LEAD MARKET BIOECONOMY: TRANSFORMATION AND SCALING FOR SUSTAINABILITY AND THE RESOURCE TRANSITION

POSITION PAPER OF THE DIALOGUE PLATFORM INDUSTRIAL BIOECONOMY

The German Federal Ministry for Economic Affairs and Climate Action (BMWK) founded the dialogue platform “Industrial Bioeconomy” (DPIB) in 2018 to foster the industrial change. The dialogue platform aims at industry, the public and politicians alike. It suggests proposals regarding the promotion of the industrial bioeconomy, the design of framework conditions, sustainability, and supply structures as well as communication.

This position paper exclusively reflects the recommendations and assessments of the authors involved in the position paper and does not necessarily represent the opinion of the Federal Ministry for Economic Affairs and Climate Action or the publisher VDI Technologiezentrum GmbH.

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1 Bioeconomy: the key to sustainable industrial economy

For decades, the German industry was regarded as an example for economic recovery and guaranteed a high standard of living in our country. Along with visionary thinking, technical progress and entrepreneurial spirit, the decisive factor for its growth was access to cheap fossil resources, primarily for energy supply. To secure industrial performance in times of geopolitical tension, to achieve the UN Sustainable Development Goals (SDGs) and the goal of net greenhouse gas neutrality as enshrined in the Climate Change Act by 2045, a paradigm shift is required towards a more sustainable way of production and consumption. In addition to the defossilisation of the energy sector, which is currently one focus point of political decision-makers, there is also a high demand to transform important industrial sectors. This must also be reflected in strategic political action. One initial step has been taken with rising CO_2 prices and the German government's intention to aim at CO_2 neutrality. However, the transformation to a sustainable economy requires alternative carbon sources as well as the consideration of circular economy, efficient material and raw material coupling and efficient coupling with renewable energies. "Green" technologies need to be developed, scaled up and established in the market to achieve these ambitious goals. The raw materials transformation is an essential part of defossilising fossil industry as shown in Figure 1.

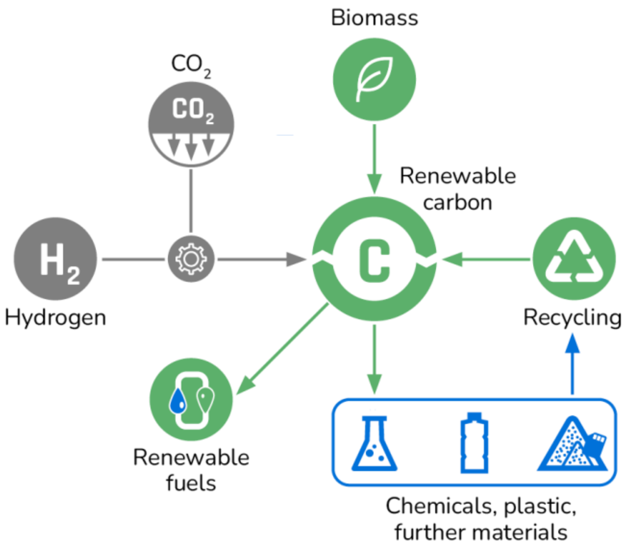

Fig. 1: Approaches for defossilising industry as an important part of the raw materials transformation[1]

Major economies all around the world have started to defossilise commodity and energy flows with programmes, such as the Inflation Reduction Act and the US government's *Executive Order on Advancing Biotechnology and Biomanufacturing Innovation*[2]. Germany needs to follow up, to reshape the path to a sustainable industry and to massively accelerate the transformation of important industrial sectors. Many technologies have been developed by science and industry has already started their implementation in many fields of application.

However, to achieve the rightly ambitious goals and to secure the basis for our high standard of living in the future, Germany needs to take on a pioneering role in the transformation in competition with industrialised countries. All relevant industries and stakeholders should contribute to the common goal of developing and applying new tech-

[1] Source: Federal Ministry for Economic Affairs and Climate Action

[2] Executive Order on Advancing Biotechnology and Biomanufacturing Innovation for a Sustainable, Safe, and Secure American Bioeconomy at https://www.whitehouse.gov/briefing-room/presidential-actions/2022/09/12/executive-order-on-advancing-biotechnology-and-biomanufacturing-innovation-for-a-sustainable-safe-and-secure-american-bioeconomy/ as well as Bold Goals for U.S. Biotechnology and Biomanufacturing: Harnessing Research and Development to Further Societal Goals at 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

nologies and infrastructures under suitable framework conditions. Furthermore, they should contribute to the formation und adaption of new value chains which consider the principle of sustainable circular economy. It is the task of the government to combine technology and resource sovereignty with climate protection goals in a sustainable industrial policy and to involve various groups of society to accelerate the establishment and integration of one of the most important green markets of the future[1]: **the bioeconomy.**

The industrial bioeconomy lays the foundation to replace fossil-based products and processes with bio-based ones and to create completely new products, production processes and business models by combining biological knowledge with technological solutions and exploiting the natural properties of biogenic raw materials with regards to their recyclability, renewability and adaptability. Bioeconomic innovations are based on the sustainable use of resources, the bio-based substitution of fossil raw materials, the use of residues or by-product streams and the utilisation of biotechnological processes.

Box 1: Definition of the industrial bioeconomy[2]

The aim of this paper by the DPIB is to demonstrates how the transition to a post-fossil and economically successful industrial age can succeed with the support of the bioeconomy. Addressee of this paper is the BMWK in its role as the leading state actor for industrial transformation and transfer, and for the development of a sustainable industrial policy. Based on the mission statement "Industrial Bioeconomy: Strengthening and Sustainably Shaping Germany as a Place for Business and Investment", the DPIB has underlined the current and future significance of the industrial bioeconomy. To develop Germany into a lead market for the sustainable and cycle-oriented bioeconomy, this paper outlines the need for an integrative process involving many relevant stakeholders and presents a framework for action that is required. The paper focuses largely on the chemical and processing industry. Other aspects, such as innovative approaches in the food sector or the link between topics addressed here, will be taken up in a separate paper.

Implementation requires coordinated efforts of all stakeholders and setting of a political course in regulatory, structural and funding policy. All measures must aim at achieving the effective establishment of suitable framework conditions for transforming industry in their entirety. Besides the regulatory and process policy framework and the reliability of framework conditions for investments and in funding policy, what is particularly important is an increase in domestic demand for bioeconomy products. In parallel, measures should also be carried out at European level to prevent competitive disadvantages in the common market and to enhance a positive stimulus for the transformation. Besides aspects of raw material production, recycling and supply as well as raw material processing, the potential of key technologies such as biotechnology or materials research must also be given greater consideration here[3].

