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Sustainable bio-resource pathways towards a fossil-free world: the European bioeconomy in a global development context

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EXECUTIVE SUMMARY

The universality principle of Agenda 2030 and the call for integrated SDG implementation require that addressing one (environment or development) dimension when moving towards a bioeconomy must not come at the cost of another dimension, and that implementation in one country or region must not compromise sustainable development in other locations.

Besides the EU, an increasing number of countries are developing and implementing bioeconomy strategies. While the original emphasis of most of these strategies was on climate protection and on reducing dependency on fossil resources, other sustainability dimensions need to be addressed as well, in particular those spelled out by the Sustainable Development Goals (SDGs), so that bioeconomy transitions become integral part of an overall sustainability transition. This requires improvements on the consumption and production side (see SDG 12), to avoid excessive demands on bioresources as a result of bioeconomy transitions and the substitution of fossil resources. Depending on the respective biophysical, socio-economic, political and cultural context, key sustainability constraints and bioeconomy transition pathways and the associated innovations will vary.

The EU is embedded in a global context and is closely interlinked with other countries and regions, e.g. through trade and the exchange of goods, finance, knowledge and people but also through shared responsibility for global commons such as climate and biosphere. For meeting all its demands (with per-capita ecological footprints exceeding the available biocapacity by far), while reducing its current dependence on fossil resources, the EU increasingly depends on biomass from other world regions (with growing net imports of biomass). Accordingly, the EU bioeconomy strategy has to be implemented simultaneously in, by and with Europe:

in Europe bio-based products, which substitute fossil-based products, must be produced, processed, consumed and reused more sustainably, integrating supply-side and demand-side measures;

by Europe means ensuring sustainable sourcing and fair international supply chains for bio-based products, with minimized external environmental and socio-economic footprints and enhanced synergies and co-benefits all along the supply chains, also minimizing overall pressure on global commons;

with Europe refers to north-south(-south) partnerships, e.g. through development cooperation, sharing of knowledge & technologies, innovations and investments, trade agreements, and other mechanisms in which the different partners' respective strengths are combined.

Such an integrated bioeconomy transition needs to be enabled by an appropriate governance framework and improved policy coherence, mainstreaming the EU bioeconomy strategy with existing strategies and policies such as circular and green economy, climate and long-term strategies, environment, agriculture, forestry, resource efficiency, development and trade policies. With that the bioeconomy may become a lens for overall improvements in policy coherence.

A knowledge-based bioeconomy, which accounts for all of these horizontal and vertical interlinkages and requirements relies on quantitative scientific evidence and science-based targets and solutions. This policy paper presents some initial evidence, and gaps in terms of synergies and tradeoffs across different policy areas, sectors and regions. It provides initial guiding principles for the implementation of the EU bioeconomy strategy and solutions in a global development context, inviting further dialogue between science, policy and practice.

1 Motivation for a bioeconomy transition - opportunities and risks

Before the industrial revolution and the discovery of fossil fuels, the European and other economies were essentially bio-based. The production of food, feed, fuel and fibre and hence biomass has always been instrumental for economic growth and development. The rapid adoption of fossil resources as inputs for the energy sector, for a wide range of chemicals and for other value-added products, has accelerated development and led to a restructuring of economies and societies across the globe over the past century.

With growing knowledge and awareness of the finite nature of fossil resources and the growing climate, environmental, socio-economic and geopolitical impacts of their exploitation and use and the associated risks, the EU and many individual European and other countries have and are developing bioeconomy strategies¹. A new bio-based economy or bioeconomy can help to address the dilemma of meeting increasing demands for goods and services of a growing and more wealthy population, while at the same time halting the over-exploitation of resources and degradation of ecosystems and biodiversity and also mitigating climate change. So the expectation is that a new knowledge based bioeconomy can reconcile various inter-linked environmental, economic and societal development challenges. The transition to such a bioeconomy as part of an overall sustainability transition promotes green and inclusive growth, moving beyond low productivity “natural economies” and high-input fossil economies which have come to their limit, as depicted by figure 1.

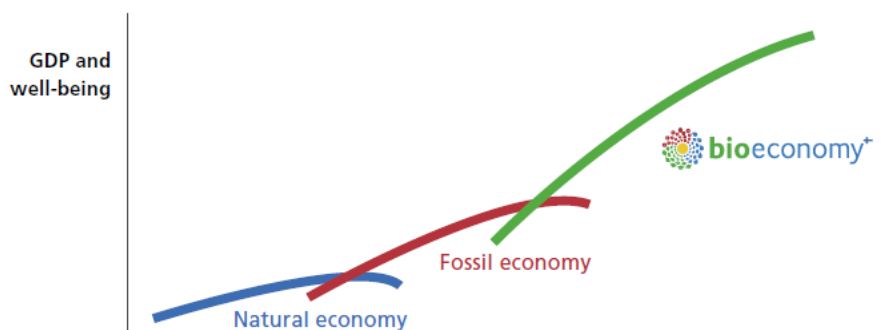


Figure 1. Trends over time and potentials for enhancing GDP and human well-being, of different types of economies (from the Finnish Bioeconomy Strategy²)

Sustainable bioeconomy pathways lead to enhanced production of biomass in an environmentally friendly manner, processing and allocation of bioresources more efficiently to the various uses, increased benefits derived from these bioresources and fair distribution of the benefits along

¹ Bioeconomy (related) strategies have been adopted or are currently developed by more than 50 countries (German Bioeconomy Council, <http://biooekonomierat.de/en/international0/>)

² http://biotalous.fi/wp-content/uploads/2014/08/The_Finnish_Bioeconomy_Strategy_110620141.pdf

international supply chains. To that end, a number of – not necessarily consistent – bioeconomy visions have been developed.

