The European chemical industry wants to boost its Bioeconomy sector: platform chemicals and polymers for plastics as promising opportunities

Sustainable bioeconomy is the renewable and an innovative segment of the circular economy. In its position on the bioeconomy of 2016, Cefic identified the European chemical industry as a key enabler in the bioeconomy. Bio-Based Products (BBPs) developed by the chemical industry are key to support the European Green Deal and Europe's ambition to become climate neutral by 2050. Yet BBPs are not yet implemented at large scale, as illustrated by their very low share - 2.5 % - of the total Bioeconomy turnover. The European Chemical industry sees the importance of unlocking the use of sustainable biomass as a feedstock and is calling upon the policymakers to provide a supportive policy framework to bring the bio-based production at scale.

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Executive Summary

In 2012, the European Commission released its first “Bioeconomy Strategy for Europe”. Its ambition was to “*drive the transition from a fossil-based to a bio-based society, with research and innovation as the motor”.* Ten years later, in the context of the Green Deal and of the Recovery Plan for Europe, this paper aims at reviewing the level of uptake of bio-based chemical products in the European economy, identifying the potential hurdles to their deployment and proposing policy options to overcome such obstacles.

The European Commission defines bioeconomy as “*using renewable biological resources from land and sea, like crops, forests, fish, animals and micro-organisms to produce food, materials and energy. Stronger development of the bioeconomy will help the EU accelerate progress towards a circular and low-carbon economy. It will help modernise and strengthen the EU industrial base, creating new value chains and greener, more cost-effective industrial processes, while protecting biodiversity and the environment*.”[1] Europe’s growth strategy, with the Green Deal and the Recovery and Resilience plan, provides an important opportunity for the bioeconomy to scale up, as investments in new innovative and (more) sustainable bio-based industries can play a critical role to support the green transition.

Ramping up sustainable bioeconomy activities is a condition for society at large to remain below the 1.5°C limit of global temperature rise[2], as well as work towards the EU Green Deal’s ultimate goal of climate neutrality by 2050 and reduce its dependence on fossil fuels. A Joint Research Centre (JRC) study identified 10 bio-based product (BBP) categories. Two of these BBPs: “Platform” and the “Polymers for plastics” (a.k.a. bio-based plastics) show potential for having a large impact on the overall development of the bioeconomy in the EU once hurdles such as Technological readiness, Economic & Market potential, Social & Environmental impacts can be overcome.

To bring bio-based products in general, and platform and polymers for plastics in particular, at scale:

We, the European chemical industry, envision to:

- increase the sustainable and efficient use of biomass to produce circular bio-based chemicals,
- source sustainable biomass to manufacture such bio-based chemicals,
- increase the use of bio-waste and bio-residues as feedstocks to contribute to a more circular economy where that makes sense from a lifecycle point of view,
- provide evidence for/document the environmental and climate benefits of our products, such as through LCAs and similar tools (from cradle to gate) that recognise the unique features of bio-based products,
- promote further recycling (mechanical, organic and chemical) of all chemicals, including bio-based ones.

To make this possible, we call on policymakers to consider in their decision-making:

- Sufficient financing and funding streams of bio-based production projects under the Horizon Europe, Public Private Partnerships (e.g. Circular Biobased Europe) and the European Circular Bioeconomy Fund. Make sure that part of such funding is earmarked to feedstocks pre-treatment and preparation technologies to ensure a stable and consistent supply of biological resources to bio-based industries. Allocate also some funding to improved and novel recycling technologies that would allow the cost-effective handling of co-mingled flows of polymers at once.
- The importance of an EU Bioeconomy Monitoring System[3] in providing trustworthy data and robust indicators supporting a truly sustainable and circular bioeconomy.

- Enabling regulations to valorise residues and waste occurring during BBPs production. Adapt and clarify the end-of-waste legislation and definitions accordingly.
- Ensuring science-based, proportionate, and predictable regulations that foster innovation from the intelligent combination of biological, chemical, and engineering sciences and IT.
- Enabling the quadruple helix model to drive purchasing and consumption patterns.
- Awareness raising fact-based campaigns and activities that would help lifting misunderstandings around bio-based products and their assumed benefits, especially on bio-polymers for plastics.

Background

In 2012, the European Commission released its first "Bioeconomy Strategy for Europe". Its ambition was to "*drive the transition from a fossil-based to a bio-based society, with research and innovation as the motor".* Ten years later, in the context of the Green Deal and of the Recovery Plan for Europe, this paper aims at reviewing the level of uptake of bio-based chemical products in the European economy, identifying the potential hurdles to their deployment and proposing policy options to overcome such obstacles.