Decisions regarding the technology pathways to follow in the future pave the way for this forward-looking lead market and the economic future of our continent. The political and societal framework must allow for maximum openness to technology to design approaches to accomplish the transformation.

To achieve the transformation to a sustainable economy, political decisions that must be made today, such as a possible prioritisation of the use or non-use of biomass(es) or the use of innovative technologies, must consider that this will pave the way for the future, which can either endanger or favour the industrial bioeconomy. Therefore, these decisions must be coherently designed and meaningfully support the sustainable transformation of the economy in line with the specified political goals with regulatory and procedural measures and the limitation of the availability of biomass due, among other things, to land and water restrictions (see Chapter 2) as well as the need to safeguard world food security.

[1] The global green tech market will grow to nearly six trillion euros by 2025; source: https://www.rolandberger.com/de/Insights/Publications/Doppelte-Chance-f%C3%BCr-Europas-Industrie.html.

[2] Source: https://www.bmwk.de/Redaktion/DE/Dossier/Industrielle-Biooekonomie/neue_Dossierseite/leitbild-2-0-pdf.pdf?__blob=publicationFile&v=10

3 The potential of these key technologies has already been demonstrated in recent years in the manufacture of vaccines, the use and recycling of residual materials to produce high-quality chemicals, and the manufacture of climate-neutral products using CO_2 as a raw material.

1.1 Transformation pathways of the industrial bioeconomy

The approaches supported by the industrial bioeconomy offer wide opportunities and a high potential for companies – whether global corporations, SMEs or start-ups- to expand their predominantly fossil-based resources by adding self-regenerating and other renewable raw materials, e.g. CO_2-based raw material sources or recyclates. This makes a decisive contribution to the defossilisation and recycling of materials and raw materials in Germany. Evaluation of the numerous examples within the framework of the work carried out by the Industrial Bioeconomy Platform has shown that industry has embarked on the outlined transformation pathway towards a sustainable bioeconomy, both technologically and in terms of post-fossil raw materials. Some companies started developing, scaling and marketing bioeconomic products decades ago and are now preparing to convert their production to cascading use or recycling. Here, the complete transformation can be expected as early as this decade. Other companies and sectors will only achieve full transformation in 2050 and later. Therefore, the speed of implementation needs to be significantly increased to achieve the political climate and environmental protection goals set within the specified timeframe and to herald the end of the fossil fuel era. However, efficient and targeted government action that supports this transformation pathway presupposes that the implementation of the bioeconomy is not to be understood as a sequential process, but as running in parallel in different development phases and business models. Possible phases of the implementation of the bioeconomy from the companies' point of view are shown in Figure 2.

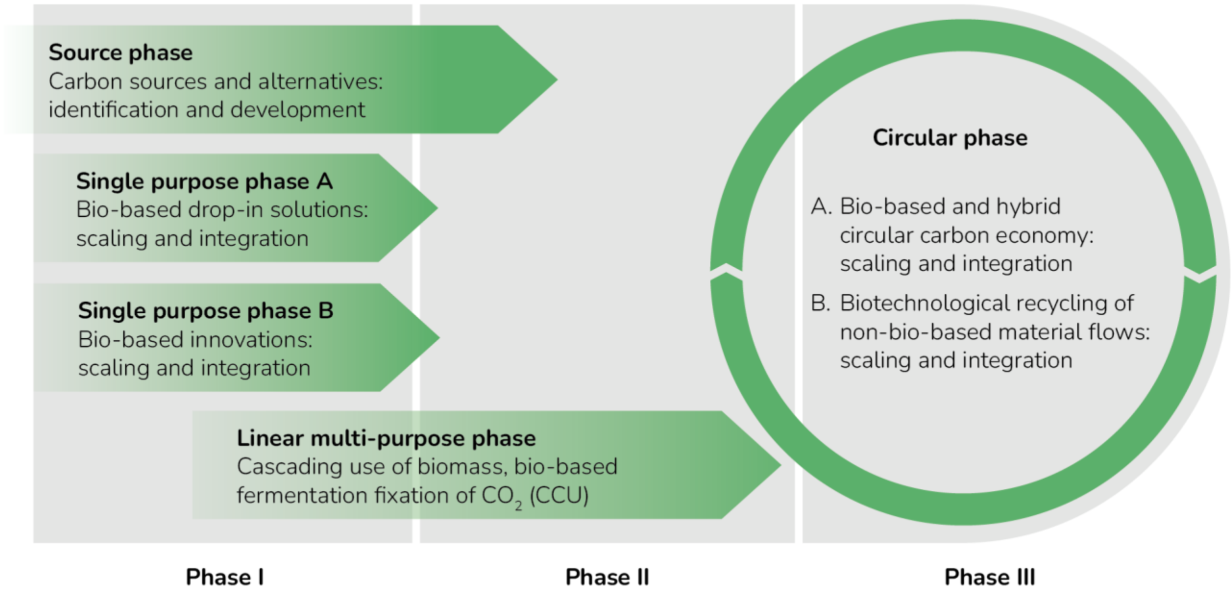

Fig. 2: Possible phases of the implementation of the bioeconomy from the companies' point of view[1]

Business models for entering the bioeconomy can either target raw materials or products based on renewable rather than on fossil sources or secondary sources, or those produced by biological processes. These innovative drop-in solutions (Single Purpose Phase A) are to be integrated competitively into existing value chains through sustainable raw material sources. This may be preceded by a longer process of sourcing, in which the carbon must first be developed from sustainable sources (the sourcing phase)[2]. Companies whose processes and products are not aimed at replacing raw materials and products from fossil sources as homologously as possible, but rather at developing innovative raw materials and products with entirely new properties (and new benefits), are in the so-called Single purpose Phase B. When production processes are transferred to cascading use, linear production processes, that serve just one single purpose, must be enhanced into circular multi-purpose process systems to use a bio-based product as a material as long as possible and to recycle it energetically at the end of its life.

[1] Source: Federal Ministry for Economic Affairs and Climate Action

[2] The same is true for other elements, e.g. phosphorus or critical metals, but they are not the subject of the paper presented here.

A sustainable bioeconomy keeps the intermediate stages and products in the cycle as long as possible if it's feasible for the products. Ideally, "waste" should be almost non-existent, and the occasional supply of "fresh" bio-based raw materials would only compensate any losses that incur during recycling. Following the example of the natural world, growth and resource consumption could be largely decoupled.