1.1 Bioeconomy visions and opportunities

a bioresources (substitution) vision - decarbonizing development, phasing out the use of fossil fuels and other fossil-based resources, substituting them by bio-based renewable resources and new valorization of these bioresources;

a biotechnology and innovations vision - promoting technological, social and institutional innovations, e.g. new and more sustainable products, more efficient and cascading use of natural resources and biomass, recycling (contributing to a circular economy), increasing longevity and repair, introducing 2nd and 3rd generation bioresources (e.g. lignin or algae), better integrated production and consumption along global value chains or value nets, taking into account the full set of bio-based products (rather than focusing on individual products such as biofuels), and also new forms of institutions and governance;

an agricultural innovation and rural development vision - diversifying, revitalising and modernising agriculture, forestry and biomass production in Europe and in other regions, with a greater variety of highly productive and adapted crops, improved and multi-functional production system and sustainable intensification, which also make marginal land more productive and better connect farmers to markets, providing more (attractive) agricultural and bioresource processing jobs and improved livelihoods, eventually achieving a rural regeneration and revitalization;

a international cooperation and development vision - opening new opportunities for the global north and south³, including transfer of knowledge, technologies and innovations, improving education and skills, drawing more strongly on each region's strengths and comparative advantages⁴, with more value-addition, benefits and jobs shifted "upstream" in the value chains i.e. closer to the primary production of biomass (within Europe but also globally), distributing wealth more evenly and fair;

a bio-ecology vision - supporting the bioeconomy transition with landscape and ecosystem-based approaches, rehabilitating degraded land for biomass production and other ecosystem services, protecting biodiversity, reducing losses and waste, focusing also on demand side management and substituting for - or avoiding - critical products (e.g. plastics), reversing critical trends of natural resource overexploitation and environmental degradation.

These different visions or combinations thereof may guide the implementation of the EU's bioeconomy strategy⁵ and hence Europe's transition pathways. Different biophysical, socio-economic, cultural and political contexts across Europe will require different combinations of elements of these visions and transition pathways, towards context-specific sustainable bioeconomies. Initial examples of moving towards bioeconomies as outlined in the above visions, include for example:

- the conversion of the Nordic Forestry Sector and its paper and pulp mills into modern biorefineries, converting almost all of the wood (including lignin and hemicellulose) into bio-

³ Johnson, F.X., 2017. Biofuels, Bioenergy and the Bioeconomy in North and South. *Ind Biotech* 13(6): 289-291.

⁴ Such as Europe's innovation capacity and cooperation model or Africa's relatively high land availability, rapid economic growth and leapfrogging capability.

⁵ Innovating for Sustainable Growth - A Bioeconomy for Europe, EU 2012

based products (going beyond paper, e.g. textiles, modern packaging material, green chemicals etc), that way optimizing biomass use⁶;

- the agro-food sector getting more resource efficient, converting more of its byproducts and wasteproducts into food and feed⁷;
- the European chemical industry is steadily increasing its use of bio-based resources in its products (presently around 10 % of total resources used);
- the consumer goods sector is also changing, by 2020 a large nordic furniture company wants to manufacture all of its plastic products – including children's toys, storage boxes and carrier bags – from bio-based resources and/or recycled material;
- biopackaging and bioplastics increasingly taking off in the EU⁸ and elsewhere⁹;
- new aquatic (e.g. algae) feedstocks help meeting protein demand¹⁰

As there are different visions, contexts and needs, there are also different bioeconomy definitions and interpretations. The bioeconomy definition according to the EU bioeconomy strategy from 2012 is: "The production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, biobased products as well as bioenergy". We show in this policy paper, that this definition needs to be updated to better reflect environment and development dimensions as spelled out in the SDGs.

1.2 Challenges and risks of a growing bioeconomy

The implementation of bioeconomy strategies in Europe and elsewhere provides many opportunities, but also comes with challenges, tradeoffs and potential conflicts related to the sustainable production, processing and use of biomass and bioresources, responsible ecological stewardship, environmental management and inclusive development.

Bioeconomy transitions can increase pressure on bioresources and hence on further biomass production, on top of existing demands and expected additional requirements for carbon sequestration for climate protection. The full implementation of the large number of new bioeconomy strategies is likely to cause additional demand and competition¹¹, which requires additional supply- and demand-side measures. Unless accompanied by such measures and technological and other innovations (e.g. expanding the genetic resource and feedstock base, cascading use, recycling, changing consumption patterns etc.), bioeconomy transitions would increase the demand for land, water and other natural resources, and with that the risk of resource degradation and threats to the intactness of forests and other ecosystems and their biodiversity, functions and services. Depending on the context and bioeconomy pathway, some of the negative impacts may even be higher per unit of bio-based products compared to fossil-based products.

⁶ for example, a number of Swedish companies are cooperating on this objective under the Sustainable Chemistry 2030 Vision

⁷ e.g. <https://biorescue.eu/>

⁸ e.g. www.biobarr.eu or <http://biosmart-project.eu/>

⁹ e.g. K. Chaisu (2016): Bioplastic industry from agricultural waste in Thailand, *J Adv Agr Tech*, 3, 4, 310-313)

¹⁰ e.g. <http://biosea-project.eu/>

¹¹ Haberl et al (2015) estimate that already now a quarter of actual biomass production / NPP is appropriated or used by humans, and it is not clear if global NPP can be increased significantly - see e.g. Running 2014: A regional look at HANPP: human consumption is increasing, NPP is not

Mitigating these potential risks and realising the above visions, also depends on close coordination of the different national bioeconomies, in order to best match bioresource production and consumption patterns and achieve sustainable sourcing and allocation of bioresources to the most beneficial uses.

Integrated implementation of the Sustainable Development Goals (SDGs) calls for major innovations on the production, processing and consumption side of bioresources, including socio-economic and institutional innovations as an important part of bioeconomy transition pathways. In some economies, in particular in less developed countries, this implies a leapfrogging to new bioeconomies without going through the fossil-based stage (see figure 1) or other unsustainable development curves. Science can help to better understand the associated risks, mitigate tradeoffs and identify knowledge-based sustainable bioeconomy pathways. Studies have for example shown that a combination of sustainable biomass sourcing and sustainable agricultural intensification, supported by coherent policies, can increase the availability of bioresources and food security, while at the same time mitigating climate change and reducing pressures on biodiversity and other natural resources¹².

