EU Outlook for Biomass Flows and Bio-based Products

Perspectives de l'Union européenne pour les flux de biomasse et les produits d'origine biologique

Biomasseströme und biobasierte Produkte – Perspektiven in der EU

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Understanding the importance of the bioeconomy and its analysis

Existing food systems are not sustainable and a rising global demand for food, feed, biomaterials and bioenergy will further intensify the pressure on natural resources and increase conflicts between supply and demand for biomass as a key material. Current policy instruments including the European Green Deal, the Farm-to-Fork Strategy, and the CAP 2023–2027 aim to design sustainable food systems that guarantee food security, sustainable production, and an efficient use of biomass resources. The importance of the bioeconomy as a catalyst for implementing the EU Green Deal has been acknowledged by the European Commission (European Commission, 2020). The bioeconomy encompasses all sectors and services that produce, process, use and distribute biological resources, including ecosystem services. The EU Bioeconomy Strategy (adopted in 2012; updated in 2018) and its Action Plan call for sustainable extraction, processing and use of biological resources in Europe as a pathway to achieve environmental, social and economic goals.

Despite the progress made regarding the implementation of the Bioeconomy Strategy, there are some critical factors that hinder progress towards the 2030 ambitions. The EU Bioeconomy Strategy Progress Report (published in 2022) urges additional efforts for better management of land and biological resources, as well as further actions to bring consumption towards a sustainable pathway. A major reason beyond both implementation gaps is the limited understanding of complex interactions between the components of the bioeconomy, i.e. how biomass flows into, through and out of the EU economy. Tensions between supply and demand of biomass emerge from the pressure on resources due to a variety of reasons, e.g. climate change mitigation, nature protection, the provision of ecosystem services and supply of biomass for both existing (e.g. food, feed, seed, bioenergy) and emerging uses (e.g. bio-based chemicals and bio-based construction). A cross-sectoral and cross-regional approach is helpful to identify and address trade-offs between policy targets and competing uses of land and biomass in the context of the aim to achieve a sustainable and efficient distribution of the available biomass over the different bioeconomy sectors.

Transition pathways towards sustainable food systems within and across countries can be diverse due to heterogeneous land patterns and agricultural production structures, the variety of potential industries competing for specific biomass feedstocks, as well as differing policy frameworks in place. There is no one-size-fits-all approach on how biomass should flow throughout an economy and in which industry it should end up. The Bioeconomy Strategy Action Plan recommends that initiatives aimed at exploiting the full potential of the bioeconomy should best take place at the country or regional level. Dedicated regional bioeconomy governance structures and strategies should promote and support specific biological resources, and concrete cross-sectoral cooperation and sustainability principles.

> "Pour une croissance future du secteur chimique biosourcé dans l'Union européenne et des matières premières biologiques associées, il faut porter davantage d'attention à l'approvisionnement durable en biomasse (échangée)."

A key element for those involved in the bioeconomy is to understand how biomass is supplied, as well as how it flows through the economy and how

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it is used for alternative purposes, e.g. food, feed, seed, bioenergy and bio-based materials. Bringing together the supply and the demand for biomass within the economy provides new insights into the net availability of biological resources for the bio-based industry, as well as gives an indication of the types of feedstock imports on which the bio-based industries rely e.g. palm oil. In this context, anticipating bioeconomy market trends is also of strategic importance when thinking of economic development in the future. However, the complexity of the food system and especially the diversity of pathways towards achieving a sustainable supply and efficient use of biomass, requires tools that can monitor and quantitatively analyse these aspects.

To the best of our knowledge there is no single model that represents all aspects of the food system, links primary agriculture with bio-based industries, covers the whole EU and is applicable for *ex-post* and *ex-ante* analysis. Hence, the EU H2020 BioMonitor project used a suite of methods and simulation tools, which in combination can address a variety of environmental, economic and social aspects of the bioeconomy in the EU and its Member States (see Table 1).

In short, the main aims of this article are to quantify the medium-term development of EU bio-based chemical markets assuming a business-as-usual situation, and to estimate the consequences of this development for required *versus* available biological feedstock types.

> “Das künftige Wachstum des bio-basierten Chemiesektors in der EU und die damit verbundene Nachfrage nach biologischen Rohstoffen erfordert mehr Aufmerksamkeit für die nachhaltige Beschaffung von (gehandelter) Biomasse.”

A quantitative representation of the EU bioeconomy

Evidence-based policymaking is key when thinking of (re)designing both agricultural systems and the bioeconomy in the future (Gonzalez-Martinez *et al.*, 2021). Focusing on agriculture, there is a well-established tradition of publishing, on a yearly basis, market outlooks by the European Commission and the OECD-FAO. These outlooks are based on the projections generated by quantitative models like AGMEMOD (Chantreuil *et al.*, 2012) and AGLINK-COSIMO (OECD, 2015). When looking at the bio-based economy, AGMEMOD did not have a ‘counterpart’ until the development of the BioMAT model. BioMAT was launched at the end of 2022 and provides a representation of the EU bio-based chemical value chains for the EU-27 Member States.

