Scoping paper

[Biotechnology IPCEI with focus on bio-based chemicals]

1. DESCRIPTION OF THE INITIATIVE AND SCOPE

Background/necessity/motivation

Dependence on fossil raw materials poses many challenges: it creates economic and geopolitical dependencies on third countries, undermines the strategic autonomy of the Union, pollutes the environment, contributes to global warming and reduces biodiversity. In order to secure industrial performance even in geopolitically tense times, to achieve the UN Sustainable Development Goals (SDGs) and the desired greenhouse gas neutrality, investments in cleaner production models are needed - from a production and economic model that is currently still characterised by fossil carbon compounds and linear approaches to a more sustainable, circular, climate-neutral approach. This transformation will not succeed with renewable energies and the prospect of green hydrogen alone. While in individual sectors, such as individual mobility in road transport, carbon-containing starting compounds can be dispensed with, they are an indispensable part of the value chain in a large number of sectors.

Carbon is the central element of organic chemistry and cannot be replaced as a raw material or as an auxiliary material and alloying element in other sectors. For a resilient and net-zero economy, it is therefore essential to replace fossil carbon sources with sustainable and renewable carbon sources. Defossilization refers to the process of reducing or eliminating the use of fossil carbon (oil, gas, coal) in energy production, transportation, and industry. It involves transitioning to renewable energy sources as well as adopting energy-efficient technologies and practices to decrease reliance on fossil carbon and reduce greenhouse gas emissions. There are three renewable carbon sources to support defossilization:

- Carbon from biomass
- Carbon from recycling
- Carbon from Carbon Capture and Utilisation “CCU”.

The cascading use of sustainable biomass, biomass residues and waste streams for chemical production is a key principle in bio-based industries. It involves using a variety of conversion technologies to extract or convert multiple valuable products from the same organic feedstock, ultimately contributing to a more sustainable and circular economy. By utilizing both 1st and 2nd generation biomass and waste streams, this approach supports the creation of a wide range of bio-based chemicals while reducing environmental impact. The circular economy and cascading use of biomass strengthen concepts towards resource efficiency and ideally a true circular usage of resources. They should aim to keep nutrients such as nitrogen, phosphate or carbon used in the cycle for as long as possible. Only at the end of a cascading use, carbon-containing products should be sent for thermal utilisation. This approach makes it necessary to prioritise bio-based resources for material use over energy use. Incineration should only be a path if all other economically viable cascade stages have been exhausted. This simultaneously optimizes the use of resources for bio-based chemical production as well as it increases sustainability–provided that the new uses are energy-efficient and offer a proven sustainability benefit. By using waste streams previously unused value can be generated, and new value chains are created. This also has positive environmental effects and large economic potential.

On top of using renewable carbon sources, the successful transformation to a resilient and net-zero economy requires better integration of the circular economy, resource-efficient material and raw material coupling and efficient coupling with renewable energies. To achieve climate neutrality, processes and procedures aimed at processing these three alternative carbon sources must be scaled to find their way to markets and market penetration. This requires development and, above all, scaling of- and commercialisation technologies, products and processes that utilise bio-based, recycled or CCU-based materials. To achieve leverage effects in the context of greenhouse gas emissions, a focus on mass value chains with large sales, like bio-based chemicals, is most promising. In order to ensure the sustainability benefit of bio-based chemical production, it is possible to use the tools of life cycle assessments (LCA) according to the ISO guidelines.

The transformation requires massive investments in the development of new innovative technologies, their scaling and the construction of new production facilities. Currently, the high capital and operational costs of alternative carbon options and missing cost competitiveness with their fossil-based counterparts are a significant barrier to investment. The planning and construction of large chemical production plants of established processes alone takes between 6 and 10 years. To decarbonize (or defossilize) the four largest carbon-intensive sectors, including the chemical industry, there is an investment need of around €340 billion in the EU over the next 15 years. These investments are crucial to maintain the competitiveness and to reinforce the resilience of European industry while meeting climate targets. The estimated global market for bio-based platform chemicals is expected to reach USD 21.22 billion by 2029, with an annual growth rate of 6.61% over the forecast period (2024-2029)[1].

Planned Area of Intervention/Relevant Sectors

Bio-based chemicals are basic chemical molecules that server as a starting point for a broad range of chemical syntheses pathways. Thus, they are also the key to more ensuing value chains across a number of industrial sectors (cross-sectoral approach). Bio-based chemicals can either be novel, resulting in novel production processes and products further down the value chain, or drop-in, meaning they are chemically identical with their fossil counterparts and can be fed into existing and established processes. Due to their chemical nature (often small, not very complex molecules), a number of bio-based chemicals are accessible from all three renewable carbon sources: CO2, recycled chemicals or biomass.