Another risk associated with bioeconomy transitions is that industrialised countries such as those in Europe, continue their resource intensive consumption patterns¹³, based on increasing net imports of raw bioresources (using the bioeconomy as an excuse for continued business as usual), while at the same time some countries of the global south stay or become providers of these bioresources¹⁴ without also advancing towards modern (bio)economies that include adding value to biomass upstream in the supply chains. Improved international cooperation and a fair allocation of the benefits of a global bioeconomy transition, along the full supply chain, is important to mitigate these risks. However, robust tools for measuring the distribution of costs and benefits are still largely missing.

Realising bioeconomy opportunities whilst addressing the associated challenges and minimising risks implies:

1. learning from the past by evaluating observed effects of bioeconomy policies, innovations and pathways, in order to develop context- and scale-specific, environmental and socio-economic sustainability criteria;
2. taking stock of the current patterns of biomass and bioresources supply and demand, to assess geographically explicit potentials and limitations of the bioeconomy;
3. developing a set of integrated future bioeconomy scenarios which account for innovations and other trends and which explore potentials and limitations of biomass and bioresources in the EU and globally.

This policy paper presents some initial scientific evidence, identifying synergies and tradeoffs across different sectors, regions and policy areas, and it provides some guiding principles for the implementation of bioeconomy strategies at EU and Member State level and solutions in a global development context, inviting further dialogue between science and policy making.

¹² Heck et al. (2018): Land use options for staying within the Planetary Boundaries – Synergies and trade-offs between global and local sustainability goals, *Global Env. Change*, 49, 73-84; Obersteiner et al. (2016): Assessing the land resource–food price nexus of the Sustainable Development Goals, *Sci. Adv.* 2, e1501499

¹³ e.g. Wackernagel et al. (2017) or UNEP (2017): material footprint per capita, <https://unstats.un.org/sdgs/indicators/database/?indicator=12.2.1>

¹⁴ UNEP (2016). Global Material Flows and Resource Productivity

2 A bioeconomy transition in Europe

The universality principle of Agenda 2030 and the call for integrated SDG implementation require that addressing one (environment or development) dimension must not come at the cost of another dimension, and that implementing SDGs in one country or region must not compromise sustainable development in other locations.

The EU is embedded in a global context and hence is closely tied to other countries and regions through trade and the exchange of goods, finance, technology, knowledge and people but also through shared responsibility for global commons such as climate, atmosphere, biosphere etc. Accordingly Europe's bioeconomy transition needs to address SDGs not only in Europe, but also in other regions. The EU bioeconomy strategy thus has to be simultaneously implemented in, by and with Europe:

In Europe means that bio-based products need to be produced, processed, consumed and reused sustainably (sustainable consumption and production), e.g. through integrated land use in multi-functional production systems which protect ecosystems and biodiversity, through improved efficiency in processing and allocation of bioresources to different end uses, as well as through cascading use, recycling, reduced wastage and reduced per-capita consumption (e.g. of livestock products) and footprints (sufficiency) within Europe;

By Europe means sustainable sourcing of bioresources and fair international supply chains of biobased products, with minimised external environmental and socio-economic footprints and improved synergies and (co-)benefits all along the supply chains, in particular also towards the upstream end of the supply chains, also minimizing overall pressure on global commons;

With Europe refers to north-south(-south) partnerships, e.g. through development cooperation, capacity building, sharing of knowledge & technologies, technological/social/institutional innovations (e.g. sustainable agricultural intensification), green investments, trade agreements, fair benefit sharing and other mechanisms in which the different partners' respective strengths and comparative advantages are combined.

The global north and south have common but differentiated responsibilities in a coordinated bioeconomy transition, towards enhanced benefits for all, while negotiating tradeoffs and minimizing unintended negative effects. That calls for improved international cooperation, fair trade regulations for biobased products and technological, socio-economic and institutional innovations along integrated value chains, and eventually responsible consumption and production (SDG 12). For that, European and other bioeconomy strategies need to be closely coordinated in a global development context.

2.1 The biophysical context for bioeconomy transitions in Europe

Implementation of the EU bioeconomy strategy needs to be underpinned by a comprehensive and quantitative data and information base, related to the production, processing and (re-) use of bioresources and the benefits to be generated. The box below provides some initial information towards that end, derived from the European Commission's Bioeconomy Knowledge Center.

Box 1: Initial quantitative synthesis of the EU bioresources situation

- The EU currently produced between 1.6 and 2.2 billion tonnes of biomass fresh matter yearly¹⁵;
- in dry matter agriculture produces almost 1 billion tons and forestry produces 0.5 billion tons;
- the agricultural biomass used (dry matter) is composed of ca. 0.5 billion tons crop economic production, 0.1 bt crop residues (another 0.3 bt of residues are not used), 0.1 bt grazing biomass and 0.1 bt imports (the latter comprises 60% food products, 30% non-manufactured crop products and 10% material products), exports are of similar magnitude;
- out of the 0.1 bt of biowaste generated in the EU, about 25% are recycled¹⁶;
- 62% of EU's biomass use is for food and feed, 19% for bioenergy and 19% for biomaterials;
- 65% of the EU's agricultural biomass use is for feed;
- forest biomass net annual increment in the EU is 0.4-0.5 billion tons in dry matter of which about 70% is harvested;
- forest standing biomass / stock in the EU increases at more than 1% annually;
- 52% of woody biomass is used for materials and 48% for energy¹⁷.