Like other modelling tools in the agricultural field, BioMAT projects future market developments assuming a continuation of past trends and existing policies to generate a baseline. In a scenario context, BioMAT permits exploration of how changes in driving factors, e.g. policies, macroeconomic circumstances, climate conditions and availability of biological raw feedstock could influence the ‘business-as-usual’ situation presented in the baseline. Box 1 describes more technical details on the BioMAT model and its relationship with AGMEMOD.

Outlook for the bio-based chemical market in the EU-27

AGMEMOD and BioMAT are used in combination to provide outlooks for agrifood and bio-based commodity markets in the EU and its Member

Table 1: Models in the BioMonitor toolbox

	Value chains	Indicators	Geographical location	Timeframe
Input-Ouput; econometric; trend analysis	Bioeconomy sectors; bio-based products	Socio-economic; environmental	Case-based; country-based data	Case-based
AGMEMOD	Agri-food products markets; biofuels	Economic	EU member states; Balkan countries; East-African countries; Ukraine; Russia	2030, 2050
BIOMAT	Bio-based product markets	Techno-economic	EU member states	2030, 2050
EFISCEN	Forest resources	Environmental	EU member states; other European countries	2030, 2050
EFI-GTM	Forest and wood-based products and markets	Economic	EU member states; world regions	2030, 2050
MAGNET	Bioeconomy sectors; overall economy	Socio-economic; environmental	EU member states; 141 world regions	2030, 2050

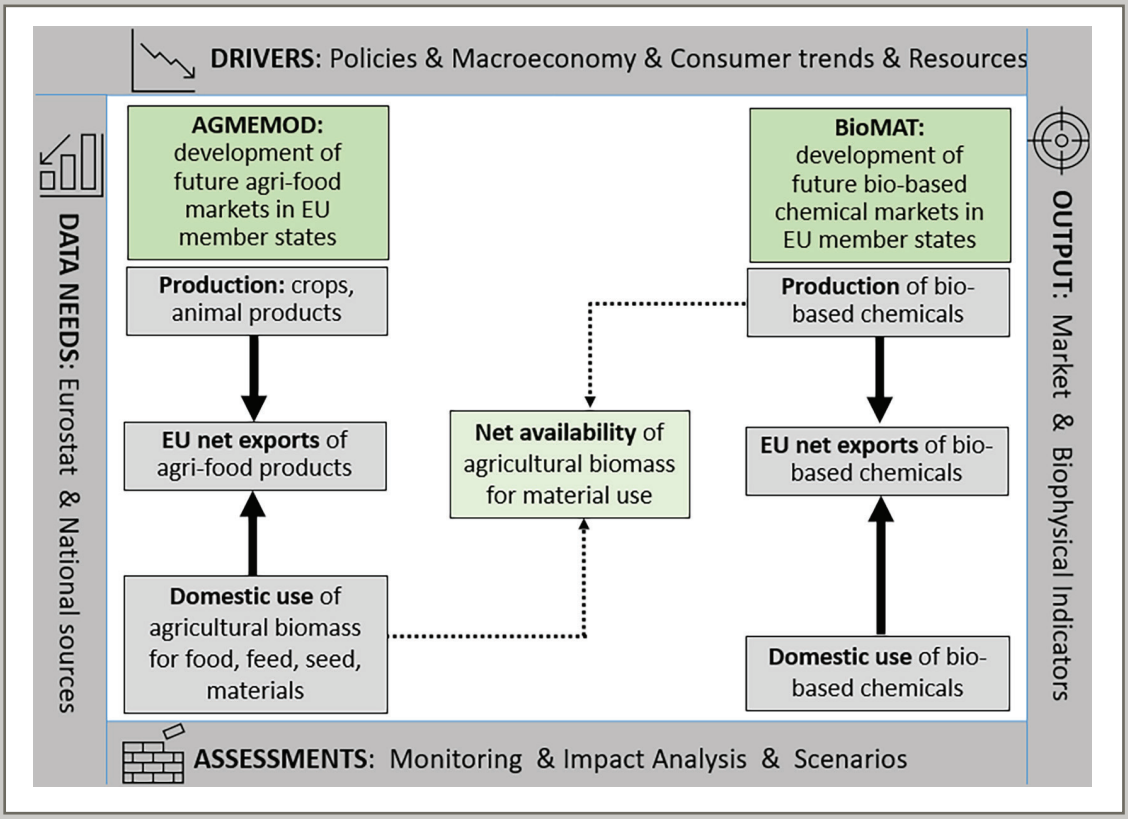
Note: AGMEMOD (Chantreuil *et al.*, 2012), EFISCEN (Verkerk *et al.*, 2016), EFI-GTM (Kallio *et al.*, 2004), and MAGNET (Woltjer and Kuiper, 2014) are existing models. BioMAT is a newly developed tool that can address future markets of bio-based chemical applications in EU Member States and their needs for biological resources.