The most important and relevant sectors for the production and use of bio-based chemicals include those industries that rely on the production of a variety of chemical products and require large quantities of basic chemicals. These sectors are often central to the economy and the manufacture of products that are further processed or consumed in many other sectors. The planned area of intervention includes producers of renewable carbon and manufacturing and processing sectors. The most relevant sector for bio-based chemicals is the chemical industry, which uses them as raw or starting materials for the production of a wide range of end products in many industries further down the value chain such as plastics, dyes, pharmaceuticals, agrochemicals, fine chemicals and food and feed ingredients sectors. Potential examples are ethylene, propylene and benzene, which play a central role in the production of polymers, solvents and other chemical compounds. Other examples would be emerging bio-based chemical such as FDCA or Succinic acid, which may prove vital for the industry transformation. The plastics and packaging industry is one of the largest consumers of

[1] Research and markets: Bio-based Platform Chemicals - Market Share Analysis, Industry Trends & Statistics, Growth Forecasts 2019 – 2029, 2024

bio-based chemicals, as these serve as precursors for the production of plastics (e.g. polyethylene, polypropylene, PET) and other polymer materials. Platform chemicals such as ethylene, propylene and terephthalic acid are crucial for the production of polymers used in packaging, automotive parts, electronics, cosmetics and many other areas. In agricultural and agrochemicals, bio-based chemicals play a role in the production of agrochemicals such as pesticides, fertilisers and other agricultural chemicals. Biotech solutions are critical to the development of sustainable agricultural practices that utilise living organisms. In addition, bio-based chemicals can also be used as feedstock for fermentation in food-feed industry. The textile industry uses platform chemicals to produce synthetic fibres such as polyester, nylon and other polyamides. The future increased use of bio-based chemicals generated from renewable carbon in these industrial sectors not only contributes to the promotion of more sustainable production methods but can also be an important lever to reduce dependencies on fossil raw materials and minimise the environmental impact by reducing greenhouse gas emissions. The (further) development, scaling-up and utilisation of bio-based, recycling-based and CCU-based chemicals are therefore crucial for the transition to a more resilient and circular chemical industry and to promote investments in the sector. Beyond drop-in chemicals, biotechnology can open up pathways to novel solutions by creating dedicated molecules with innovative functionalities for different applications, but also by providing means of chemical conversion that are inspired by nature and much more energy- and resource-efficient than their conventional counterparts. Examples are biotech solutions enabling sustainable agricultural practises that use living organism.

Potential for research activities and innovation results:

Scientific and technological innovation: The promotion of bio-based chemicals from renewable carbon favours research and development, leading to new chemical processes and materials. In the long term, this can lead to ground-breaking innovations in various industries.

Challenges/market barriers:

Compared to fossil-based chemicals, which are highly developed and produced on a large scale through decades of optimisation, the production-costs of bio-, recycled- and CCU-based chemicals are still higher and therefore currently only competitive to a limited extent. For the production and use of bio-based chemicals from renewable carbon, the economic viability must be proven and further optimised through R&D&I activities and upscaling through first industrial deployment (no mass production).Transnational efforts are needed to drive breakthrough innovation on a large scale and accelerate the technological advances required to fully realise the potential of the sector and make bio-based chemicals from renewable carbon economically competitive with fossil-based feedstocks. Several strategic value chains and technologies are outlined below to illustrate and to serve as examples of potential use cases. This should by no means be understood as exhaustive or in the sense of excluding other use cases.

Use case 1: By utilising C1-based fermentation platforms (chemical compounds with one carbon atom such as CO, CO_2 or CH_4), it is possible to integrate alternative carbon sources from process water, agricultural waste or end-of-life materials as raw material input-streams into chemical value chains for bio-based chemicals from alternative carbon sources.

Use case 2: The production of C3 (e.g. lactic acid) and C4 (e.g. succinic acid, butandiol) can be achieved by feeding microorganism with the feedstock in use case 3 generated intermediates or raw materials such as carbohydrates, nutrients or other carbon sources

Use case 3: CO_2 utilisation, also known as carbon capture utilization, in a circular economy offers a variety of approaches to reduce CO_2 emissions and even convert them into valuable raw materials and products (such as methane, methanol or acetate). CO_2 can be used due to separation and capturing technologies. In this first step, CO_2 or CO is removed from industrial waste gases (e.g. from bionic CCU point sources such as bioethanol plants, cement factories or steelworks).

Use-case 4: Using gaseous carbon sources, genetic engineering enables the direct, fermentative synthesis of chemicals. The process incorporates CO_2 into the product and enables carbon-negative production of e.g. ethanol, methanol, acetones, isopropanol, n-butanol, isoprene n-octanol, MEG1 and butanediol. This illustrates that CO2 is not just a waste product but can be utilised as a valuable resource in a closed-loop system that contribute to a more sustainable and climate-friendly economy. By using the greenhouse gas CO2 as a building block, modern and innovative technology can have an unprecedented impact on the climate changes and on efficient biomanufacturing.

Use Case 5**:** Technologies for the extraction and conversion of lignin from biomass into bio-aromatics and other platform molecules are key enablers for replacing fossil-derived components in plastics, coatings and advanced materials.