1.2 Transformation in practice

The presentation of 28 profiled example regions[1] and more than 35 best practice examples of the industrial bioeconomy and many other initiatives impressively demonstrate the dynamics in the development of Germany's bioeconomy. Further to the long-established use of biotechnology for producing vitamins, amino acids, ethanol, citric and lactic acid as well as medicines and vaccines in industry, but also, for example, for purifying water. Start-ups and SMEs, but also large-scale industrial companies, are developing numerous new approaches for sustainable production processes and products. Many of them are already available on the market today and even more are in the pipeline.

A particular challenge of the industrial bioeconomy is the scale-up of innovative processes. In recent years, however, significant developments can be distinguished here, too. One highlight is the construction of a large-scale facility for producing glycol from beech wood by the company UPM in Leuna, which will be used as a drop-in chemical for bioplastics and textiles, or the facilities of Südzucker/Zeitz[2] for the industrial production of ethanol for manufacturing the solvent ethyl acetate. Corresponding production capacities in which German companies are involved as technology suppliers or as operators are also being built up in other European countries. Current technological developments include two processes developed by Covestro – one for bio-based hexamethylene diamine (HMDA) and one for bio-based aniline – which provide raw materials for producing bio-based polyurethanes. All the latter products are required on a scale of several 100,000 tonnes per year, which means that when the processes are established, further investments in the billion-euro range will follow.

One example of a new biomass source is the Russian dandelion as an alternative source of natural rubber[3], which is economically attractive and ecologically or socially harmless. This is where replacing the unsustainable source or supply chain is important. Rubber is listed as a critical raw material for the European Union on account of its strategic importance as the only raw material of biogenic origin (ETRMA, 2017; EU, 2020). The close cooperation between science and industry has led to the establishment of the "Taraxagum Lab Anklam" (investment approx. €35m), a globally unique R&D facility for breeding, cultivation and raw material extraction. It is currently the basis for a dynamically developing industrial segment for innovative rubber products in Germany (and beyond). The next step will be to initiate the construction of an industrial plant, which will require billions of further investments.

However, these industrial bioeconomy plants not only produce bio-based raw materials for defossilisation, but also create future-proof jobs: each of these plants is expected to employ 100 to 150 people. Table 1 shows examples of plants that are currently under construction or have just started operation.

Investments made over the past decade based on ever-improving framework conditions are remarkable. They demonstrate the incipient economic success and feasibility of the bioeconomy. However, compared to chemical and related industries, they are merely a "drop in the ocean". Moreover, besides the sustainable, circular supply of raw materials, they focus on the marketing of corresponding "green technologies" for mechanical and plant engineering. The transformation to a circular and sustainable (bio)economy requires massive further concerted efforts and a significant improvement of the framework conditions.

[1] The map with best-practice examples of the industrial bioeconomy can be found at https://www.bmwk.de/Navigation/Karte/SiteGlobals/Forms/Formulare/karte-bestpractice-formular.html

[2] See https://onlinelibrary.wiley.com/doi/epdf/10.1002/cite.202000061

[3] To make a substantial contribution to NR production, about 50,000 hectares are needed. This is not about displacing the current NR production with rubber trees, but rather about securing the future additional NR demand with dandelions to protect valuable tropical forests. In cultivation, the focus is on secondary yield areas, not only in Germany but throughout Europe. Also, new crops increase agrobiodiversity without competing with food production.

Company	Product/topic	Location/start-up	Investment volume
Clariant	Ethanol from straw	Podari (Romania) (2022)	approx. €250m
Continental	Dandelion rubber	Anklam (2018)	€35m
Evonik	Rhamnolipids (organic detergent)	Ľupča (Slovakia) (2024)	Three-digit million euros
Südzucker/ CropEnergies	Ethyl acetate (organic solvent)	Zeitz (2025)	€120-130m
UPM	Glycol, lignin, industrial sugar	Leuna (2024)	€1.18bn

Table 1: Facilities for the large-scale implementation of biotechnology-based processes[1]

2 Prioritising the use of renewable and sustainable resources for the bioeconomy

A fundamental transformation of industry is required to achieve the goal of net greenhouse gas neutrality in Germany by 2045. Currently our industry is characterised by using fossil carbon compounds and linear approaches opposed to a circular climate-neutral mode of production and economy. This transformation will not succeed with renewable energies and, in the future, climate-neutral hydrogen alone.[2] While starting compounds containing carbon can be dispensed with in certain sectors, such as individual mobility in road transport, they are regarded as an indispensable part of the value chain in many sectors. Carbon is a central component of organic chemistry. It cannot be replaced as a raw material or as an auxiliary substance and alloying element in other sectors, such as the steel industry. For a sustainable economy, replacing fossil carbon sources with sustainable and renewable sources of supply is, therefore, essential. Only three sources can be considered (cf. also Fig. 1).

- Biomass
- Recycled secondary raw materials from residual and waste materials as well as wastewater and exhaust air
- CO_2 from waste gas streams – not only from biomass combustion, but also from industrial processes (e.g. steel or cement production, waste incineration) or from the atmosphere ("carbon capture and utilisation", CCU).

The development of these raw material sources connects economic sectors that often act separately up to now (agriculture with primary industries; use of residual, waste, wastewater and side streams from various industries; nutrients from municipal wastewater management or waste management with agricultural activities). Thus offers the possibility to establish new business models in terms of new sector linkages. Using alternative carbon sources and secondary raw materials for industry and linking them in a circular economy model will thus maintain, increase and create new value. Thus, it lays the foundation for a resource-efficient and sustainable circular economy. The development of alternative carbon sources is of great strategic importance for the transformation of industry and is associated with significant adjustments to the existing material flows and the (industrial) partners involved. However, industry can and will only be able to enhance the transformation process if the long-term and sustainable availability of biomass and thus, in particular, its main component – carbon – can be ensured.[3] To promote this on the part of the government, the availability and supply of biomass to industry must be regarded as a core element in relevant strategies (e.g. the biomass strategy and bioeconomy strategy [or their implementation plan]).

In this context, in their approaches to utilisation, the respective strategies should be clearly oriented towards the principle of cascading use. Consequently, biomass should be used in long-lasting products for as long as possible, until they are then recycled for energy at the end of their possible recycling cycles. Research and development should be directed towards the design of innovative and economically viable uses for sustainably available forms of biomass

[1] Source: author's own diagram

[2] https://www.wirtschaft.nrw/carbon-management-strategie-nrw

[3] Alternatively, biological carbon capture and utilisation (CCUBIO) offers an efficient and scalable solution for CO_2 recycling and thus offers the option of decoupling the biological conversion of CO_2 into new carbon raw materials from land and water consumption.

and the use of new approaches to tap biomass potential that was previously inaccessible for further material processing on account of poor separation or recycling.