The European Commission defines bioeconomy[4],[5] as "using renewable biological resources from land and sea, like crops, forests, fish, animals and micro-organisms to produce food, materials and energy. Stronger development of the bioeconomy will help the EU accelerate progress towards a circular and low-carbon economy. It will help modernise and strengthen the EU industrial base, creating new value chains and greener, more cost-effective industrial processes, while protecting biodiversity and the environment."

Ramping up sustainable bioeconomy activities is a condition for society at large to remain below the 1.5°C limit of global temperature rise[2], as well as meet the ambitions of the EU Green Deal to reduce greenhouse gas emissions by at least 55% by 2030 (using 1990 as baseline) and the ultimate goal of climate neutrality by 2050. It can also contribute to reducing the dependence of Europe's economy on fossil fuels.

Bio-based products need scaling up

BBPs[6] from the chemicals and plastics sector represent only a small portion of the whole European bioeconomy sector. They generate approximately 2.5% of the total bioeconomy turnover, equaling around Euro 60 billion. These same sectors are worth 11 % of the turnover generated by the entire European chemical industry (including plastics but excluding pharmaceuticals), which is around 543 billion Euro[7b]. The European bioeconomy sector as a whole has a turnover of approximately Euro 2,400 billion. About 50% of this turnover is generated by food and beverages, around 25% are from agriculture and forestry, and the remaining 25% are goods with relevance to the chemicals, pharmaceutical, pulp & paper, forest, textile, fuels and energy sectors[8].

What role can the chemical industry play?

Renewable resources of biological origin offer the chemical industry an opportunity to diversify its feedstocks to produce BBPs. In its Mid-Century Vision, Cefic estimates that biomass consumption for production of chemicals can double by 2050 with respect to the baseline of 2018[9]. This helps close the already small gap between the EU Value Added/Turnover ratio of BBPs and the one of the entire chemical industry[a].

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[a] *The proposed ratio [Value Added]/[Turnover] is used here to put in perspective the existing differences/similarities between the whole chemical industry (bio+fossil-based) and the sole sub-sector of chemical bio-based industry, comparing similar data across them. Fully knowing that it is not a commonly used indicator in economic evaluations, in this context it is used for comparative reasons.*

- *For bio-based Chemical Industry (Bio-based chemicals, rubber & bio-based plastics, excluding biofuels and pharmaceuticals) - [Value Added]/[Turnover] ratio = 26 %*
- *For the whole (bio+fossil-based) Chemical Industry (All chemicals, excluding fuels and pharmaceuticals) - [Value Added]/[Turnover] ratio = 31 % data taken and calculated respectively from ref [7a] and [7b].*

The chemical industry intends to boost the contribution of its BBPs in the bioeconomy sector to further increase the resource efficiency and diversity of supply. The chemical industry is seeking to scale-up BBPs of novel ("dedicated") or analogue ("drop-in") chemical structure, with an improved sustainability profile and a performance and functionality which is at least equal to or better than existing alternatives. Existing alternatives are currently mostly fossil derived (see Annex II).

Bio-Based Products hurdles

According to the JRC[10], the chemical industry produces different BBP categories of variable bio-based volume shares within the total production per category, with some categories at 0.3% and others reaching even 60% bio-based volume shares, leading to an average bio-based share estimation of around 3% (Annex I, A) of the total production volume of chemicals.

A Joint Research Centre (JRC) study[10] identified 10 categories of BBPs (see Annex I). Across the different BBP categories, a SWOT analysis has been carried out by the JRC to assess the innovation potential towards further developing and commercialising BBPs, accounting for their current status.

While the four development potential aspects on which SWOT analysis was carried out (Annex I, B) are relevant, it is believed by the industry that hurdles (weaknesses & threats) pertaining to the aspects of *Technological readiness*, *Economic & Market potential*, *Social & Environmental impacts* might have a stronger impact in limiting the BBPs development, compared to the hurdles pertaining to *Legal & Regulatory* aspects.

Whilst the chemical industry is innovating and developing a broad range of BBPs for many different reasons (market demand, compatibility with other bio-based components, ….) , it is expected that focusing on the two categories of "***Platform***" and "***Polymers for plastics***", accounting for about 75% of the total volume of chemicals, and addressing the barriers that prevent their development can lead to large positive impacts on the total average bio-based share.