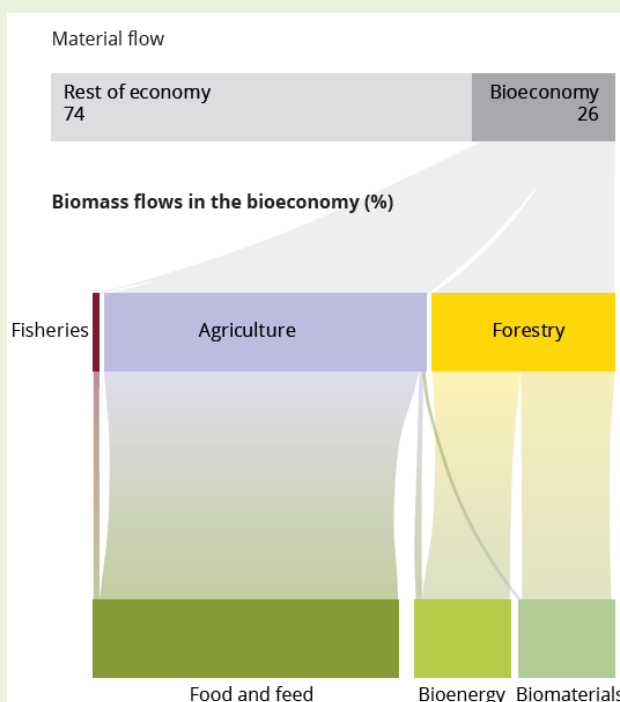


Figure from *The Circular Economy and the Bioeconomy*, EEA report 08/2018

Note that this initial information needs to be complemented with more detailed data on the current situation, trends and projections, e.g. in terms of the different types of biomass produced, processed and used for different purposes, main producing regions within the EU and regions from which the EU imports and to which the EU exports bioresources, key processing and value adding steps within and outside of the EU, trade balances etc.

There is a well-known positive correlation for almost all nations between their human development (measured by the Human Development Index) and their ecological footprint (measured as global

¹⁵ Rozon et al. (2015) *The Bioeconomy in the European Union in numbers*, Facts and figures on biomass, turnover and employment, JRC.

¹⁶ *The Circular Economy and the Bioeconomy*, EEA report 08/2018

¹⁷ Camia et al. (2018): *Biomass production, supply, uses and flows in the European Union*.

hectares of bioproductive land required to to meet per-capita demand)¹⁸. Countries with a high Human Development Index continue to have high per-capita ecological footprints, no absolute decoupling of these two indicators has been achieved to date. EU countries' per-capita ecological footprints far exceeds the available world biocapacity (average global hectare per person), which is clearly unsustainable¹⁹. Hence Europe's bioeconomy concepts and transition need to go beyond technological innovations and improvements in resource efficiency and emphasise other elements in particular on the demand side of biobased products, to achieve an absolute decoupling, which reduces natural resource to sustainable levels²⁰.

The EU per-capita ecological footprints not only exceed the available biocapacity, the EU also strongly relies on biomass production in other world regions. The following figures depict the amounts of biomass produced within Europe vs. imports from outside of Europe to meet food and non-food demands in EU member countries.

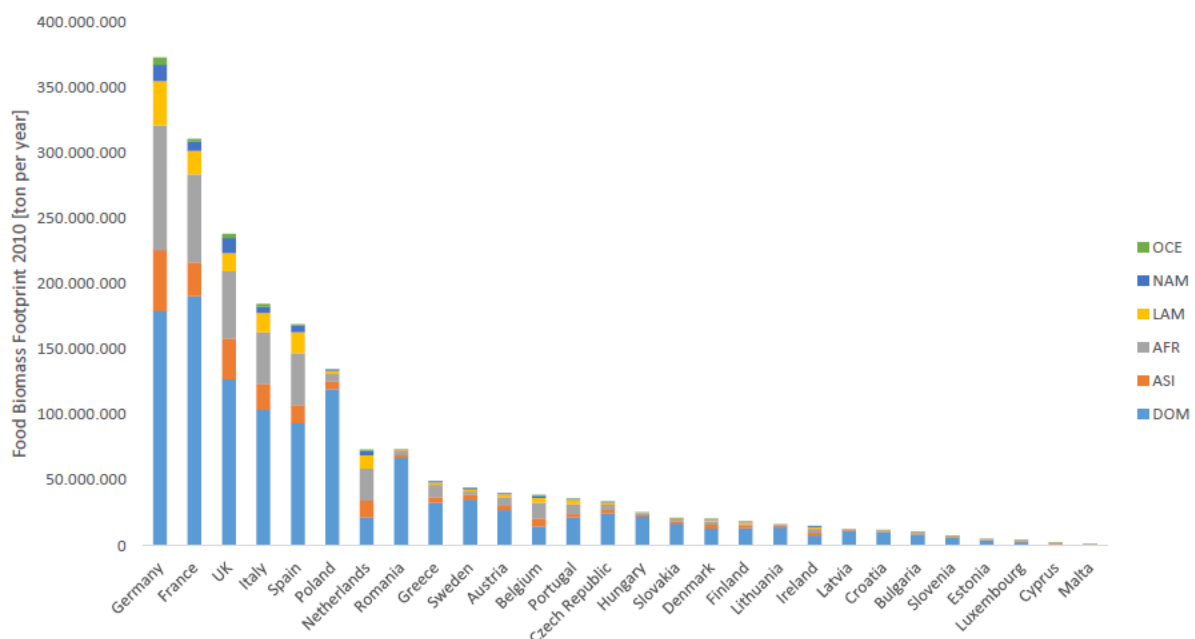


Figure 2: Biomass footprints related to food demands for EU countries; bar colours indicate the origin of imports from the world regions Oceania (OCE), North-America (NAM), LAM (Latin-America), AFR (Africa), ASI (Asia) and production within Europe (DOM).

¹⁸ Wackernagel et al. (2017): Making the Sustainable Development Goals Consistent with Sustainability, Frontiers in Energy Research

¹⁹ Freudenberger et al. (2010): A view on global patterns and interlinkages of biodiversity and human development.. In: Ibisch et al. (eds.) CBD Technical Series 54.

²⁰ Biber-Freudenberger et al. (2018) Sustainability performance of national bio-economies. Sustainability 10(8), 2705.