Recommendations for appropriate measures:

- Cultivate biomass on arable land (agroforestry), marginal sites and possibly degraded land using cultivation systems that, besides producing biomass, also enhance soil health and biodiversity, as well as guarantee an income for farmers and foresters in the medium term.
- Develop and implement efficient extraction and utilisation concepts for carbon or raw materials from biomass sources, recycling processes and CO_2 (CCUBIO) including the production methods and processing procedures required for this in industry; to this end, biomass, secondary raw material and CO_2 sources, some of which are yet untapped, must be made accessible (consistency of regulations).
- Reduce pressure on limited land and water and support sustainably produced industrial raw materials in Germany by incorporating biotechnology and recycling or reclamation, tapping sustainable non-surface biomass e.g. from fermentation processes or algae, and establishing biomass production that avoids competition regarding land and food. In this context, the utilization of organisms, other than plants, which can produce raw materials for industry from CO_2, decoupled from land and water requirements.
- Strengthen cascading use and make the utilisation of biomass as a material a priority. Energy-related use is part of the bioeconomy but can only be based on residual material flows that can no longer be efficiently used as materials in recycling cycles.

One central approach in the transition of the raw material supply for the bioeconomy is to expand the cascading use of biologically produced raw materials through sector coupling, including waste and wastewater management in integrated industrial plants and bioeconomy regions. This is a key in partially decoupling biomass production and thus land use from the resulting added value. The quality of the biomass primarily introduced into the cycle is of central importance. Therefore, at each cascading level, the aim must be to achieve the longest possible and most consistent cycle (one positive example: fibre recycling in the paper industry reduces the need for primary wood fibres and so relieves the pressure on primary production). Increasing the recycling rate at each cascading stage, increases the retention time of materials and carbon, thus reducing the need to feed in more primary biomass. At the same time, it allows the economy to be aligned with existing planetary and regional boundaries.

Recommendations for appropriate measures:

- Focus on yield-optimised primary biomass or raw materials to achieve the most efficient implementation of closed-loop processes.
- As far as possible decouple the value-added turnover of biomass-based carbon resources and primary production through recycling strategies and cascading use.
- Bio(technology)-based) cascading use and recycling demand new regulations for waste treatment. For example, residues from industrial biotechnological use of straw must be assessed as fertiliser (and not as industrial waste) and treated as such, or the feeding of bio-waste to insects as their natural food source should be permitted.
- Bio(technology)-based) cascading use and recycling require new regulations for waste treatment. For example, residues from industrial biotechnological straw utilization can be evaluated as fertilizer (and not as industrial waste) and treated as such, or the feeding of biowaste to insects as their natural food source can be permitted.

Carbon dioxide from industrial waste gas streams and from the atmosphere should be a further resource for carbon as soon as possible. It will contribute to climate protection when used in long-life products and in industrial processes or as sources of multistage (and thus long-lasting) use. According to the IPPC, to achieve the 1.5° C goal, emissions must be reduced if possible and other climate-active gases must also be removed from the atmosphere. For example, fixed CO_2 can be converted into raw materials via fermentation or other biological processes (CCUBIO), or the emission of nitrous oxide in sewage treatment plants can be avoided by previously converting nitrogen into new nitrogen fertiliser for agriculture. To demonstrate this economically, the products of CO_2 use from industrial processes and from the atmosphere should be used as industrial raw materials. The prerequisites for this are efficient industrial processes, including biotechnological ones, which are powered by renewable energies, and the establishment or expansion of a CO_2 infrastructure.

<u>Recommendations for appropriate measures:</u>

- Drive the decoupling (where possible) of the economy from land-based primary production by using secondary biomass and other carbon resources combined with negative emissions.
- The production of renewable energy must be efficient and – where land is relevant – must be carried out with the dual use of land (energy and resource) or without the use of land required for biomass formation.

The sustainable use of biomass needs to be strengthened by new innovative business models.

The individual phases of developing a sustainable industrial bioeconomy from inefficient, linear uses to expanding biomass or carbon resources in the context of negative emissions and sustainability via cascading use and the closed-loop economy, require the further development and adaptation of existing business models. In the transition between the individual phases, attractive goals must be implemented by means of adequate incentive systems and (where required) regulatory measures, which offer industry flexibility in achieving the targets on the one hand, but also provide reliable framework conditions for investments on the other hand.

<u>Recommendations for appropriate measures:</u>

- To calculate and amortise investment costs for the development of infrastructures for the sustainable use of biomass realistically, reliable framework conditions for the industry are required. In the interests of a sustainable industrial policy, it is essential to take this principle into account in the priorities of future strategies, laws or regulations.
- The cascading and circular economy demand new sector couplings, some of which are specific to regions; they must be accompanied and controlled by incentive systems (lead markets, risk reduction, etc.) of the public sector.
- Regardless of the policy objective, the management of biomass and carbon flows demand an overall strategy that is coherent and consistent. Besides economic incentive schemes and instruments, this needs to consider the technical interoperability of carbon sources, enabling industry to combine different carbon streams.

Despite all the tendencies to ensure quantity and quality in supply and production chains, the demand for bio-based raw materials for the German economy will not be met from Germany alone, not even in the long term. For this very reason, a responsible agricultural and forestry policy must ensure that sustainable management and land use concepts in Germany are designed in such a way that most of the biomass required can be obtained from regional cultivation and accumulation. Imports of certain biomasses from member states of the European Union and third countries can continue to contribute to the supply security of the domestic bioeconomy but will only be able to have a limited share in the foreseeable future. Therefore, regulatory cuts in the cultivation and use of renewable and regional raw materials in Germany must not lead to our biogenic raw material needs being increasingly imported from regions of the world that need their natural resources for their own transformation. In the case of imports, it must also be ensured that sustainability criteria are adhered without any reductions or concessions.

To be able to use bioeconomic resources globally, the same criteria must be required for sustainable provision or production, first at the European level and then also at an international level. This lays the foundations for sustainable import options. Furthermore, this creates the possibility that business models and sustainability benchmarks of the industrial bioeconomy developed in Germany can be exported. Other countries can thus benefit from the technologies of an efficient bioeconomy.

