number of scenarios designed by the user.

One limitation of the model in its current format is that it provides only an aggregated global analysis. This makes it unsuitable currently to identify, or consider, issues of trade, social or environmental local contexts, or infrastructure that influence bioeconomy decision-making. A focus on improving the local capabilities of this model would be a useful next step.

The modelling for each innovation was conducted in three stages.

Stage 1: Estimating demand

For each innovation – alternative proteins, bioplastics and cross-laminated timber – future demand was identified for materials and products in analogous traditional sectors.

For example, for alternative proteins, the future calorie and protein demands for the population were calculated based on the global population within the analysis. For cross-laminated timber, future urban expansion was calculated based on SSP2 predictions for urban populations and additional urban space required to accommodate them. SSP2 is the 'middle of the road' climate story where the world follows historical trends for social, economic and technical indicators.[98] For bioplastics, future demand was estimated based on OECD projections of plastic consumption per capita.[99]

Stage 2: Substituting with alternative products

For each innovation, we calculated the amounts of bio-based alternatives required to meet demand. A literature review was conducted to show the feedstocks required to produce the equivalent amount of alternative proteins, bioplastics and cross-laminated timber. The market uptake was based on the parameters shown in Annex B.

---

96 International Institute for Applied Systems Analysis (2023), 'Full of Economic-Environment Linkages and Integration dX/dt (FeliX)', https://iiasa.ac.at/models-tools-data/felix.
97 Walsh, B. J. et al. (2015), 'New feed sources key to ambitious climate targets', *Carbon balance and management*, 10, pp. 1–8, https://doi.org/10.1186/s13021-015-0040-7.
98 Hausfather, Z. (2018), 'Explainer: How 'Shared Socioeconomic Pathways' explore future climate change', https://www.carbonbrief.org/explainer-how-shared-socioeconomic-pathways-explore-future-climate-change.
99 OECD (2022), *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options*, https://www.oecd-ilibrary.org/environment/global-plastics-outlook_de747aef-en.

Stage 3: Simulating land footprint

The total land footprint of the feedstocks required to meet biomass demand were calculated based on current agricultural yields and incorporated existing trends in productivity.

In each scenario, population and GDP followed the SSP2 pathway, but the pathways for GDP were dynamically adjusted for damage based on global warming. Across each scenario, the role of other bio-based sectors remains relatively constant. The other largest source of biomass use – bioenergy – increases its market share from 5.6 per cent in 2023 to a maximum of 8.1 per cent in 2050 in the Far-reaching Scenario.

Annex B. Model parameters

The table illustrates the parameters used to assess simultaneous use of all innovations for Limited Transition and Far-reaching Transition scenarios in 2050 and 2100.

Table A1. Inputs and parameters for Limited Transition and Far-reaching Transition scenarios

Parameter			Limited Transition (2050)	Limited Transition (2100)	Far-reaching Transition (2050)	Far-reaching Transition (2100)
Market share of alternative proteins*	Percentage of global market for pasture meat, crop meat, dairy and eggs replaced by alternative proteins	Pasture meat	8.3%	25%	16.7%	50%
		Crop meat	4.3%	13%	8.3%	25%
		Dairy	15%	45%	30%	90%
		Eggs	6.7%	20%	13.3%	40%
Relative proportion of technologies in the overall alternative proteins market	Breakdown of market use of plant-based product, precision fermentation and lab-grown cultured meats (% plant-based/% precision fermentation/% lab-grown cultured meat)	Pasture meat	33%/33%/33%	20%/40%/40%	33%/33%/33%	20%/40%/40%
		Crop meat	33%/33%/33%	20%/40%/40%	33%/33%/33%	20%/40%/40%
		Dairy	50%/50%/0%	33%/66%/0%	50%/50%/0%	33%/66%/0%
		Eggs	0%/100%/0%	0%/100%/0%	0%/100%/0%	0%/100%/0%
Final cement share per residential building**	Percentage of cement industry replaced by cross-laminated timber.		2.3%	8%	6.6%	20%
Cross-laminated timber (CLT) land footprint***	The relative ratio of land for CLT plantations from forest land, crop land and pastureland.		5%/5%/90%	5%/5%/90%	5%/5%/90%	25%/5%/70%
Market share of bioplastics******	A share of the total plastics market sourced from bioplastics.		5.6%	19.1%	10%	50%