Source: BioMonitor project (Infopack #1, 2021).

Box 1: Description of the BioMAT modelling approach

The Bio-based MATerial model (BioMAT) is a new tool for monitoring and analysing the medium- and longer-term development of bio-based chemical markets in EU Member States in terms of supply, use, trade and prices (Van Leeuwen *et al.*, 2022). All products belong to the sector NACE C20 *Manufacture of chemicals and chemical products* with the PRODCOM statistics clustered in fifteen (semi-)final applications, respectively; *chemical platform products, solvents, polymers for plastics, paints and coatings, surfactants, lubricants, adhesives, cosmetics, man-made fibers, pharmaceuticals, biofuels, food & feed, building material, agrochemicals, and other products*. The development of BioMAT started with the application of data imputation techniques to fill data gaps in the existing statistics while ensuring consistency across countries and products and related statistics (COMEXT, SBS) in the database used for the estimation of the model. As most chemical products in PRODCOM are reported as hybrid products, each is split into a bio-based and fossil-based part. Following this, each bio-based product is linked to biomass feedstock types and conversion rates indicating how much of the feedstock type is needed to produce the product (Sturm *et al.*, 2023). To sum, the starting point of the BioMAT database is the existing statistics which are supplemented with expert knowledge (left vertical bar, Figure 1) in order to safeguard regular updates at the individual product and Member State levels. BioMAT is a module of the established Agricultural Member State Modelling (AGMEMOD) tool (Chantreuil *et al.*, 2012) and thus follows the same multi-country and multi-commodity systematic approach. The main difference with AGMEMOD is the product scope. AGMEMOD analyses the supply of agri-food commodities and distributes these over main uses, i.e. food, feed, seed, stocks and materials (3 boxes on left side, Figure 1). BioMAT looks at the supply and use of industrial bio-based products downstream of the value chain (3 boxes on right side, Figure 1) as well as the biomass needed to manufacture the bio-based products. The demand for biomass from those industries is connected to the supply of biomass available for material use that AGMEMOD provides (box in centre, Figure 1). Both BioMAT and AGMEMOD provide a set of economic-technical indicators for respectively bio-based chemical applications and agri-food commodities in the EU and its Member States (right vertical bar, Figure 1) in a baseline situation. Both models are also suitable for impact assessments and scenario analysis (bottom horizontal bar, Figure 1).

Figure 1: Schematic illustration of BioMAT modelling approach



Source: Authors.

BioMAT aims to describe how the behaviour of suppliers and users influences the development of bio-based production and use, which are quantified by means of the shares of bio-based products within a specific chemical application. Therefore, *estimating the size of bio-based shares from key factors is a core effort of BioMAT in order to split the total market of a chemical application over its fossil-based and bio-based parts*. In this respect, the supply of any bio-based application is driven by technology, policies, availability and prices of biomass feedstock, and the raw oil price for the competing fossil-based application. Factors like economic development (income, world prices), demographic factors and consumer preferences (upper horizontal bar, Figure 1) explain the demand for each bio-based application.

States until 2030 in a baseline case. This baseline reflects a continuation of the 'business-as-usual' situation and incorporates assumptions on policy and trends (like consumer preferences, economic and demographic developments) in the coming years.

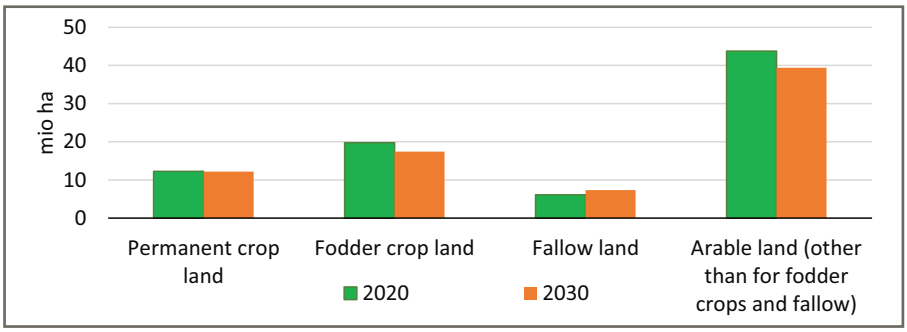
Agrifood commodity markets. AGMEMOD presents the future of agrifood markets, which is consistent with the OECD's agri-food projections for the EU and the European Commission's 2022 Medium-Term Outlook. It represents production, consumption, yields and trade for the main commodity groups (cereals, oilseeds, dairy and meats). Note that any disruptive shock that may happen in future, but is not yet known, e.g. due to geopolitics, extreme weather conditions, plant or animal diseases, is disregarded.