Recommendations for appropriate measures:

- The use of national biomass must take into consideration the needs of German industry for international sourcing, otherwise unsustainable sources will be used abroad, while practices that are not feasible internationally are employed in Germany.
- The industrial bioeconomy must pursue a holistic and systemic approach that also considers any indirect consequences of adapting German biomass usage, if applicable, without jeopardising the supply base of German industry for the development of a sustainable, biologically transformed industry.
- A responsible agricultural and forestry policy ensures, through sustainable management and land use concepts, that most of the biomass required can be obtained from regional cultivation and accumulation.
- In this context, the timeframes for adapting the industry to sustainable bio-based raw materials must be considered, since only a gradual (phased) changeover can lead to the sustainable development of the industrial structure and the preservation of the existing industrial value chains.

The shift to an industrial bioeconomy with the sustainable, efficient use of biomass and carbon resources provides the environment for business and science along the entire value chain to develop exportable technologies and products for a sustainable bioeconomy. Besides the use of bio-based resources from Germany and imports, product, technology and business model development along the phases is an important driver of economic innovation in the industry. The products, technologies and business models developed in Germany can also be sold or marketed worldwide and used to realise climate and sustainability goals.

Recommendations for appropriate measures:

- For Germany to become a world leader in the bioeconomy, what is required is not only the development and manufacture of technological innovations, but also the development of a sustainable biogenic resource policy that ensures the availability of sustainably produced or accumulating biomass for these high value uses. The aim is to develop and promote forms of land use that focus on and strengthen climate adaptation and biodiversity.
- The development of relevant technologies and business models and their application in a sustainable industrial bioeconomy in the phases described help to spread sustainable economic concepts worldwide and should therefore be included in corresponding strategies (e.g. the biomass strategy and bioeconomy strategy).
- The biomass strategy should be closely coupled with the industrial bioeconomy so that it gains value for climate and resource protection beyond Germany by exporting technologies and adapted business models. Linking it with other strategies such as the Carbon Management Strategy and the Circular Economy Strategy is also supported.

Biomass supply is to be understood as a task of international cooperation and development policy. To achieve the greatest possible effects for global sustainability, dialogue should be initiated with the partner countries. Common land-use planning and joint research and development can be the starting point for new global value chains which offer new added value potential outside Europe as well as a more resilient supply of raw materials for Germany.

3 Regulatory and process policy measures to generate a market pull for bio-based products

Usually consumers and industry are only willing to turn to bio-based and climate-neutral solutions if they are high innovative or cost and effort-neutral. Only a minority of consumers are willing and can afford to pay a “green bonus” for packaging, for example, or to accept the expense of timber-based architectural solutions. However, the development of markets for sustainable products is essential for the development and implementation of process and product innovations by companies. To establish a lead market for sustainable bioeconomy in Germany and Europe the policy must create positive market incentives and remove legal restrictions.

3.1 Bio-based packaging materials

Usually, bio-based and biodegradable plastics are more expensive than conventional packaging materials such as fossil-based polyester. Companies wishing to switch to bio-based packaging materials must pass on the extra price to the consumer. If the development of the CO_2 price on the one hand and EU regulations (Packaging Regulation) as well as consumer interest on the other hand do not provide sufficient incentives for developing the business models, it should be examined whether incentives can be created and additional costs for the end customer avoided by creating incentives (e.g. tax relief) for companies or brand owners that bring bio-based packaging onto the market.

3.2 CO_2 pricing with a directional effect

The economic policy measure of CO_2 pricing already shows a certain directional effect in industry. However, owing to the massively higher quantities of CO_2 that are released from energy use, and because of the relatively favourable CO_2 price to date (e.g. for oil below 15% of the price), the effect of CO_2 certificates on the shift away from fossil raw materials in material use is not particularly pronounced. Therefore, measures must be taken independently of the energy industry's CO_2-certificates to make the defossilisation of chemical products more attractive and so force the use of timber as a raw material and substitute for classic concrete or stone construction, for example, in the construction industry.

3.3 Achieving climate goals through sustainable CO_2 sequestration

Sequestering carbon from the atmosphere (and point sources whose CO_2 does not enter the atmosphere in the first place) is necessary to bring CO_2 levels back down. IPPC calculations show that to maintain the 1.5 and 2 degree goal in the medium term, not only net zero emissions but the active sequestration of atmospheric carbon is required. In addition to carbon capture and storage (CCS) processes, in which carbon is stored in geological formations and so permanently removed from the carbon cycle (and must be replaced in the cycle to meet raw material demand), long-lived, carbon-containing products are an interesting option in the context of carbon capture and utilisation (CCU).

As already elaborated above, carbon dioxide fermentation offers one important option to effectively extract CO_2 from sources with high CO_2 concentrations (bioethanol, biogas plants, industrial processes, etc.). The effectiveness of sequestration essentially depends on how long-lived materials or materials that are in the material cycle for a long period of time (including product design) are produced from the platform chemicals obtained.

Another option for long-term carbon storage in terms of CCU or CCS is the construction industry. The large quantities of material required and the long utilisation phase – in some cases over decades – create great potential for bio-based raw materials for construction. Of particular interest is the use of CO_2 or residual and side streams that would otherwise be utilised for energy. Fibre-based raw materials used as construction, functional and insulating materials in the construction industry are becoming increasingly interesting for products from the industrial bioeconomy. Progress in the EU-wide harmonisation of product standards in the construction sector and a revision of the EU Construction Products Regulation are prerequisites for this.

Timber construction makes direct use of forest-based raw materials. Wooden architecture is an ideal way to bind CO_2 in the long term. However, the building codes of the individual federal states often do not allow timber to be used to construct multi-family houses and farm buildings, and the use of other bio-based materials is also restricted. Moreover, there is a dearth of suppliers and architects and construction engineers who are familiar with timber construction and bio-based building materials. Revising and harmonising the different building codes of the federal states with the aim of facilitating and incentivising or promoting nationwide timber construction and the use of bio-based building materials for both public buildings, infrastructure and in the private sector can create incentives and opportunities for developers. Furthermore, it is necessary to establish chairs at colleges and universities to train architects with a focus on timber construction and bio-based building materials.