The following hurdles per product category are thus believed to be the most relevant ones at an EU level in limiting the BBPs development. They have been shortlisted among a long list of more than 60 hurdles resulting from the mentioned SWOT analysis carried out by JRC***.***

"*Platform*" category
The "***platform"*** category represents chemical building blocks in the manufacture of a broad range of products. For the BBPs belonging to this category two main hurdles compared to fossil-based products are considered to be relevant and need to be overcome first. Both hurdles pertain to the *Economic & Market potential* aspects:

- **High production costs** (identified as weakness in the JRC SWOT analysis)
- **Large amount of investment needed for new production plants** (identified as threat in the JRC SWOT analysis)

The hurdle of **Biomass availability in case of full roll out**, pertaining to the same *Economic & market potential* aspects and often seen as one of the major issues for BBPs industry development, may not be considered as critical and/or relevant provided the following usage criteria if we assume that:

- future biomass consumption is made up predominantly by residues[11] from the agricultural sector and forestry, thus reducing as much as possible "on-purpose" cultivations, as well as made by bio-waste[12], so using the full potential of unavoidable waste and residues from production processes. On this, EU policy makers can help the chemical industry by setting the right policy framework, including adequate definitions for waste and residues and preventing valuable materials from being wasted;
- future biomass is sustainably sourced.

Considering the above hurdles, we believe the "***platform***" category can really see a relevant increase in its actual bio-based share via the development of the so-called "***drop-in***" (and "smart drop-in") BBPs – chemically identical to existing fossil-based products – rather than the "***dedicated***" ones – which are BBPs made in a bio-based pathway that do not have an identical fossil-based counterpart (see Annex II and ref. [13] for more details on "drop-in" and "dedicated" BBPs).

An increased share could be reached if existing plants are converted to allow for the use of both fossil and biomass raw materials, ensuring a robust, credible and transparent traceability and a correct attribution of the relative renewability claims of the BBPs so obtained, through the use of efficient and recognised chain of custody systems. [14, 15]

Special attention must be paid to issues regarding the use of diverse biomass resources, by improving flexibility of the production processes with regard to their feedstocks, with the aim to avoid supply issues and therefore significant price fluctuations. Biomass pretreatment technologies must be available and allow for a relatively inexpensive switch to feedstocks of lower price and quality, which results in lower production costs.

Also, the switch from first generation biomass (e.g. sugar, starch, oil) to second generation biomass (e.g. straw, wood residues, organic waste) and in the future third generation biomass (e.g. algae and aquatic biomass) will generate advantages in sustainability and improved market access conditions.

In this context, at EU policy level, much more attention and resources should be dedicated to the financing of projects targeting novel biomass pretreatment technologies (process stages occurring before the biomass conversion stages) and "***drop-in***" BBPs within the Horizon Europe programme and specifically in the new Public Private Partnership "Circular Bio-based Europe"[16].

The availability of technology platforms for biomass pre-treatment could also lead to the birth of consortium plants in accordance with EU competition laws, with larger capacities and serving different biorefineries abroad, possibly involving the primary sector actors more and more in the BBPs industry and making them co-beneficiaries of the added value achieved.

Moreover, this could further facilitate cascading mode operations (i.e. production of BBPs and energy from wastes and residues), to also be incentivised through the adoption of a proper end-of-waste regulation for bio-residues and bio-waste originated in both pre-treatment and bio-refineries plants, leveraging on their inherent zero GHG emissions[17].

"Polymers for plastics" category

It is important to note that, whichever the bio-based plastics (biodegradable, compostable or not biodegradable/not compostable), one may ask what is the difference between an oil-based or bio-based plastic pollution dispersed in our oceans?[18]. In other words, lack of proper waste management and marine pollution due to both bio-based or fossil-based plastics should be absolutely addressed and prevented and biodegradability should not be used as a solution to the lack of proper waste management.

In fact, the priority should be to keep all the plastic molecules – both fossil and bio-based – inside the economic circle for as long as possible, beyond their traditional life cycle, through complementary mechanical and chemical recycling[19].

On the sustainability of bio-based plastics, the EU Circular Economy Action Plan clearly outlines that "*the Commission will address emerging sustainability challenges by developing a policy framework on the sourcing, labelling and use of bio-based plastics, based on assessing where the use of bio-based feedstock results in genuine environmental benefits, going beyond reduction in using fossil resources*."