> "The future growth of the EU bio-based chemical sector and of the associated demand for biological feedstocks requires more attention for sustainable sourcing of (traded) biomass."

In light of competing claims on the agricultural biomass that is produced in the EU, AGMEMOD gives supply information, such as hectares of arable land available for biomass production (Figure 2), or production volumes (top of Figure 3) and self-sufficiency rates for cultivated crops in 2030 (bottom of Figure 3).

As indicated in Figure 4 (top), the most important application of feedstocks such as maize, soft wheat and soybeans is feed use, with 45 miot (dry weight), 50 miot and 28 miot, respectively. Focusing on direct food use, about 40 miot of soft wheat and 22 miot of sugar beet (dry weight) are expected to be

Figure 2: Arable crop land in EU (mio ha), 2020 and 2030



Source: AGMEMOD.

used by 2030. To sum, more than half of the arable crop volumes produced in the EU over the period 2020–2030 are intended for feed applications, one quarter for food use, and around 6 per cent and 8 per cent for biofuel and material use, respectively (bottom of Figure 4).

Drawing attention to biomass feedstock availability for material and biofuel uses, Figure 5 reports on the relevant developments for the observed (2010–2018) and projected (2019–2030) periods.

It shows the use of starch (processed from soft wheat, maize, and potatoes), industrial sugars (from sugar beets, isoglucose and sugar) and industrial plant oils (from rapeseed, sunflower and soybean) for production of bio-based materials and biofuels. These feedstock types relate to commodities captured by AGMEMOD. Starch will continue representing at least half of total biomass feedstock available for material use up to 2030. Plant oils are expected to slightly increase their relative contribution to the total, representing 30 per cent. Note that biomass feedstock for material use produced outside the EU (like sugar cane or palm oil) is not covered in Figure 5, nor is the biomass available from sources like wood and biomass residues. Currently the interest in data on agricultural residues (from primary production, processed industry and household food waste) is increasing, especially in the context of an efficient and circular use of resources. When information becomes available these feedstock types could be added to AGMEMOD's biomass balance.

Bio-based chemical application markets. BioMAT represents the market development of bio-based chemical applications in the EU over 2010–2030 (in volumes, left axis of Figure 6). Although not included in the figure, we found that the expected annual growth rate of production and consumption of the average bio-based chemical application from 2018 to 2030 is four times higher than its fossil-based counterpart (2.7 per cent versus 0.7 per cent). This is caused by a declining ratio between bio-based and fossil-based prices for chemical products. The dotted line shows the expected moderate growth of the bio-based share in total chemical production from 13 per cent in 2010 to 17 per cent in 2030 (right axis of Figure 6). In the analysed period, the EU remains a net-importer (in kton) of chemical product applications.

Figure 7 shows a breakdown of the total bio-based chemical production by individual product application categories. With regard to the use of

Biorefinery processing biomass into bio-based intermediates © Authors.

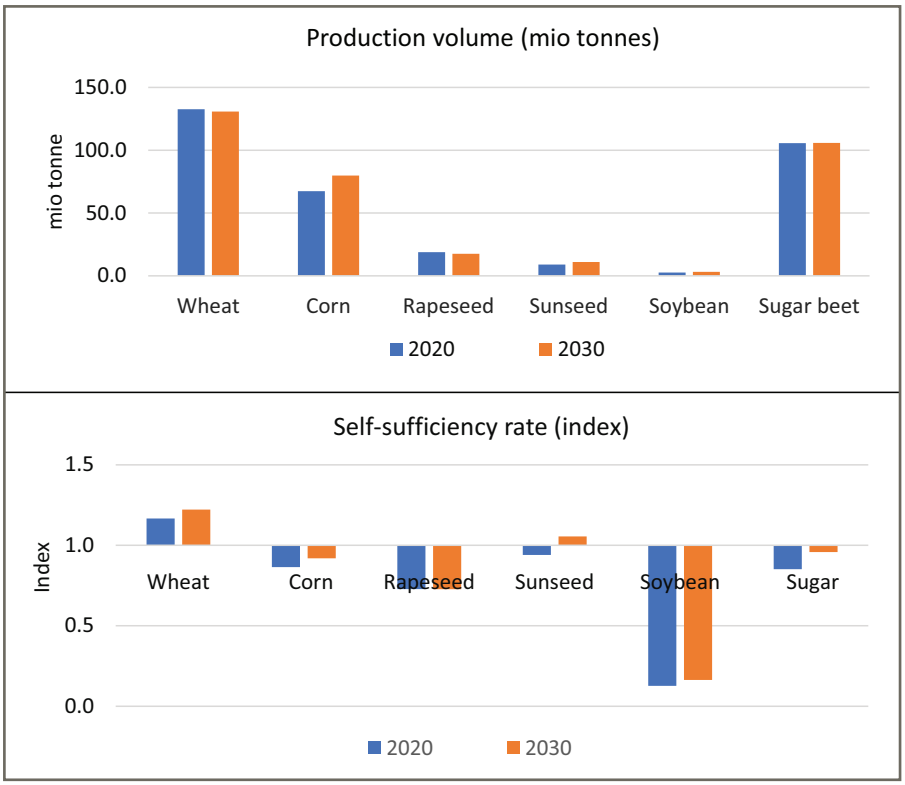
biological feedstock by the bio-based chemical industry, Figure 8 shows the projected needs, per type, for any distinguished bio-based chemical applications in EU in 2030. About one third regards industrial plant oil, followed by starch (21 per cent), wood lignocellulosic (13 per cent), animal biomass (10 per cent) and sugars (6 per cent).