Such processes enable the cascading valorisation of sustainable biomasses for the synthesis of bio-based platform chemicals which can contribute significantly to defossilizing the chemical industry and other producing industries thereby making accessible a significant European bio-feedstock basis and increasing resource efficiency.

Links to other scopes

This initiative is linked with two other scopes prepared for one or more potential IPCEI candidates in biotechnology – bio-based materials and key components for food and feed.

Key components for food and feed: bio-based chemicals and key components for food and feed can utilize similar bio-based feedstocks – such as agricultural residues, forestry by-products, and marine biomass – and be produced in the same biorefinery. This shared feedstock and production site can streamline supply chains and reduce costs through economies of scale. Biochemical processes used to convert biomass into platform chemicals can also be adapted to produce food and feed components. For example, fermentation processes used to produce bio-based chemicals can be optimized to produce alternative proteins and other nutritional ingredients.

Bio-based materials: Bio-based chemicals that are compliant to all chemical regulations enable functionalisation and long-lasting performance for bio-based materials. Reusability and recyclability are key to ensure sustainability aspects for bio-based materials and hence bio-based chemicals support to achieve these objectives. As bio-based platform chemicals are considered to be building blocks enabling to produce various polymers, and therefore application possibilities for bio-based materials do not have any limitations, but will not support value chains if one of these would be missing.

2. POLICY OBJECTIVES

The proposed IPCEI biotechnology is in line with the following policy objectives.

- The EU 2030 and 2040 climate targets and the EU 2050 net zero target:
    - By 2030, EU emissions are to be reduced by at least 55% compared to 1990 levels (Green Deal target).
    - There is an interim target for 2040, but this is closely linked to the progress made by 2030 and technological developments.
    - The EU is committed to achieving net-zero emissions by 2050, meaning that greenhouse gas emissions are to be reduced to zero, with any remaining emissions being offset by climate protection measures such as reforestation or CO_2 capture.

- Strengthening competitiveness of the EU industry: The EU is committed to tap the significant growth potential of bio-based chemicals and materials substituting fossil-based counterparts, and related industries.
- Increasing energy efficiency and promoting the circular economy to conserve resources and reduce waste.
- Adaptation strategies for climate change: Special emphasis was placed on support for countries already suffering from the effects of climate change through adaptation strategies and resilience building.
- Minimizing the impact on health, climate and the environment during sourcing, production, use and end-of-life of chemicals, materials and products. Resources should be sustainably sourced. The transition to defossilisation is in line with and builds on established EU policy frameworks
- Strengthening resilience by reducing dependence on fossil resources: The increasing defossilisation of the EU industry aims to reduce dependence on fossil resources by increasing the use of alternative carbon resources, green technologies and efficiency improvements.
- Promoting innovation and investment: Incentivise investment in innovative technologies that support defossilisation, such as green hydrogen production, CO_2 capture and energy storage. To guide the innovation process, an approach in line with the "safe and sustainable by design" (SSbD) framework is recommended.
- Several initiatives in preparation, such as the Bioeconomy Strategy, Strategy for European Life Sciences, Industrial Decarbonisation Accelerator Act, European Biotech Act and the Circular Economy Act, further support the strategic objectives of the potential Biotech IPCEI candidate:
    - European Biotech Act:
        - Create a forward-looking framework conducive to innovation and leverage the potential that biotechnologies can bring to our economy.
        - Improving access to funding and the commercialisation of biotechnological products.
        - Ensuring the EU's competitiveness and innovative strength at a global level in the biotechnology sector.
    - Upcoming Circular Economy Act:
        - Promote the circular economy, covering the entire life cycle of products and focussing on reuse, recycling and resource efficiency.
        - Reduction of waste and environmental impact through the optimisation of production processes and the development of recycling technologies.
        - Supporting sustainable production methods and promoting energy efficiency in industrial processes.
  - EU Industry Decarbonisation Accelerator Act, supporting lead markets for EU made clean products.

3. Conclusion of Scoping Phase

Based on the above, which takes on board the consultation with stakeholders at EU level, the working group considers that a possible IPCEI candidate on bio-based chemicals may be suitable.

It is therefore proposed to enter an in-depth phase analysis to confirm the suitability, desirability and feasibility of a possible IPCEI candidate on bio-based chemicals.

DISCLAIMER

This scoping paper was drafted by the Working Group for **Biotechnology** of the Joint European Forum for Important Projects of Common European Interest (JEF-IPCEI). The objective of this document is to contribute to pre-screening of whether certain technologies, infrastructures, value chains or sectors could be suitable candidates for potential new IPCEIs. It should facilitate exchanges with representatives of industries and/or academia about potential IPCEIs in the pre-screened technology and/or infrastructure areas. This exchange does not prejudge whether an IPCEI will subsequently be pursued. It does not indicate a commitment, or approval by the participating Member States or by the European Commission on certain technologies, infrastructures or value chains, or an available budget and it does not bind any participant in this exchange.

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