3.4 Normative and legal framework conditions

Depending on the application (e.g. food contact materials, building materials, etc.), the use of new materials needs to comply with legal requirements and standards. They must be constantly developed and adapted. Specifications, e.g. on quality and safety standards, must be defined in the following areas in particular:

1) Raw materials (including residual and waste materials)
2) Products (e.g. new foods)
3) Recyclates (e.g. from bioplastics)
4) Processes (with or without intermediate mixing steps)

Many parts of legislation have emerged in the era of linear value chains (from the raw material to the end product). The change of perspective to the circular economy leads to disruptions, especially in the industrial bioeconomy, because traditional legal norms hinder or slow down innovation. There is an urgent need here to adapt existing regulatory and political instruments and laws, e.g. waste, circular economy, regulatory and agricultural law, preferably in the EU internal market, GHG and fuel emissions trading law (Federal Emissions Trading Act [BEHG]). It is, however, also worth mentioning approval procedures that are not suitable for novel production processes, such as the construction of biorefineries, which are subject to a wide variety of requirements of traditional industries that are difficult to reconcile, but do not have their own adapted approval law.

With a view to a new National Biomass Strategy and the implementation plan for the National Bioeconomy Strategy that is currently being drawn up, the framework conditions for applying bio-based, sustainable processes and products should not only be supported, but, in return, subsidies that are harmful to the climate and biodiversity should also be reduced.

3.5 Labour market policy measures

The successful transformation towards a defossilisation of industry can only be achieved by a motivated and qualified workforce. To prepare employees for these processes and maintain their employability, there is a need for information qualification and engagement. For this purpose, the planned (corporate) strategies must be clarified and explained. In addition, the training needs must be surveyed and qualification measures developed in cooperation with the staff representation bodies.

1. Make transformation processes transparent

To take society (and the workforce) along on the path to the post-fossil future, the processes must be presented in a transparent, comprehensible and appreciative manner from the very beginning. Appropriate information materials which present the challenges, potentials and requirements should be available as well as Funding opportunities.

2. Further training/qualifications

The transformation changes process flows. Increasingly, the demands on employees are changing, and this social transformation process requires training of the staff. Identifying the qualification needs and implementing appropriate qualification measures are vital. Funding must also be made available for these actions.

3. Training

An innovative industry needs well-trained and skilled staff. Besides training employees, the training of young people is the prerequisite for survival in a competitive market. Demand-oriented training with content that covers the requirements of the industrial bioeconomy must be ensured. Accordingly, the training regulations must be regularly reviewed and, if necessary, adapted or revised.

4 Continuous R&D&I funding policy for a sustainable industrial policy

Investing in research and development pays off because it is the most important engine of economic growth. Vice versa it follows that a lack of or insufficient funding, especially around future markets, weakens the future economic position on the world markets. The transformation is forcing companies to continuously develop their products and business models more than ever before and not just limit themselves to extrapolating further sales and growth opportunities in an existing market area that has not yet been exhausted. Companies are being forced to actively engage in growth markets, such as the bioeconomy, and to introduce forward-looking technologies that aim at a more efficient and environmentally friendly use of resources. This requires not only an adjustment of their R&D&I strategy and staff training, but also long-term investment decisions for capital-intensive fixed assets and the development of the requisite technical infrastructure.

A classification of possible funding measures could be made according to the definition of the possible impact to be achieved and according to the Technology Readiness Level (TRL), as shown in Figure 3.

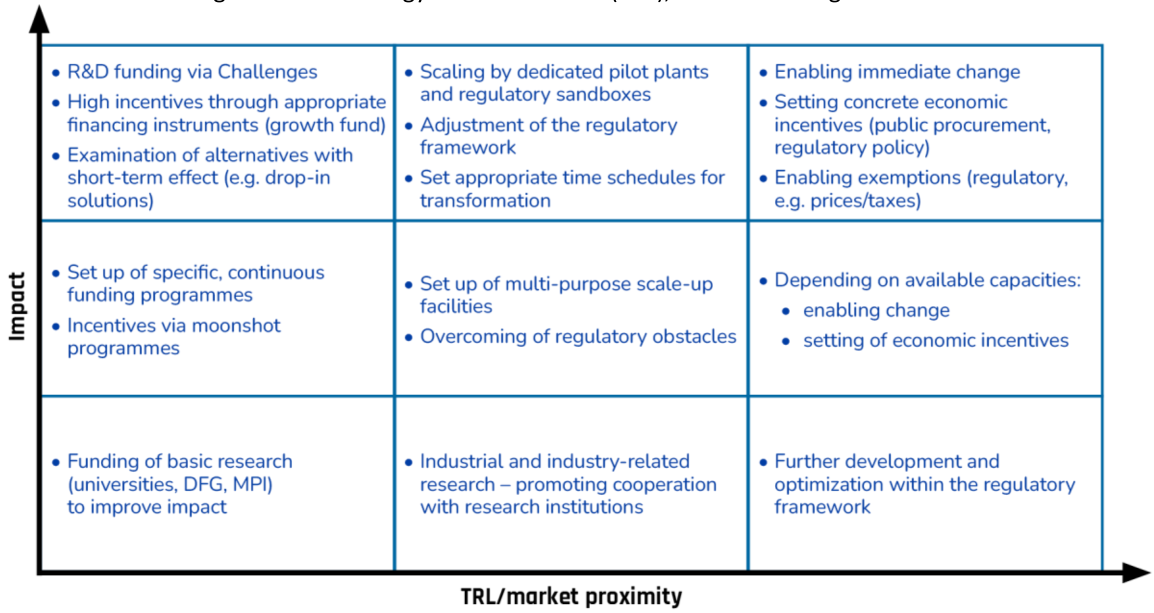

Fig. 3: Matrix for classifying funding measures according to the TRL[1]

High-impact technologies require specific support, while low-impact technologies should rather benefit from general measures. Figure 3 enables a classification of different technologies, processes and products to be made according to their market proximity or technology maturity (X-axis) and their impact (Y-axis) and provides suggestions for appropriate instruments and measures in each case.

The X-axis gives an impression of the timescale in which the technologies can be expected to enter the market on a large scale. This is not to be understood as linear, but as divided into three technology maturity levels: 1-6 (technology development), 7-8 (scaling) and 9 (market entry). What should be noted is that even technologies with a maturity level of 9 cannot have any immediate impact until plants have been accordingly converted or constructed.
The impact shown on the Y-axis must be defined by policymakers, in consultation with the stakeholders involved, as long term as possible, and should refer to areas such as market size, CO_2 avoidance potential, etc. in a technology-neutral manner. Even if the framework conditions must remain in place in the long term (keyword: investment security), the proposed instruments and measures should be regularly reviewed to detect any undesirable developments and readjusted if need be.