The volume of industrial sugars, starch and industrial plant oil respectively that is available for the EU bio-based chemical industry, i.e. the feedstock volumes which remains on the supply side after allocating to food, feed, and seed applications in EU and abroad (provided by AGMEMOD), is compared to their required amounts from the EU bio-based chemical industry (provided by BioMAT). While the industrial sugar market is quite balanced, there exists an excess-demand for starch and plant oils (for reasons see Sturm *et al.*, 2023). The excess-demand for starch for material and biofuel use (when correcting for starch used by the paper industry), might increase from 1.4 miot in 2020 to 2.9 miot in 2030. Moreover, the excess-demand for industrial plant oils in the EU is expected to grow from 10.1 miot in 2020 to 15.6 miot in 2030. As plant oils form the dominant feedstock in the bio-based chemical sector, and given that its vast majority originates from non-EU regions, there is a strong need for sustainable sourcing of (traded) biomass.

Lessons learnt

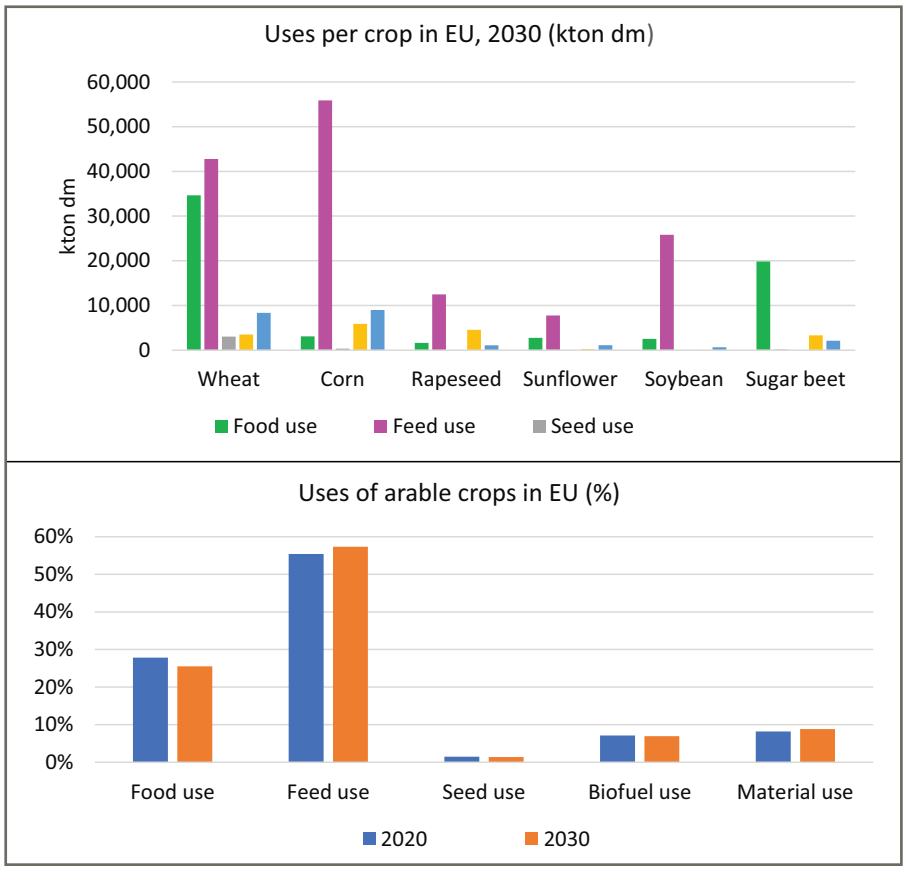
The transition towards a more sustainable food and more bio-based industrial system will rely on the availability of sustainable biomass feedstock and appropriate processing technologies, as well as substantial market penetration of bio-based products. On the production side, additional investments to improve the existing production methods, reduce waste and deliver new products will be required. On the consumption side, raising awareness, informing consumers about the implications of their choices, and changing their behaviour by means of fiscal (tax) instruments are among the available tools to increase the uptake of bio-based products. Regardless the target of the intervention, i.e. farmers, processing industry, industrial users and consumers, there is a need for a transparent and well-designed policy framework that favours the

Figure 3: Production volume (mio tonnes) and self-sufficiency rates (index) of crops in EU, 2020 and 2030



Source: AGMEMOD.