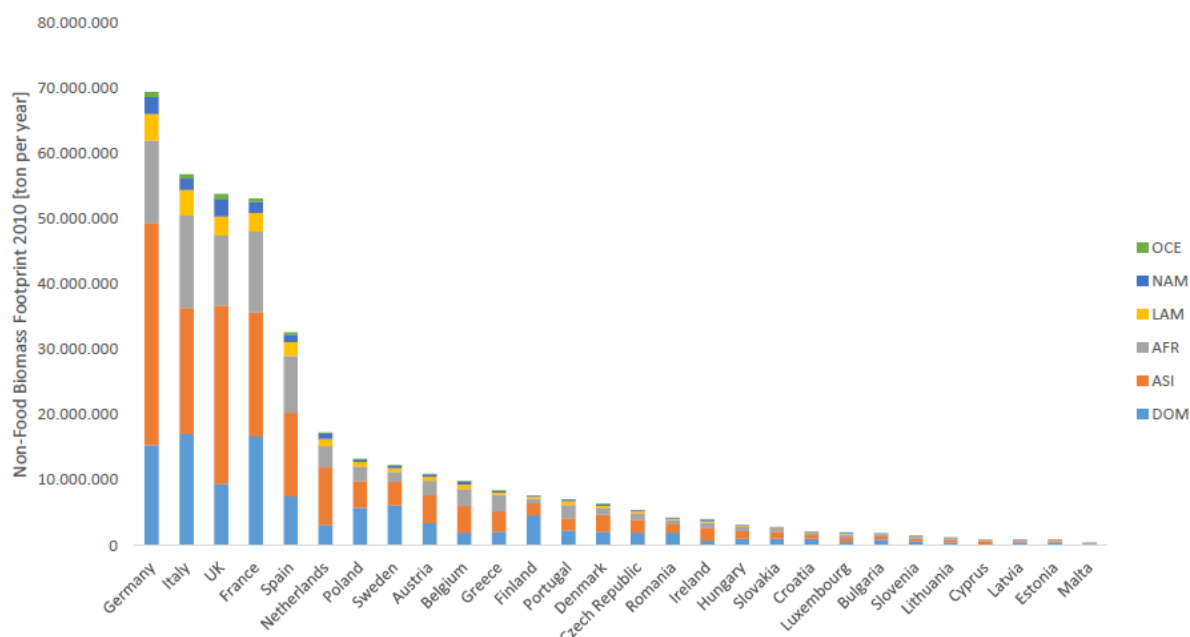


Figure 3: Biomass footprints related to non-food demands for EU countries, bar colours indicate the origin of imports from the world regions Oceania (OCE), North-America (NAM), LAM (Latin-America), AFR (Africa), ASI (Asia) and production within Europe (DOM).

These figures show that a large fraction of biomass demands are met from outside of Europe. In particular non food demands are primarily met from overseas production and imports. Food-related biomass imports originate mainly from Africa, while biomass for non-food purposes is imported mainly from Asia. Total external biomass requirements embedded in imports for meeting Europe's total consumptive demands may be even higher than the above figures indicate, given that only part of the required biomass gets physically incorporated into the traded commodities (in particular livestock products require several times their own weight as input of vegetal biomass).

Trend analysis shows that the EU increasingly depends on (net) imports of bioresources from other regions for food as well as non-food purposes. What may seem to be a decoupling of economic development from resource use in some European countries, is in fact rather an externalization of resource use to other world regions. The imported fraction of Europe's total biomass footprint has increased by 33% between 1995 and 2009, the import fraction of total timber demand has increased by 23 %²¹. By now, two thirds of the cropland required to satisfy EU non-food and non-feed bioresource demands are located in other world regions²². So the EU's level of self-sufficiency in bioresources continues to decrease. While self-sufficiency is not an end in itself, the impacts of the EU's growing imports in the corresponding exporting regions need to be carefully assessed and – if necessary – mitigated, in order to ensure universal and integrated SDG implementation.

The EU's imports of bioresources go hand in hand with an externalization of environmental and socio-economic effects, which may affect SDG implementation in the exporting regions positively or negatively, e.g. in terms of generating revenues and employment, changing production structures or causing additional resource use, harmful emissions and environmental pressures. While in the EU

²¹ The Circular Economy and the Bioeconomy, EEA report 08/2018

²² Bruckner et al. 2018, The global cropland footprint of the non-food bioeconomy, ZEF discussion paper

biomass production and processing is regulated by various environmental standards, this is not necessarily the case in several of the regions which produce biomass for export to Europe²³. Resource intensities or environmental footprints per unit of product in other regions can be higher or lower from those for production within Europe.

Looking for example at biodiversity impacts, the EU causes more external threats to biodiversity than most other importing regions, with almost all of the EU's external biodiversity footprints occurring in developing countries²⁴. Accordingly, Europe's increasing biomass imports may cause additional biodiversity losses in other regions. While Europe has lost a large part of its own biodiversity over the past centuries, many of the current exporters to Europe still belong to the so called megadiverse countries²⁵. Some of these suffer from limited implementation of policies and of law enforcement and of high corruption rates.

EU bioeconomy policies need to foster mutual benefits of trade in bioresources including opportunities for technology transfer and institutional capacity-building. The EU bioeconomy needs to develop synergistically with other countries' and regions' bioeconomies, supported by cooperation platforms and international governance mechanisms, towards globally sustainable consumption, production and sourcing.

International coordination and cooperation on transitions towards knowledge-based bioeconomies depend on methodological and analytical frameworks, tools²⁶ and indicators²⁷, for systematically assessing (context- and scale-specific) tradeoffs and synergies across all relevant environment and development dimensions in Europe and in other regions. Comprehensive assessments, which take into account the complexities and uncertainties associated with new bioeconomies and their impacts across sectors, scales and regions provide the basis for horizontal and vertical policy-coherence. These assessments have to integrate bottom-up and top-down environment, climate and socio-economic sustainability criteria, including feedback loops and telecoupling effects up to global scale, highlighting sustainability implications of Europe's actions also in other parts of the world. Hence science needs to provide the evidence base for evaluating, comparing and eventually monitoring different transition pathways of the EU for their internal and external effects.