The defossilisation of our economy, to which the bioeconomy can make a significant contribution, is a task for society as a whole and has, therefore, to be addressed integrative. Entrepreneurial approaches must be accompanied by an innovation policy that recognises entrepreneurial risk and continuously encourages but also demands the transformation of companies. A future-oriented industrial policy that keeps added value in the country must ensure that the innovative capacity of industry in green future markets, such as the bioeconomy, is supported by targeted funding. It is thus recommended that the BMWK further develops the key issues of its innovation and technology policy in the context of the industrial bioeconomy in a framework programme.

[1] Source: CLIB Cluster industrielle Biotechnologie e.V.

Building on the results of applied industrial research, the focus must increasingly be on integrating process steps into commercialisable processes and their testing (piloting) and demonstration. New processes for future-oriented defossilised products and their conversion into marketable products lead to the strengthening of companies that generate new added value.

4.1 Further development of the Industrial Bioeconomy funding programme

For the first time the BMWK is funding the verification and upscaling of new bio-based processes in multi-purpose demonstration plants (component A), the planning of single-purpose demonstration plants (component B), the transfer of bio-based products and processes into regional industrial value chains and the establishment of innovation clusters (component C). The funding will also be used to scale up bio-based drop-in solutions as well as to develop alternative renewable carbon sources (CO_2, recyclates, biomass). Even though the programme addresses some important requirements of the industry, there are open challenges that must be addressed by further development of the funding conditions to accelerate the establishment of bioeconomy. These include the following:

- The pilot plant structure in Germany is not sufficient. There are too few plants that guarantee targeted, process-engineering pre-treatment of biomass for downstream processes or make CO_2 fixation on an industrial scale and the recovery of other limited valuable materials from waste, wastewater or exhaust air economically viable. Furthermore, only individual process steps can be represented in most plants; an overall process in the sense of a biorefinery can only be realised in exceptional cases (cf. urban and industrial biorefineries[1] in Baden-Württemberg).
- For single-purpose pilot plants, only part of the engineering is supported by Building Block B. The cost of engineering is usually 18 to 20% of the total investment. Since pilot plants usually cost between 10 and 20 million euros, the major share of the financial effort (and thus the risk) remains with the companies. SMEs or start-ups cannot raise this financing obligation and venture capital is not available to establish pure hardware (facilities). This is a gap that needs to be closed.

4.2 Promoting enabling technologies for the use of bio-based raw materials

'Enabling technologies' are processes or technologies that enable the use of bio-based raw materials, make them economically applicable or ensure their resource-conserving and environmentally friendly recovery. Examples are the following:

- Digestion of lignocellulosic biomass (wood, straw, grasses) using all available raw materials such as cellulose, hemicellulose and lignin. In this area, there is a lack of continuously operating machines to process large quantities of biomass economically with little water consumption. The same applies to other biomasses that are produced in the starch and rubber industries, for example.
- Membrane processes that significantly reduce water consumption to minimise the need for heating and cooling energy and the amount of wastewater produced.
- Enzymatic processes e.g. for the digestion of biogenic raw materials or for the recycling of biogenic and non-biogenic polymers
- Biological processes for the recovery of non-biological elements (e.g. gold and rare earths) and micronutrients (phosphates, nitrogen compounds) from household and industrial waste and wastewater

The development of such processes or technologies is cost-intensive and success is not guaranteed. Small and medium-sized enterprises are not able to take this risk. Usually products or processes are supported by funding which directly realize the production Technologies that do not directly contribute to the production of products but enable a processes or economic efficiency are rarely addressed by public funding programmes. Targeted funding for such "enabling technologies" would help the mechanical and plant engineering sector and the process industry to gain a technological edge in international competition.

[1] https://um.baden-wuerttemberg.de/de/umwelt-natur/umwelt-wirtschaft/biooekonomie/bio-ab-cycling

4.3 Transformation spaces: regulatory sandboxes with experimentation clauses

Regulatory sandboxes are established instruments for testing implementation in the real economy. However, regulatory sandboxes do not cover all aspects that are necessary for a genuine transformation. Often, regulatory sandboxes are limited to individual processes or product levels. In transformation spaces, the entire value chain is integrated and experimentation clauses are also tried out and evaluated across different value networks as models. The results are then incorporated into the transfer and adaptation of framework conditions in other regions or value creation networks.

Regulatory sandboxes function as test spaces for innovations and new regulations along complete, integrated value chains. They enable the testing of new technologies, approaches, methods and business models in experimental spaces and together with many stakeholders involved, and then draw conclusions for the political framework. Participation and inclusive learning are characteristic of this type of cooperation. This should enable findings from science to be incorporated into practice not only more quickly; regulatory sandboxes can also help to strengthen social acceptance for innovations and change processes. In the current coalition agreement, the Federal Government has committed itself to passing a Regulatory Sandboxes Act (*Reallaborgesetz*) that provides uniform and innovation-friendly framework conditions for regulatory sandboxes and allows new freedom to test innovations.

4.4 Funding modules for developing business models

Besides traditional business models, new approaches need to be explored which, for example, create sustainable value-added networks across multiple actors for this, existing or emerging short value chains of producers of biomass and manufacturers of sustainable products are expanded towards integrated value-added networks and circular economy approaches. Promoting sustainability assessments such as Life Cycle Assessments (LCAs), developing digital product passports or creating platforms for the networking of actors can make a significant contribution to this.

4.5 Promoting the establishment of integrated value chains and the production of sustainable quantities and qualities of process-specific biomass

In the background of the climate change, resource scarcity and supply shortages of fossil and traditionally used raw materials many fossil-based or unsustainable bio-based industrial sectors need to shift to an economically viable and ecologically responsible bio-based economy. This requires the consideration of the entire value chain, including current utilisation of biomass, its sustainable production and provision in the required quantity and quality. Many industrial manufacturing processes, e.g. in the coating, construction, rubber and pharmaceutical industry, have special requirements on the raw material, which cannot or only with great effort be provided by biomasses. The targeted breeding, development and sustainable provision of customised biomasses and other raw materials (e.g. industrial plants, algae) that enable better, more efficient (bio-)technological processing and utilisation of the desired raw materials (also in existing processes) as well as possibly novel product innovations should, therefore, always be considered as part of integrated value chains.

4.6 Promoting the establishment of pilot plants for new processes

The best practice examples (chapter 1) show the need for pilot and demonstration plants for developing new processes in the industrial bioeconomy and the high need of investments. Further plants are planned or their construction is about to start (CLIB NRW; Straubing). The BMWK funding programme Industrial Bioeconomy (Use of Multi-Purpose Plants) has already helped to achieve gains in development.