Figure 4: Uses per crop and distribution (kton dm) of agricultural biomass over uses (%) in EU, 2020 and 2030



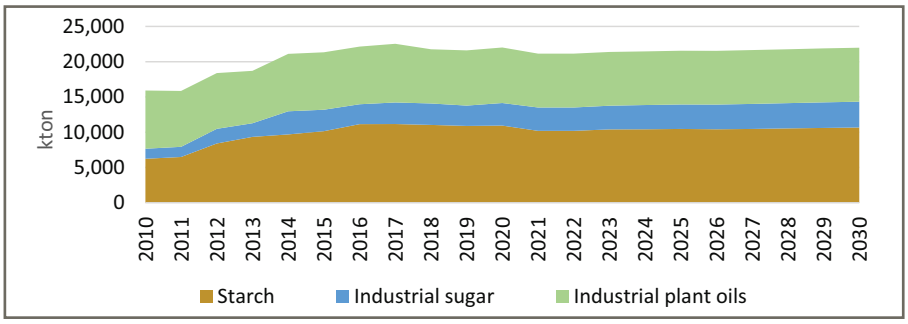
Source: AGMEMOD.

development of sustainable activities along different supply chains.

The implementation of appropriate policies related to the bioeconomy and the assessment of their impacts can profit from the insights provided by quantitative modelling tools. This approach has proven relevant in other fields such as agricultural or energy policies. Since the modelling related to primary agricultural production in the EU-27 is well-covered by AGMEMOD, there is a need to get insights into the secondary stages of the supply chain. This will improve our understanding of the demand from the bio-based chemical industry and the final use of its output in the EU Member States. This is the contribution of the BioMAT model, embedded in the AGMEMOD governance system what allows the easy cooperation of both modelling tools to generate medium and long-run projections.

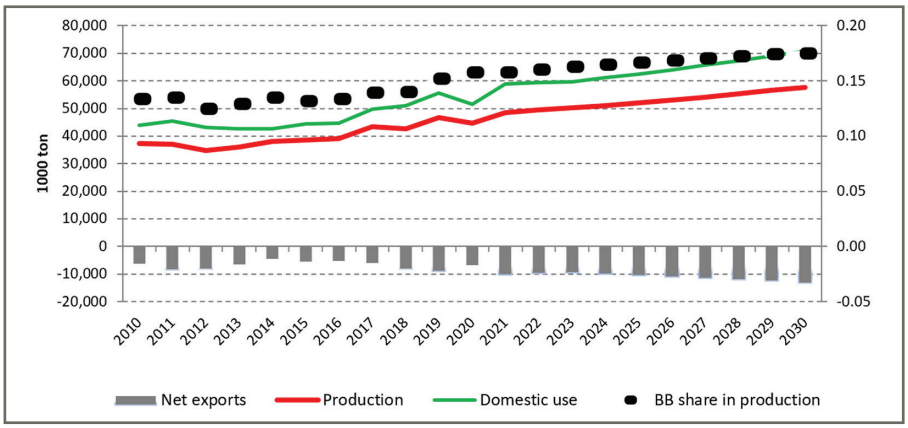
A final comment regarding validation of the market outlooks delivered by these tools is due. The AGMEMOD baseline is updated every year and validated with EU and national policymakers and agrifood industry representatives. Since BioMAT has recently been developed, a solid validation procedure for its baseline still needs to be established. The initial validation exercise has relied on the insights provided by economic market experts and engineering experts.

Figure 5: Agricultural biomass available for material and biofuel use (kton) in EU, 2010–2030



Source: AGMEMOD.

Figure 6: Development of production and use of total bio-based chemical applications (kton, left axis) and the bio-based share in total chemical production (%, right axis) in the EU, in 2010–2030



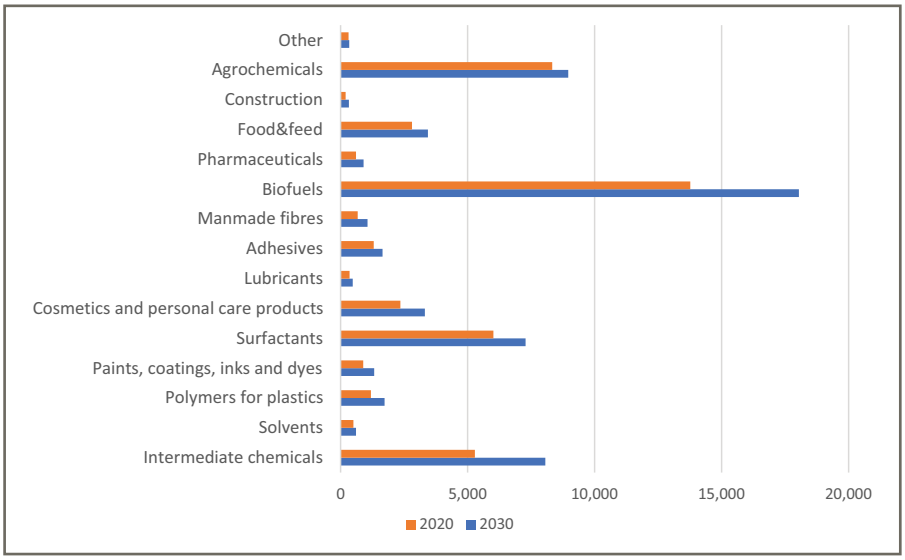
Source: BioMAT.