2.2 The institutional context for bioeconomy transitions in Europe

Bioeconomy comes with complex interactions, synergies and tradeoffs across sectors, disciplines, scales and regions and therefore touches upon various different local, national and international policy areas, from environment and climate to agriculture, industry, development and trade. Successful bioeconomy transitions in, by and with Europe depend on mainstreaming bioeconomy strategies into existing policy frameworks.

²³ With the exception of where those commodities placed on the EU market are required to satisfy sustainability criteria, such as those for biofuels that count towards the EU's renewable energy targets.

²⁴ Lenzen et al. 2012: International trade drives biodiversity threats in developing nations, *Nature*, 486, 109

²⁵ Nations that harbour the majority of Earth's species and high numbers of endemic species.

²⁶ For example, life cycle analysis (LCA) and its integration with top-down methods such as Multi-Regional Input-Output (MRIO) tables, Integrated Assessment Models (IAMs)...., participatory scenario development etc.

²⁷ Some of the SDG indicators can be used for that, see <https://unstats.un.org/sdgs/> - however beyond their current efficiency focus, a total use perspective is required.

Among the various national and EU policy frameworks with which the bioeconomy strategy needs to be aligned are the circular and green economy²⁸, resource efficiency²⁹, the future Common Agricultural Policy (including Member State strategic plans), energy (including other renewables besides bioenergy³⁰), the EU's climate action in the context of the Paris Agreement including Member State Long-Term Low-Emission Strategies, the Lisbon Strategy and others. A nexus approach³¹ can support the alignment and mainstreaming of bioeconomy transitions with these policy areas and frameworks. Through the various interactions with other policy areas, bioeconomy transitions can also serve as a lens for improving coherence and effectiveness of existing policies towards reconciling societal and environmental challenges (see table below). As Europe is at a crucial turning point in the development of its policies, moving attention from 2020 to the 2030 and mid-century horizons, opportunities arise for improving policy coherence.

Table 1: Examples of policies that could be improved through sustainable bioeconomy proofing

Policy	Coherence enabled through the bioeconomy lens
The EU's contribution to the SDGs (COM(2016) 739)	On aligning the EU's contribution to the SDGs through the promotion and use of bioresources at appropriate scales and intensity.
The Common Agricultural Policy (regulations: 1307/2013; 1308/2013; 1305/2013 & 1306/2013) and future CAP beyond 2020	On the focus and scale of support provided for the production of bioresources; On the criteria to ensure sustainable production and use. On the development of CAP strategic plans post 2020
Governance of the Energy Union (COM(2016) 759)	On Member State long term low emission strategies with a 50 year perspective.
Recast Renewable Energy Directive II	On the criteria to ensure production and consumption within sustainable limits and appropriate balance between energy and material uses.
LULUCF Regulation ((EU)2018/841) and the Effort Sharing Regulation ((EU)2018/842)	On the mitigation value of bioresources in situ and in their different end uses
Eco-design directive (2009/125/EC) and the Eco label regulation (No 66/2010)	On requirements for design and construction to enable the integration of bio-materials and their separation for recovery after use; On enabling consumers to make informed decisions.
Packaging & packaging waste directive (2004/12/EC)	On requirements for the content of packaging linked to the integration of bio-materials.
Waste framework directive (2008/98/EC)	On the prevention of waste and improved recovery of bio-materials to reduce the pressure on bioresources.
Construction products regulation ((EU)305/2011)	On the quality and content of bioresources used in construction
EU forest strategy (COM(2013)659)	On the governance and use of forests to produce bioresources
Raw material initiative (COM(2011)25) and the European Innovation Partnership (EIP) on Raw Materials	On ensuring the sustainable supply of bioresources
EU public procurement directives (e.g. 2014/25/EU)	On the promotion and purchasing of bioresources and bio-based products through public procurement
Horizon Europe (COM(2018)435) (replacing Horizon2020 Regulation (EU) 1291/2013)	On the research and innovation needs to support a sustainable and circular bioeconomy

Coordination of the bioeconomy transition with other policy areas can start for example from the 7th Environment Action Programme (EAP) as an entry point for a wide range of environmental issues,

²⁸ see The Circular Economy and the Bioeconomy, EEA report 08/2018

²⁹ see EU Roadmap to a Resource Efficient Europe (2011)

³⁰ taking into account the low conversion efficiency from sunlight to bioenergy compared to the direct conversion of sunlight to heat or electricity.

³¹ Liu et al. (2018): Nexus approaches to global sustainable development, Nature Sustainability, 1, 466-476

ambitions and policies³². The 7th EAP states that “a sustainable bioeconomy can [also] contribute to intelligent and green growth in Europe, and, at the same time, it will benefit from improved resource efficiency”. The development of the 8th EAP provides a natural transition towards 2030.

A circular bioeconomy with a transition beyond fossil resources, necessitates a comprehensive approach to the production, sourcing, use and consumption of bioresources, including the scale, intensity and length of this use, as well as recycling, reuse and disposal, also avoiding rebound effects where feasible. Current strategies that promote the use of bioresources have not yet comprehensively addressed these challenges, but have primarily focused on the potential of the bioeconomy to deliver added value and economic growth of individual sectors. Here the integration of circularity concepts into bioeconomy transition pathways is essential. This may be further facilitated by ensuring alignment between the development of bioeconomy strategies and actions in line with the long-term strategies that Member States will be required to set out under the Governance Regulation (once adopted). These long-term strategies address all sectors in the economy, and will for the first time set out plans for how the rural land using sectors can contribute to climate ambition, with implications for bioeconomy developments.

In the same way that the 7th EAP provides an overarching framework across a wide range of environmental issues and that the EU Policy Coherence for Development³³ provides an overarching framework across a wide range of development issues, the bioeconomy strategy must provide the necessary framework for coherence across a wider range of related policies. This has to extend beyond the limited initial focus on energy, climate and land use, and requires the political will to take such a comprehensive approach at EU and Member State level.