On biodegradable plastics, the 2018 EU Plastics Strategy sets out a cautious approach for their use. While acknowledging that targeted applications have shown some benefits, the strategy points out that *"It is important to ensure that consumers are provided with clear and correct information, and to make sure that biodegradable plastics are not put forward as a solution to littering".* Moreover, *"Applications with clear environmental benefits (and criteria for such applications) should be identified, and in those cases the Commission will consider measures to stimulate innovation and drive market developments in the right direction".*

Furthermore, the Group of Chief Scientific Advisors provided several recommendations[20], in answering to the following question: "*from a scientific point-of-view and an end-of-life perspective, and applying to plastics that biodegrade either in the terrestrial, riverine or marine environments, and considering the waste hierarchy and circular economy approach: What are the criteria and corresponding applications of such plastics that are beneficial to the environment, compared with non-biodegradable plastics?".* Cefic acknowledges these recommendations, especially:

- Recommendation 1 – *"Limit the use of biodegradable plastics in the open environment to specific applications for which reduction, reuse, and recycling are not feasible"*
- Recommendation 2 – "*Support the development of coherent testing and certification standards for biodegradation of plastic in the open environment"*
- Recommendation 3 – "*Promote the supply of accurate information on the properties, appropriate use and disposal, and limitations of biodegradable plastics to relevant user groups*"

The question of the added value of "compostability" and "biodegradability" in the circular economy - where reuse and recovery should be preferred – has been discussed[21]. In some cases, biodegradability might not be a goal in itself, since it would penalize recycling possibilities.

As a matter of fact, the evidence seems weak in favour of any particular agronomic nutrients benefit associated with compostable plastic material. Therefore material choices for products and packaging should prioritise recyclability, except where the use of compostable plastics have proven added benefits such as increasing the collection of organic waste and its diversion from residual waste or reduction in plastic contamination of compost.

Well aware of all the above-mentioned limitations of bio-based plastics, we want to focus our attention on how to develop the "**Polymers for plastics**" category (this is how bio-based plastics are referenced in the JRC study). The following main hurdles pertaining to *Social & Environmental impacts*, to *Economic & Market potential* and to *Technological readiness* – are seen to be relevant for the development of this category:

- **Bio-plastics production and plastic recycling sectors are not in harmony** (identified as threat in the SWOT analysis)
- **Increasing public criticism of bio-based plastics** (identified as threat in the SWOT analysis)
- **High production costs** (identified as weakness in the SWOT analysis)
- **Need for technological improvements** (identified as weakness in the SWOT analysis)

(See Annex IB for the full JRC SWOT analysis)

The threat that **bio-plastics production and plastic recycling sectors are not in harmony** – clearly referring to all non-compostable materials (then biodegradable and non-biodegradable, considering that compostable bio-based plastics already have their own collecting circuit) – can be overcome by fostering the development of on one side "***drop-in***" bio-based plastics, which can be recycled together with traditional plastics, and promoting on the other side "***dedicated***" bio-based plastics showing full compatibility with conventional plastics in mechanical recycling or, when the sorting and additives pollution issues do not allow for this, by developing appropriate technologies for chemical recycling of both bio-based and conventional plastics.

Increasing public criticism of bio-based plastics addresses the issue of corresponding land use change in the frame of the larger age-old debate between Malthusians and Cornucopians[22], this might be overcome by adopting the sustainable aforementioned usage criteria for biomasses (listed on page 6), as well as through specific educational fact/science-based projects, which can greatly contribute in overcoming such criticism among consumers.

The weaknesses **Need for technological improvements** and **high production costs** might be seen, to some extent, as two sides of the same coin: they both frequently refer to the need of better purification and post-treatment costly technologies (to be adopted in producing bio-based plastics), to bring bio-based plastics to the necessary levels of safety and higher performances required for "***dedicated***" BBPs.

For both "*drop-in*" and "*dedicated*" bio-based plastics, quality problems come very often from impurities not removed from the starting biomass, which negatively affect the conversion stages and lead to the need of costly purification stages downstream.

In this context, much more attention and resources should be dedicated to the financing of projects targeting appropriate biomass purification and downstream treatment technologies for intermediates (to improve then the entire bio-based process technology by focusing before and after the conversion stages), as well as to the entire process system modelling, within the Horizon Europe programme and specifically in the new Public Private Partnership "Circular Bio-based Europe" [16].

Conclusions and recommendations

This paper shows that the most promising pathways to increase in the short to medium term the overall use of biomass by the European chemical industry are by addressing the barriers that prevent the development of "***Platform chemicals***" and "***Polymers for plastics***".

More generally, the European chemical industry wants to contribute to the development of a bioeconomy and BBPs – both drop-in and dedicated - that are sustainable and circular, fully supporting the successful implementation of the 2030 Agenda and its Sustainable Development Goals, as well as to contribute to the objectives and priorities of the European Green Deal.