Implications for decision-making and policy design

The following specific features of BioMAT can be of interest for policymakers and other relevant stakeholders involved in the bioeconomy: the model explains how the production of bio-based materials has evolved in the past and identifies the overall historical trends that occurred in the EU bioeconomy. For example, it shows the evolution of the share of bio-based production in the chemical industry and provides projections for these uses. Moreover, it provides projections on the shares of bio-based materials in the chemical industry that are currently produced and where, and plausible production volumes in 2030. BioMAT can also respond to questions regarding the expected biomass feedstock needed to produce these innovative materials in 2030 and whether it will be met by available EU production. Therefore, it can also help policymakers to anticipate the potential trade flows of the EU with the rest of the world. All these questions can be addressed when looking at the baseline/simulated scenarios of the BioMAT model.

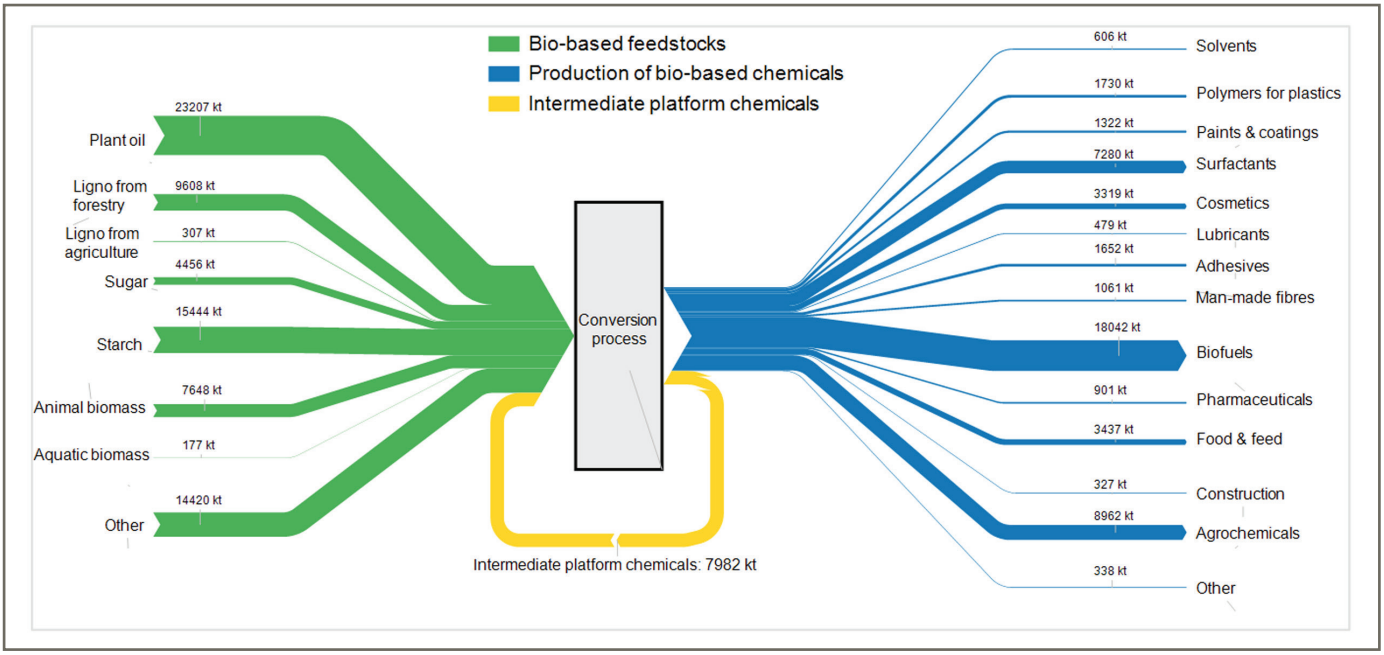
Other relevant applications of the model are in the context of alternative scenario simulation and

Figure 7: Production of bio-based chemical application (miot) in the EU, 2020 and 2030



Source: BioMAT.

Figure 8: Use of biological resources by bio-based chemical applications (kton) in EU, 2030



Source: BioMAT.

sensitivity analysis. Specifically, the model could provide responses regarding the implications of changes in the driving factors influencing the development of the future bio-based material markets in terms of policy measures, technological progress, environmental and consumer trends.