It will be essential that sustainability principles and criteria are applied consistently throughout the full supply chain, from production and sourcing, through all processing steps to end uses and recycling (see SDG 12 – Responsible Consumption and Production). A comprehensive bioeconomy strategy facilitates this by mainstreaming bioeconomy elements into all relevant sectors and policies, which will require a thorough scanning of all relevant policies for entry points, potential tradeoffs, risks and opportunities for increasing policy coherence.

Central to enabling the bioeconomy in the EU will be the Common Agricultural Policy with the tools and budget available to deliver change in both the agriculture, forestry and wider rural sectors. Beyond 2020 the CAP will aim to deliver against nine specific objectives (figure 4) all of which, as illustrated in this paper, could be facilitated through development of a sustainable bioeconomy. The bioeconomy features explicitly as one of the CAP’s objectives – in relation to ‘vibrant rural areas’ – specifically “Promote



Figure 4. The nine CAP specific objectives. Source: DG AGRI

³² Volker A et al. (2011) Towards a 7th environment action programme: potential options and priorities. Policy paper on ‘Charting Europe’s environmental policy future’.

³³ see Policy Coherence for Development, 2015 EU Report.

employment, growth, social inclusion and local development in rural areas, including bio-economy and sustainable forestry” (COM(2018)392)³⁴. Each Member State will be tasked with drawing up a CAP Strategic Plan to outline their targets and expected results according to these nine objectives. It is therefore essential that the CAP strategic plans are aligned to the aims of the EU bioeconomy strategy and that public funds through the CAP are used to support the sustainable development of the EU and Member State bioeconomies.

Innovation and the interface between science and policy is also essential as part of the transition towards sustainable bioeconomy development. In addition to the significant budgetary resources available through the CAP for implementing rural development measures, the Horizon Europe programme envisages a specific budget of €10 billion set aside for research and innovation in food, agriculture, rural development and the bioeconomy. This could help to unlock more sustainable approaches to producing and utilising biomass as well as providing the necessary understanding and evidence on which to make decisions about appropriate and proportionate use of biomass.

Inclusive and well-designed governance mechanisms and capacitated implementation networks³⁵ are needed to guide bioeconomic transitions and regulate and manage conflicting goals with the aim of minimizing risks, trade-offs and to create synergies in bioeconomic transformative processes. Accompanying long-term and pro-active policies, strategies and actions across countries and regions are required, which address risks and conflicting goals associated with national bioeconomy strategies^{36 37}, which also help to overcome path-dependencies in existing economic patterns³⁸. The required national and international governance frameworks have to be based on scientific assessments, which also address the competitiveness of bio-based companies and their products through different forms of direct and indirect subsidies and public outreach. Measures towards that end include awareness raising, participatory platforms, conferences, training programs and other formats, including green and social entrepreneurship, as well as legislative, policy and financial support mechanisms and institutions. Science can also support the prioritization (“ranking”) of context-specific solutions, by developing and applying a broad range of environmental and socio-economic sustainability criteria. Not all of these criteria need to be developed de novo for the bioeconomy. Some criteria and tools such as product environmental footprints³⁹ can be adapted to the needs of a bioeconomy.

2.3 The international context for bioeconomy transitions in Europe

Implementing the EU bioeconomy strategy brings responsibilities but also opportunities for Europe, with its strong international interlinkages. These responsibilities relate on the one hand to Europe’s

³⁴ https://ec.europa.eu/commission/sites/beta-political/files/budget-may2018-cap-strategic-plans_en.pdf

³⁵ Förster, J.J., Downsborough, L. and Chomba, M.J. 2017. When policy hits reality: structure, agency and power in South African water governance. *Society & Natural Resources*, 30(4): 521-536 <http://dx.doi.org/10.1080/08941920.2016.1268658>

³⁶ Dietz, T et al. (2018): Governance of the bioeconomy: A global comparative study of national bioeconomy strategies, *Sustainability* 2018, 10, 3190; doi:10.3390/su10093190.

³⁷ Pfau, S et al. (2014) Visions of Sustainability in Bioeconomy Research. *Sustainability*, 6(3): 1222-1249

³⁸ Bröring, S et al. (2017) Kriterien für den Erfolg der Bioökonomie. In *Bioökonomie für Einsteiger*; Pietsch, J. Ed.; Springer Spektrum, 161-177

³⁹ www.pre-sustainability.com/sustainability-consulting/sustainable-innovation/product-environmental-footprinting

high per-capita biomass footprints and imports and exports of bioresources and the associated impacts in the trade partner countries, and on the other hand to international and global frameworks such as the SDGs and the protection of global commons such as climate and biosphere. Additionally, the EU has adopted and translated into its policies various international and bilateral agreements and policy conventions and legal frameworks, which range from the CBD, TOPS and TRIPS to WTO and CETA. Maintaining its focus on multilateralism also presents Europe with many opportunities for improved biomass production and bioresources supply chains.

Tradeoffs and potentially conflicting goals between bioeconomy and SDG implementation evident in national bioeconomy strategies, concern in particular food security (SDG 2); poverty and inequality (SDG 1, 10); land, soil and water (SDG 6, 7, 14, 15), health (SDG 3) and climate change (SDG 13). The table below shows some of these risks and opportunities. Out of 41 countries with explicit bioeconomy strategies that were analysed, 26 have not identified any conflicting goals and risks, whereas China and a few African states explicitly recognize the need to manage risks as a crucial challenge in shaping a sustainable bioeconomy. Overall, European states show the highest political sensitivity to potential risks and goal conflicts.