It is therefore important to track environmental, social and economic progress of bioeconomy, as well as its contribution to Green Deal and SDGs through the EU Bioeconomy Monitoring System, established within the framework of the European Commission's Knowledge Centre for Bioeconomy.

Europe's growth strategy, with the Green Deal and the Recovery and Resilience plan, provides an important opportunity also for the bioeconomy, as these public investments in new innovative and (more) sustainable bio-based industries can play a critical role to support the green transition, especially after the COVID economic downturn.

Nevertheless, we recognise that "*bioeconomy* (and BBPs) *are not a panacea for all challenges*. *As economic analysis shows, the picture is more complex and characterised by trade-off"* [23], as this paper also clearly shows.

The European chemical industry recognises that important barriers for BBPs development are due to technological, market and social aspects. Such hurdles must be then faced first and foremost, as only overcoming these hurdles will allow for the creation of a fertile economic ground for BBPs.

On the raw material side, the chemical industry is committed and fully supports the sustainable sourcing of raw material biomass to produce any bio-based plastics, to be assessed through proper means such as LCA evaluation of the entire value chain[b].

Only in this scenario can effective measures addressing the lack of those well-known Law & Regulatory aspects – often blamed for negatively affecting BBPs development[24] – be adopted and successfully implemented to promote the BBPs sector growth.

We, the chemical industry, envision to:

- increase the sustainable and efficient use of biomass to produce circular bio-based chemicals,
- source sustainable biomass to manufacture such bio-based chemicals,
- increase the use of bio-waste and bio-residues as feedstocks to contribute to a more circular economy where that makes sense from a lifecycle point of view,
- provide evidence for/document the environmental and climate benefits of our products through LCAs and similar tools (from cradle to gate) that recognise the unique features of bio-based products,

[b] *Bio-based and fossil-based plastics are certainly different, but they equally require to be developed and managed under the sole driver of sustainability, as "bio" should not be a driver in itself for developing bio-based plastics. We want to reaffirm here the key role of sustainability as a main driver for going bio, possibly achieved through the adoption of circularity at any stages. LCA measures sustainability on several impact categories (see the list of the most relevant impact categories at page 10, JRC Technical Report, 2016, Guide for interpreting life cycle assessment result, Zampori et al.), which inherently means to take into account all the results obtained for the different impact categories, with the purpose to correctly assess sustainability as a whole. The impact category of Climate change should not be then prioritised over the other impact categories such as Human toxicity, Cancer effects, Photochemical ozone formation, Acidification of soil and water, Terrestrial eutrophication, Marine eutrophication, Land use, Water resource depletion and many others.*

- promote further reclamation and recycling (mechanical, organic and chemical) of all chemicals, including bio-based ones.

To make this possible, we call on policymakers to consider in their decision-making:

- Planning for sufficient financing and funding streams of bio-based production projects under the Horizon Europe, Public Private Partnerships (e.g. Circular Biobased Europe) and the European Circular Bioeconomy Fund. Make sure that part of such funding is earmarked to feedstocks pre-treatment and preparation technologies to ensure a stable and consistent supply of biological resources to bio-based industries. Allocate also some funding to improved and novel recycling technologies that would allow the cost-effective handling of co-mingled flows of polymers at once.
- The importance of EU Bioeconomy Monitoring System in providing trustworthy data and robust indicators supporting a truly sustainable and circular bioeconomy.
- Enabling regulations to valorise residues and waste occurring during BBPs production. Adapt and clarify the end-of-waste legislation and definitions accordingly.
- Ensuring science-based, proportionate and predictable regulations that foster innovation from the intelligent combination of biological, chemical, and engineering sciences and IT
- Enabling the quadruple helix model[c] to drive purchasing and consumption patterns.
- Awareness raising fact-based campaigns and activities that would help lifting misunderstandings around bio-based products and their assumed benefits, especially on bio-polymers for plastics.

These recommendations are equally relevant for the two bio-based products identified in this paper as to other categories of current and future drop-in and dedicated bio-based chemicals.

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About Cefic
Cefic, the European Chemical Industry Council, founded in 1972, is the voice of large, medium and small chemical companies across Europe, which provide 1.2 million jobs and account for 16% of world chemicals production.