Note

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Further Reading

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Summary

EU Outlook for Biomass Flows and Bio-based Products

The Bioeconomy Strategy Action Plan calls for sustainable extraction, processing, and use of biological resources in Europe as a pathway to achieve environmental, social and economic goals. However, the transition towards sustainable food systems within and across countries is diverse due to the existing heterogeneous land patterns and agricultural production structures, the variety of potential industries competing for specific biomass feedstocks, and the national policy frameworks in place. Therefore, it is key for policymakers to understand how biomass is supplied, and how it flows through the economy and is used for alternative purposes. This calls for tools that can monitor and quantitatively analyse these aspects. BioMAT has projected the annual growth rate of the EU bio-based chemical production from 2018 to 2030 to be four times higher than its fossil-based counterpart. The associated net-availability of industrial sugars in 2030 is quite balanced, but excess demands for starch and plant oils will increase to fulfil requirements of a growing bio-based chemical sector. As a vast amount of biological feedstock for material use originates from non-EU regions (e.g. palm oil), sustainable sourcing and a better use of biological residues should be emphasised. Scenario analyses are helpful to consider consequences of assessing different technical pathways or policies.

Perspectives de l'Union européenne pour les flux de biomasse et les produits d'origine biologique

Le plan d'action stratégique pour la bioéconomie appelle à une extraction, une transformation et une utilisation durables des ressources biologiques en Europe comme moyen d'atteindre les objectifs environnementaux, sociaux et économiques. Cependant, la transition vers des systèmes alimentaires durables au sein et entre les pays est diversifiée en raison de l'hétérogénéité des structures foncières et de production agricole, de la variété des industries potentielles en concurrence pour des matières premières spécifiques de la biomasse et des cadres de politique nationaux en place. Il est donc essentiel que les décideurs de l'action publique comprennent la manière dont la biomasse est fournie, circule dans l'économie et est utilisée à d'autres fins. Cela nécessite des outils capables de suivre et d'analyser quantitativement ces aspects. BioMAT prévoit que le taux de croissance annuel de la production chimique d'origine biologique dans l'Union européenne (UE) entre 2018 et 2030 sera quatre fois plus élevé que celui de la production chimique d'origine fossile. La disponibilité nette associée de sucres industriels en 2030 est assez équilibrée, mais la demande excessive d'amidon et d'huiles végétales augmentera pour répondre aux besoins d'un secteur chimique biosourcé en pleine croissance. Étant donné qu'une grande quantité de matières premières biologiques destinées à l'utilisation matérielle provient de régions hors de l'UE (par exemple l'huile de palme), un approvisionnement durable et une meilleure utilisation des résidus biologiques doivent être mis en avant. Les analyses de scénarios sont utiles pour examiner les conséquences de l'évaluation de différentes voies techniques ou de politique.

Biomasseströme und biobasierte Produkte – Perspektiven in der EU

Der Aktionsplan zur Bioökonomie-Strategie fordert die nachhaltige Gewinnung, Verarbeitung und Nutzung biologischer Ressourcen in Europa, um ökologische, soziale und wirtschaftliche Ziele zu erreichen. Der Übergang zu nachhaltigen Lebensmittelsystemen innerhalb und zwischen den Ländern ist jedoch aufgrund der bestehenden heterogenen Landmuster und landwirtschaftlichen Produktionsstrukturen nicht einheitlich. Des Weiteren ist sind die vielen potenziellen Industrien, die um bestimmte Biomasse-Rohstoffe konkurrieren und die bestehenden nationalen politischen Rahmenbedingungen sehr unterschiedlich. Daher ist es für die politischen Entscheidungsträgerinnen und Entscheidungsträger von zentraler Bedeutung, Kenntnisse über die Bereitstellung und Einsatzzwecke von Biomasse und deren Wege durch die Wertschöpfungskette zu haben. Es erfordert ein Instrumentarium, mit dem diese Aspekte überwacht und quantitativ analysiert werden können. Die BioMAT hat prognostiziert, dass die jährliche Wachstumsrate der biobasierten Chemieproduktion in der EU von 2018 bis 2030 viermal so hoch sein wird wie die der fossil-basierten. Die damit verbundene Nettoverfügbarkeit von Industriezucker im Jahr 2030 ist recht ausgeglichen. Allerdings wird der Überschussbedarf an Stärke und Pflanzenölen steigen, um die Anforderungen eines wachsenden Sektors für biobasierte Chemikalien zu erfüllen. Da ein großer Teil der biologischen Rohstoffe für die stoffliche Nutzung aus Nicht-EU-Regionen stammt (z. B. Palmöl), sollte auf eine nachhaltige Beschaffung und eine bessere Nutzung biologischer Reststoffe geachtet werden. Szenarioanalysen sind hilfreich, um die Folgen verschiedener technischer Pfade oder politischer Maßnahmen zu untersuchen.