Table 2: Possible opportunities and risks of bioeconomic transitions from an SDG perspective

Sustainability dimension (SDG)	Opportunities	Risks
Food security (SDG 2)	Increase via higher yields and more nutritious food, new production methods and sources of food	Reduction due to competition for land and food price increases
Poverty / inequality (SDG 1, 10)	Reduce via transfer of technology and leapfrogging	Increase via exclusion from technical progress
Natural resources (SDG 7, 14, 15)	Conserve by improving production methods	Degrade/loss through inefficient production and overuse
Health (SDG 3)	Improve through new and refined forms of therapy	Risk/damage through improper use of risky technologies
Climate change (SDG 13)	Mitigate through emission reduction	Exacerbate through direct and indirect land use change and growing agricultural emissions

Sources: Dietz et al. 2018. (see also von Braun, 2015⁴⁰; von Braun 2010⁴¹; Swinnen and Riviera 2013⁴²).

⁴⁰ von Braun, J. Bioeconomy (2015) Science and Technology Policy to Harmonize Biologization of Economies with Food Security. In: *The Fight Against Hunger and Malnutrition*; D. Sahn Ed.; Oxford Univ Press, 240-262

⁴¹ von Braun, J. 2010. Land Grabbing. Ursachen und Konsequenzen internationaler Landakquirierung in Entwicklungsländern. *Zeitschrift für Außen- und Sicherheitspolitik*, (3): 299-307

⁴² Swinnen et al. (2013). The global bio-economy. *Agricultural Economics*, 44(1)

Box 2: International cooperation when implementing the EU bioeconomy strategy, between EU and Africa

Here we provide as an example of the need for cross-regional coordination and global integration of the EU bioeconomy transition, the 2007 Joint Africa-EU Strategy (JAES) with its First and Second Action Plan (2008-2013) and its consecutive Roadmap 2014-2017⁴³.

The unique setting of the African continent with its relative richness in natural resources, but rather weak technological performance and governance, presents a number of opportunities for bioeconomy partnerships between Africa and Europe and associated policy priorities. A high-level participatory workshop and follow up talks with key public and private actors, identified four major points for such action:⁴⁴

1. the development of strategic bioeconomy blueprints and policy agendas, for prioritising investments and government interventions, to guide bioeconomic growth in a more circular economy;
2. private sector entrepreneurship, public sector research capacity building by development institutions, for translating scientific innovations in agriculture, health, and industry sectors into deployment of bioeconomy technologies and innovations, new jobs and sustainable growth, supported by a conducive policy environment and enforcement;
3. an African bioeconomy agenda which catalyses agro-value chain expansion also through foreign investments, and which links African farmers to regional, national and global markets, supported by multiple south-south-north partnerships and collaborative ventures; and
4. building national capacity and strengthening regional integration for research and development and innovation, including educational programs, capacity building initiatives and research collaborations.

Beyond these aspects of EU-Africa collaboration, fair trade conditions are essential for African countries to participate equally in the opportunities which the bioeconomy provides.

⁴³ See also: E.J. Morris (2014): Moving Africa towards a knowledge-based bio-economy, in: F. Wambugu and D. Kamanga (eds.), *Biotechnology in Africa*, Springer.

⁴⁴ Förster, J.J. and Virgin, I. 2018. Bioeconomy between Europe and Africa. ZEF policy brief No 29. https://www.zef.de/uploads/tx_zefnews/ZEF_Policy_brief_29_web.pdf

3 Policy recommendations

Implementing the EU bioeconomy strategy brings a wide range of new opportunities but also challenges, and accordingly a comprehensive set of environmental, social and economic sustainability criteria needs to be applied for aligning bioeconomy pathways with existing policy contexts such as green and circular economy, following their common objective to reconcile economic, environmental and social goals⁴⁵. Additional policy areas with which the bioeconomy has to be aligned include for example agriculture, forestry, resource efficiency, trade, development and of course energy and climate, with a specific emphasis on long-term low-emission strategies. That way the bioeconomy transition can become a lens for improving policy coherence.

Policy alignment needs to be accompanied by a set of technological, socio-economic and institutional innovations⁴⁶, some of which can be facilitated through the new Horizon Europe research programme, as well as changes in consumption and behaviour patterns. New economic and growth models are required to avoid a rapid increase in demand for biomass and the associated negative effects on the natural resource base and environment. These innovations and new models are to be tailored and iteratively adapted to the respective context and scale, including capacities of actors and institutions.

The EU with its strong international orientation, e.g. in terms of trade, development cooperation and financing has a responsibility to contribute to a bioeconomy transition which is in line with an overall sustainability transition and with the environment and development oriented SDGs. This bioeconomy transition has to simultaneously happen in, by and with Europe, applying sustainability criteria throughout the full bioresources supply chains and aligning bioeconomy pathways across sectors, scales and regions.

The EU can play a key role in harmonizing different bioeconomy pathways internationally, also with existing multi-lateral frameworks and agreements, by strengthening technological and institutional implementation capacity in partner countries, by levelling the playing field, improving the rules for cooperation, supporting fair trade, internalizing negative externalities and devising the necessary safeguards. Implementing the EU bioeconomy strategy at the same time needs to be accompanied by revisions of potentially harmful subsidies, and implementing effective international carbon pricing mechanisms and sustainable financing.

Bioeconomy transitions, coordinated across sectors, policy areas and regions, need to be based on thorough analysis, accounting for associated complexities and uncertainties and applying the precautionary principle of the EU⁴⁷. Therefore they need to be based on quantitative evidence, relying on state-of-the-art scientific knowledge, methods, tools, data and indicators⁴⁸. Continuous science-policy dialogue, platforms and other formats can ensure adaptive governance which constantly incorporates newly available data and information.

⁴⁵ D'amato et al. (2017): Green, circular, bio economy: A comparative analysis of sustainability avenues, *Journal of Cleaner Production*, 168, 716-734

⁴⁶ including also the deployment of other renewables besides bioenergy

⁴⁷ detailed in EU Article 191 of the Treaty on the Functioning of the European Union

⁴⁸ for example measuring the distribution of costs and benefits along international supply chains, or exploring the full range of bioeconomy-related risks, opportunities and pathways by way of integrated scenarios