[c] *Is a model of cooperation where, with stakeholders from the public and private sectors and academia, a strong emphasis is placed on citizens and their needs, especially in the development of health, social and other related services. This model brings greater social benefits and empowers citizens who are not only passive consumers of content / services but take on the role of creators of innovation. The chemical industry realizes that behavioural change passes through stages, believing that interaction is crucial to motivate and assist citizens to change towards purchasing sustainable products and services and towards circular consumption patterns. Chemical industry wants to bring BBPs closer to the citizens and establish their trust and comfort with them, improving actions to help citizens visualise, experience and feel the BBPs and their properties, establishing feedback systems for citizens to provide input and committing itself to act on the input from citizens. Chemical industry clearly reaffirms that BBPs must meet all safety and product standards in their application and use, preferably performing better than state-of-the-art alternatives, at an affordable price.*

Annex I – Categorisation of Bio-Based Products and SWOT analysis by the Joint Research Centre (ref. 10)

A. Categorisation of Bio-Based Products, their EU production, consumption and bio-based share estimates in each category.

Category	Estimation of EU bio-based production (kt/a)	Estimation of EU bio-based consumption [(1)] (kt/a)	EU biobased share (%) [(2)]
Platform chemicals	**181**	**197**	**0.3**
Solvents	75	107	2.1
Polymers for plastics	**268**	**247**	**0.4**
Paints, coatings, inks and dyes	1,002	1,293	12.5
Surfactants	1,500	1,800	60
Cosmetics and personal care products	558	558	44.2
Adhesives	237	320	11.9
Lubricants	237	220	3.2
Plasticisers	67	117	9.0
Man-made fibres	600	630	14.0
Total (all categories)	4,725	5,480	3.5

(1) Bio-based consumption = Bio-based production + Bio-based import
(2) Bio-based share = [Bio-based consumption]/[Bio-based consumption + EU fossil production]

The methodology the Joint Research Centre (JRC) adopted for the study followed (i) the identification and selection of the 10 BBP categories, (ii) the establishment of a longlist of significant BBPs and (iii) the selection of 50 relevant BBPs from this longlist for the scope of market research. The initial long list, developed as part of the Bio-Based Industries Joint Undertaking (BBI JU) project RoadToBio[d] was screened, resulting in about 350 BBPs that fall within the 10 BBPs categories listed above.

From this long list, 208 significant BBPs were selected with a Technological Readiness Level (TRL, see box) greater than 8, therefore expected to have substantial market volumes. 5.48 million tons reported in the table is the total EU consumption volume for all BBPs in this 208-long list of commercially available products[e].

50 BBPs were then selected for a detailed market study (from the longlist of 350, 208 of which have a TRL ≥ 8) on the base of a high TRL, a significant market size, a range of chemical characteristics and their nature ("*drop-in*" or "*dedicated*" BBPs), meaning that each selected BBP has a considerable relative market size so that, altogether, they should cover also a significant portion of the size of each product category (but not necessarily 90%). It is highlighted that the selected BBPs account for 90% of the production only for the category of "platform".

[d] *https://www.roadtobio.eu/*

[e] *such volume of the 208 commercially available BBPs seems not fitting very well with the overall turnover number of BBPs (60 Billion Euro) reported by Nova/BIC in ref. (8), simply because it would result into a not realistic average BBPs price of about 10 Euro/kg. Furthermore, the NOVA turnover data does not fit with the turnover one reported in table 16 of the JRC study, which is about 9.2 Billion Euro. Clarifications have been asked to JRC.*

The authors of this JRC study dealt with many uncertainties during market data collection on the selected 50 BBPs. Market data have been collected from official statistics, specialist market data suppliers, literature and individual companies, so causing different levels of reliability.

Technology Readiness Levels	
TRL 1	Basic principles observed
TRL 2	Technology concept formulated
TRL 3	Experimental proof of concept
TRL 4	Technology validated in lab
TRL 5	Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 6	Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 7	System prototype demonstration in operational environment
TRL 8	System complete and qualified
TRL 9	Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

Source: https://ec.europa.eu/research/participants/data/ref/h2020/other/wp/2018-2020/annexes/h2020-wp1820-annex-g-trl_en.pdf

(B) Strengths, weaknesses, opportunities and threats (SWOT) analysis for innovation potential of categorised BBPs.

To assess the innovation potential of the bio-based chemical industry, a SWOT analysis was performed by JRC for the 10 BBP categories mentioned in part A, based on the following four aspects of development potential:

- Innovation and Technological readiness (I&T): this refers to technological maturity, skills needed, uniqueness of the product, etc.
- Economic and Market potential (E&M): this refers to market size, customer base, capital needed, market pull and push, etc.
- Social and Environmental impacts (S&E): this refers to environmental impact, health hazards and benefits, employment, etc.
- Legal and Regulatory factors (L&R): this refers to the EU legal framework, restrictions on the use of substances, availability of grants, loans, guarantees and other funding opportunities, etc.