To convert the raw material base massively and sustainably for industry to renewable raw materials, be it for the use of lignocellulose or specifically developed crop or industrial plants such as the dandelion or designer starch potatoes, more plants and their operators are needed. The key question is this: who is to carry out this transition from a technological and industrial point of view?

Integrated pilot and demonstration plants, running 24/7, which can perform all stages of production processes (from the storage of the raw material, through pre-treatment, processing and preparation) are required. Not only the energy balance, but also the water demand as well as the purification, recirculation or recyclability of water and by-products (solid, liquid, gaseous) must be considered and optimised if necessary. Only by consideration of all influencing factors, the goal of cost optimisation for the production processes can be achieved. Ultimately, industry decisions on adopting technology are and will be based on cost and expected market. This includes both manufacturing costs and indirect costs (CO_2 tax; mandate for biodegradable or biobased products; social impact).

For the conversion of lignocellulose there is just one pilot plant in Germany (CBP, Leuna) available; to fulfil the demands at least three to five more should be built on this scale, if necessary adapted to other plant raw materials; the required investment is estimated at 10 to 15 million euros per plant. Furthermore, at least two plants that can be used as “demonstration plants” should be built, requiring an investment of at least 20 to 25 million euros per plant. There is no pilot or demonstration plant for fermentative or enzymatic food production in Germany; at least one of the demonstration plants should have FSSC 22000 certification and comply with the Food Standard.

The recommended business model is a private operating company, an investor from private industry, partnered with an academic institution (university, non-university research institutions), and substantial funding from the BMWK.

The focus must not be solely on the need for lignocellulose. Other branches of industry that are gradually adapting their production processes to make use of biogenic raw materials should be integrated. Furthermore, besides primary biomass (e.g. industrial crops), “green waste” should also be considered as a source for extracting biogenic raw materials.

What is important in the operation of these plants is their focus on industrial “output” and the possibility of being able to market the produced goods as samples. The operational objective must be to develop innovative technology in a “saleable form” based on the pilot and demonstration runs and either to build factories directly with it or to generate production facilities by licensing it to third parties. Depending on where plant-based raw materials can be produced or readily offered, this might be in Germany, in Europe or worldwide. In addition, integrated sites should be developed where non-plant-based biomass, such as microorganisms, or plant-like organisms, e.g. algae, can be produced and directly processed.

4.7 Financing/co-investment in venture capital funds following the example of state-owned funds[1]

1) One or more additional growth funds is needed. A step-by-step growth fund should provide the necessary financial resources for the transformation of companies of all sizes towards an industrial bioeconomy. The growth fund should allow the co-participation of the public sector, industry and financial investors. It is currently being clarified to which extent the venture capital funds of funds (managed by the European Investment Fund and KfW Capital at the risk of the ERP Special Fund (ERP/EIF fund of funds or ERP venture capital fund investments)) can also participate in the Bioeconomy Growth Fund.
2) What is necessary is to locate the growth fund as well as regulatory requirements and market incentives within international value networks and supply chains that exist in the framework of the EU Green Deal.
3) Since 2021, the industrial bioeconomy has gained the ECBF (European Circular Bioeconomy Fund) as a financial partner within the framework of the EU. The ECBF invests from TRL 6 onwards, i.e. there is a need for further funds that invest in earlier TRL stages.
4) A matching platform open to technology and raw materials is to be set up at the “Forum Startup Chemie” to allow the industrial bioeconomy to bring start-ups and investors together.

[1] Source: Guiding Principles 2.0 of the Industrial Bioeconomy Dialogue Platform, p. 19, Working Group 2 “Financing, Regulation, Market Incentives”, chaired by Dr Ricardo Gent (DIB) and Professor Ralf Kindervater (BIOPRO Baden-Württemberg GmbH): building a growth fund for a circular industrial bioeconomy.

4.8 Bioeconomic Important Projects of Common European Interest (IPCEI)

Due to the high investment needs, the industrialisation of bioeconomic processes and technologies in Europe exceeds the economic power of individual companies and therefore will hardly be financed by the market alone in the foreseeable future. At EU level the Green Deal offers excellent opportunities for linking up here. Industry and policy makers should jointly consider cross-border Important Projects of Common European Interest (IPCEIs). This is a transnational, important project of common European interest, that contributes fundamentally to the growth, employment and competitiveness of European industry and the economy through state funding. Breakthrough innovations and the development of infrastructures are eligible for funding.

An IPCEI must

- contribute to the strategic objectives of the European Union (EU),
- be implemented by several Member States,
- provide for its own co-financing via the participating companies or institutions,
- have positive spill-over effects throughout the EU and
- pursue very ambitious goals in terms of research and innovation, i.e. exceed the international state of the art in the sector concerned significantly.

5 On the road to transformation – next steps for implementing the Industrial Bioeconomy

The working groups of the IBDP propose the following next steps to achieve the ambitious goals for the necessary transformation towards industrial bioeconomy:

- Consider the requirements for implementing an industrial bioeconomy in the National Biomass Strategy and the Implementation Plan for the National Bioeconomy Strategy.
- To enhance the Industrial Bioeconomy funding programme to support the transfer from research to the marketplace.
- Increase market pull with regulatory measures, e.g. accelerating the market entry of bio-based products with the aid of blending quotas and material specifications.
- Continue to promote the networking of model bioeconomy regions in Germany initiated by the IBDP: potential for innovation can be raised.
- Reinforce cooperation between the relevant ministries: the successful implementation of an industrial bioeconomy can only be achieved by a joint, concerted and coordinated approach of all stakeholders involved.

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40468 Düsseldorf

Authors: Dr Marc Awenius (VDI Technologiezentrum GmbH)
Dr Viola Bronsema (BIO Deutschland e. V.; Head of Working Group 3 of the Dialogue Platform)
Dr Lena Grimm (Fraunhofer Society for the Advancement of Applied Research; Head of Working Group 1 of the Dialogue Platform)
Mathias Held (UPM GmbH)
Dennis Herzberg (CLIB – Cluster Industrielle Biotechnologie e.V.)
Dr Cay Horstmann (BIO Deutschland e. V.)
Dr Albrecht Läufer (BluCon Biotech GmbH, Corvay Consult GmbH)
Professor Dr Dirk Prüfer (Fraunhofer Institute for Molecular Biology and Applied Ecology IME, University of Münster)
Dr Kathrin Rübberdt (DECHEMA Gesellschaft für Chemische Technik und Biotechnologie e.V.; Head of Working Group 4 of the Dialogue Platform)
Dr Joachim Schulze (BioEconomy e. V.)
Professor Dr Ulrich Schurr (Forschungszentrum Jülich GmbH)