*In the Far-reaching transition scenario, the overall market for alternative proteins in 2100 was aligned with the maximum technological replacement potentials by 2050 used by the Green Alliance for the report *A New Land Dividend*.[100] The Limited Transition scenario assumes that half of this maximum potential is reached by 2100. The interim market uptake in 2050 is one-third of the market uptake by 2100. For crop meat and pasture meat, the relative market within alternative proteins for precision fermentation and lab-grown cultured meats was assumed to double in the second half of the century. ** Future markets for CLT were based on expert interviews regarding a highly ambitious scenario for CLT market share compared to traditional materials. Projections of 8 per cent to 20 per cent of new material use in buildings was considered to be very ambitious. *** New plantations for CLT were assumed to come mostly from pastureland, which is freed up by the implementation of alternative proteins. In the Far-reaching Transition scenario in 2100, the increasing land footprint of bioplastics means that CLT was largely sourced from forestry activities. The lead-in time for land clearance, planting and harvesting was not included in the modelling exercise, in line with the assumption that most of the pastureland freed up would be in tropical forest areas where growth takes less than a decade compared to the overall period to 2100 modelled. **** In the Limited Transition scenario, the market share of bioplastics was modelled to follow the continued compound annual growth rate (CAGR) of the polyethylene market (2.5 per cent) with a starting point of 1.5 per cent of the overall plastic consumption market.[101] In the Far-reaching Transition scenario, the market share of bioplastics was simulated at the point when bioplastics are the dominant type of plastic in the market.

100 Collas, L. and Benton, D. (2024), *A New Land Dividend: the opportunity of alternative proteins in Europe,* Green Alliance, https://green-alliance.org.uk/publication/a-new-land-dividend-the-opportunity-of-alternative-proteins-in-europe.
101 PR Newswire (2023), 'Bioplastics & Biopolymers Market is Projected to USD 4,713.9 Million by 2029, at a CAGR of 3.4%', https://www.prnewswire.com/news-releases/bioplastics--biopolymers-market-is-projected-to-usd-4713-9-million-by-2029--at-a-cagr-of-3-4--valuates-reports-301788454.html.

About the authors

Ana Yang is the director of the Environment and Society Centre at Chatham House. Her interests focus on how to drive change for a fairer and more sustainable future. Prior to joining Chatham House, Ana worked at the Children's Investment Fund Foundation, where she led the land use and finance workstream of the Climate Change Programme. Between 2005 and 2008, she was the executive director of FSC Brazil's Forest Stewardship Initiative and later joined the International Finance Corporation (IFC) sustainable business advisory team, advising companies and investors on impact investments in the Amazon. She is now chair of the board of Instituto Clima e Sociedade (iCS – Institute for Climate and Society), a grant-making organization based in Brazil focused on climate change and social development. Ana has an MSc in social policy and development from the London School of Economics and Political Science and a bachelor's degree in business administration from Fundação Getulio Vargas.

Henry Throp is a research associate for the Chatham House Sustainability Accelerator. He is interested in transforming land-based sectors to shift how products are sourced, distributed and used to support a more circular regenerative bioeconomy. Prior to joining Chatham House in 2019, he was awarded a Generation UK Scholarship from the British Council to intern at the Beijing-based NGO Greenovation Hub, researching the Paris alignment of multilateral institutions. Henry has an MSc in physics from Imperial College London, where he published work on the impact of climate change on tropical cyclone formation and oceanic carbon sequestration.

Suzannah Sherman is a research fellow for the Chatham House Sustainability Accelerator. Her work focuses on the role of innovation and finance in reaching sustainable built environments. She has previously held roles specializing in climate adaptation with the UK's Climate Change Committee and was an environmental consultant, leading projects to provide insights and advice to private sector organizations on environmental management. Suzannah has an MSc in environmental change and management from the University of Oxford and a BA in geography from the London School of Economics and Political Science.

Acknowledgments

The authors would like to thank Instituto Arapyaú, Suzano and MAVA Foundation for generously funding this research. The authors are grateful to stakeholders who shared their insights during a series of workshops hosted between January and April 2024, which provided vital input for this paper. Participants included stakeholders across the bioeconomy from industry, the private sector, government, international organizations, civil society and academia.

Thanks are also due to Mario Herrero, Jukka Kantola, Daniel Mason-D'Croz, Michael Obersteiner, Roberta Roesler, Caroline Ray, Roberto Waack and Aidong Yang for their partnership and insights as part of the Technical Panel for the project. The authors would like to extend a large thank you to the modelling support provided by Sibel Eker, Kok Siew Ng, Felicjan Rydzak and Deniz Koca.

Thanks to Roberto Waack, Richard King, Tim Benton and Mark Workman for their comments and to the anonymous peer reviewer for their feedback. Finally, thanks go to Michael Tsang for his contributions to and editing of this paper.

Cover image: A technician examines lentil plants inside a breeding and genetics laboratory greenhouse at the International Atomic Energy Agency (IAEA) complex in Seibersdorf, Austria, February 2023.
Photo credit: Copyright © Akos Stiller/Bloomberg/Getty Images

ISBN 978 1 78413 625 3
DOI 10.55317/9781784136253

Cite this paper: Yang, A., Throp, H. and Sherman, S. (2024), *How strategic collaboration on the bioeconomy can boost climate and nature action*, Research Paper, London: Royal Institute of International Affairs, https://doi.org/10.55317/9781784136253.

This publication is printed on FSC-certified paper.
designbysoapbox.com

Independent thinking since 1920

The Royal Institute of International Affairs
Chatham House
10 St James's Square, London SW1Y 4LE
T +44 (0)20 7957 5700
contact@chathamhouse.org | chathamhouse.org

Charity Registration Number: 208223