For each BBP category, a literature review and expert interview was performed to gather relevant strengths, weaknesses, opportunities and threats.

The most important messages for each product category emerging from the SWOT results were analysed in more detail with the help of the experts interviewed: **what follows represents the JRC's point of view and does not necessarily reflect the opinion of Cefic.**

In general, I&T readiness is considered high for BBPs and are often seen as a strength. Examples are high research and development (R&D) activity and beneficial properties such as biodegradability. Typical weaknesses within I&T readiness are challenging purification processes and lower or inconsistent quality of some of the BBPs.

The main issue in relation to E&M potential is the often-higher cost of producing BBPs compared with their fossil-based counterparts. This weakness is mentioned for nearly each BBP category and by many different data sources.

S&E impacts are critical for driving bio-based production. Many benefits are mentioned, such as lower toxicity, lower greenhouse gas emissions and the greater safety of BBPs. A major weakness of BBPs is their increased land use, which has a negative environmental impact. The greatest perceived threats in this category are consumers having a low level of awareness of BBPs and increasing public criticism towards BBPs (e.g. bio-based plastics). Public awareness is higher for some product categories (e.g. bio-based plastics, bio-based lubricants) than for others (e.g. surfactants, adhesives, partly bio-based cosmetics and personal care products).

Finally, L&R factors are very diverse and dependent on the product category. L&R factors that restrict (limit or ban) the use of fossil-based products can create markets for BBPs, such as for bio-based lubricants, or can stimulate development of BBPs through funding. The absence of general L&R factors discouraging the use of fossil resources (e.g. a general carbon tax) is seen as a threat for some product categories, preventing the further development of BBPs and production technologies.

The full set of results from the JRC SWOT analysis (Ref. 10) for the 2 categories of Platform and Polymers for plastics BBPs are reported in the table. Weaknesses & opportunities shortlisted for this paper are also highlighted.

SWOT Platform

Strengths

- Diverse feedstock use, which creates flexibility in the supply chain (I&T)
- Promotional benefits (S&E)

Weaknesses

- **High (production) cost (E&M)**

Opportunities

- Need to reduce fossil dependence in other downstream sectors, which creates a market for bio-based building blocks (S&E)

Threats

- Lack of skilled workforce (I&T)
- **Large amount of investment needed for new production plants (E&M)**
- Biomass availability in case of full rollout (E&M;)
- Low oil price (E&M)
- Low public awareness of bio-based products (S&E)
- Continual changes in environmental legislation and protocols (L&R)
- Potential legislation based on technical measures and not directly aimed at reducing greenhouse gas emissions (a CO2 tax) (L&R)
- Lack of grants for bio-based products (L&R)

SWOT Polymers for Plastics

Strengths

- Functional benefits of newly developed materials (I&T)
- Widespread R&D activity (I&T)
- Creation of jobs (S&E)

Weaknesses

- **Need for technological improvements (I&T)**
- **High (production) cost (E&M)**

Opportunities

- Decreasing cost after scaling up (E&M)
- Consumer demand (E&M)
- Pull from large brand owners (E&M)
- Need to reduce fossil dependence (S&E)
- Growing awareness of the impact of fossil products on the environment (S&E)
- Regulations stimulating the market for bio-based products in some Member States (L&R)

Threats

- Lack of infrastructure (I&T)
- Lack of investment (E&M)
- Low oil price (E&M)
- Higher cost of bio-based plastics compared with their fossil-based counterparts (E&M)
- **Increasing public criticism of biobased plastics (S&E)**
- **Bio-plastics production and plastic recycling sectors are not in harmony (S&E)**
- Lack of carbon taxation (L&R)
- Lack of standardisation and absence of a legislative framework (L&R)

Annex II – Bio-Based Products classifications (ref.13)

1 **BBPs “drop-in”**

“Drop-in” BBPs are bio-based versions of existing petrochemicals which have established markets. They are chemically identical to existing fossil-based chemicals (BIO-TIC 2014). The term “drop-in” is usually used in relation to commodity chemicals and polymers with large production volumes. Bio-based drop-in chemicals tend to differ from their petrochemical counterparts in price (mostly more expensive) and in environmental footprint (mostly lower). Regarding the ease of implementation, bio-based drop-in chemicals are easy to implement technically, as existing infrastructure can be used.

2 **BBPs “smart drop-in”**

“smart drop-in” BBPs are a special sub-group of drop-in chemicals. They are also chemically identical to existing chemicals based on fossil hydrocarbons, but their bio-based pathways provide advantages compared to the conventional pathways. Drop-in chemicals are considered to be ‘smart drop-ins’ if at least two of the following criteria apply:

- The Biomass Utilization Efficiency (BUE, see Iffland et al. 2015) from feedstock to product is significantly higher than other drop-ins.
- Their production requires significantly less energy compared to other production alternatives.
- Time-to-product is shorter due to shorter and less complex production pathways than the fossil-based counterpart or other drop-ins.
- Less toxic/harsh chemicals are used or occur as by-products during their production process compared to the fossil-based counterpart.

The pathways leading to smart drop-ins are advantageous combinations of novel/dedicated and conventional chemical pathways. This means, for example, that the biomass is processed in a new way up to a certain status and is then at a later stage fed into the conventional pathway, making the overall process shorter and more efficient. The term drop-in is usually used in relation to large commodity chemicals. In the case of smart drop-ins, this will probably apply to commodities of smaller volume (but still larger than specialty chemicals).

3 **BBPs “dedicated”**

Dedicated BBPs are chemicals which are produced via a dedicated pathway and do not have an identical fossil-based counterpart. As such, they “can be used to produce products that cannot be obtained through traditional chemical reactions and products that may offer unique and superior properties that are unattainable with fossil-based alternatives” (BIO-TIC 2014). Compared to drop-in commodity chemicals, bio-based dedicated pathways are more efficient, using not only the carbon in the biomass, but the whole biomass – carbon, oxygen, hydrogen and nitrogen. This is reflected in a high biomass utilization efficiency (BUE).” (Carus et al. 2016). New emerging synthetic strategies based on biomass can take advantage of using higher levels of structure (functionalised building blocks) already provided by nature. Instead of breaking down (defunctionalising) the naturally grown molecules into very simple molecules (e.g. syngas) which are then used further, the valuable existing functional groups can be used which results in the mentioned higher efficiency. Against this background, these chemicals are sometimes also called “novel”, even though many of these bio-based options have been around for quite some time, at least in scientific literature. This group therefore comprises both new and well-known chemicals. Industrial biotechnology and other novel technologies are becoming important biomass transformation technologies: highly specific transformation processes can be accomplished under mild reaction conditions with often very high yields.”

Annex III – References

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"The total agricultural biomass produced annually in the European Union is estimated at 956 Mt of dry matter, as averaged from 2006 to 2015 (García-Condado et al., 2017). Out of this total, 514 Mt (or 54%) are produced in the form of the primary products (biomass produced as grains, fruits, roots, tubers) with an intrinsic economic value – the reason for which the crop is cultivated – and is thus referred to as economic production. The remaining fraction of the biomass (442 Mt or 46%), which is not the primary aim of the production process (e.g. dry biomass from leaves, stems), is referred to as residue production, although sometimes residues may generate farm income (e.g. animal bedding, production of bio-energy). Residues are also essential for other uses including ecosystem services such as maintaining soil organic carbon levels in the soil or preventing soil erosion." Considering the above, it seems there is enough room for residual biomass (produced in the agricultural sector), without even considering the remaining forestry, fisheries, aquaculture and algae sectors as possible residual biomass sources.

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System modelling: *"The upscaling of conversion technologies with the related downstream processing steps for separation and purification of products is the crucial step in scaling up value circles to commercialisation." "The conversion technologies are at the very heart of value circles. They must prove they can deal with the subject biomass feedstocks (including recycled biomass-based materials) at high throughput and consistently make products with the desired qualities, at larger quantities". "The downstream processing steps (DPS) relate to the conversion processes. The conversion results (yields; purity or presence of impurities, contaminants or inhibitors; composition; etc.) will dictate the type(s) and emphasis of the DSP. These could be single or combined applications of technologies for recovery, separation and purification of the targeted intermediates/products". "The pre-treatment steps need to align with the processing/conversion and downstream processing needs for the desired products"*. (i.e. System modelling)." *"The actors in the product and market sectors can participate as strategic partners in bio-based value circles for materials" "..by co-funding necessary investments and operating costs associated with downstream processing steps to separate and purify desired product and/or intermediates streams ".* Available at: https://biconsortium.eu/sites/biconsortium.eu/files/publications/Draft%20SIRA%202030%20-%20March%202020.pdf#overlay-context=users/ben

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