BIG-Cluster: A strong partnership for a sustainable bioeconomy in the trilateral region of Flanders, the Netherlands and North-Rhine Westphalia

Looking ahead to the new innovation agenda

BIG BioInnovation Growth mega-Cluster

The chemical industry plays a key role in the bioeconomy because its products are used in agriculture, forestry, the food industry, the paper and textile industries, the bioenergy sector, and not least in the production of biobased chemicals and pharmaceuticals. Chemistry thus makes a significant contribution to the success of the bioeconomy, which now generates €2.3 trillion and employs 18.5 million people in Europe[1].

The center of the European chemical industry is formed by the German region of North Rhine-Westphalia, Flanders and the Netherlands also called the ARRR or Antwerp Rotterdam Rhine Ruhr Region, producing almost half of the European chemical turnover[2]: In order to keep this region competitive and to align with sustainability goals (climate neutrality and circularity), we have set up a collaboration on Biobased Economy in 2013 named BIG-Cluster.

From this strong position, science and industry in BIG-Cluster accept the challenge to increasingly use biobased raw materials in production. Already today their share is over 10%[3]. Our aim is to increase this share by developing processes based on conventional vegetable raw materials such as sugars and oils, but also to make greater use of raw materials that have not yet been established, such as lignocellulose, industrial and municipal waste and carbon dioxide emissions. BIG-Cluster will continue to work on initiating research and development partnerships for new biobased value chains that fit into a circular economy approach. Therefore, in addition to developing new biobased products and processes, a lot of attention goes to the use of secondary raw materials and waste, in order to contribute to the realization of a circular economy. This is our contribution to the development of the European bio- and circular economy. BIG-Cluster receives political support for this in the Action Plan „to develop a sustainable and circular bioeconomy that serves Europe's society, environment and economy[4] published by the EU Commission in 2018.

In the common Innovation Agenda of BIG-Cluster, three feedstock-to-product (F2P) flagships have been defined, which were and are of great importance for a European bioeconomy.

1) The conversion of CO/CO_2 to relatively small molecules/monomers;

2) the development of complex/highly functionalized biobased aromatic molecules;

3) the development of fuels for energy, mostly coming from dirtier or waste residues.

Their development and current significance are described on the following pages.

[1] Piotrowski S, and Carus M. 2015b. A new study by nova-Institut: EU-28 bioeconomy is worth 2 trillion euro, providing 19 million jobs. Available online: http://news.bio-based.eu/a-new-study-by-nova-institut-eu-28-bioeconomy-is-worth-2-trillion-euro-providing-19-million-jobs/

[2] https://cefic.org/app/uploads/2018/12/Cefic_FactsAnd_Figures_2018_Industrial_BROCHURE_TRADE.pdf

[3] https://cefic.org/policy-matters/innovation/bioeconomy/

[4] https://ec.europa.eu/commission/news/new-bioeconomy-strategy-sustainable-europe-2018-oct-11-0_en

CO/CO_2 utilization in the bioeconomy – from bulk to fine chemicals

The biotechnological use of CO_2 through various processes with different photosynthetic or microbial fermentation systems plays a decisive role within the bioeconomy, especially through the possibility to reduce the CO_2 footprint of these processes and products. On top of that, biotech processes have less stringent needs concerning purity of the gas stream. Over the past 20 years, these technologies have been used mainly for the biobased production of fuels and bulk chemicals (e.g. ethanol or acetone). Therefore, large quantities of air capture or C1-containing process gases (e.g. steel or cement production) and sophisticated technologies with high TRL were required. However, only a few process examples are available on an industrial production scale, e.g. the ethanol production of LanzaTech with CO_2 from steel mills of ArcelorMittal.

Many fermentative or photosynthetic conversion processes do not reach industrial scale due to limitations in scalability. Thus, the focus of process development has meanwhile moved towards the synthesis of specialty and fine chemicals. These products are produced in smaller batches and therefore offer more possibilities for small and medium scale production processes or new technical developments in this field.

In the BIG-cluster region, several SMEs and large companies established technologies at industrial scale and produce high-performance materials, e.g. Covestro or Photanol.

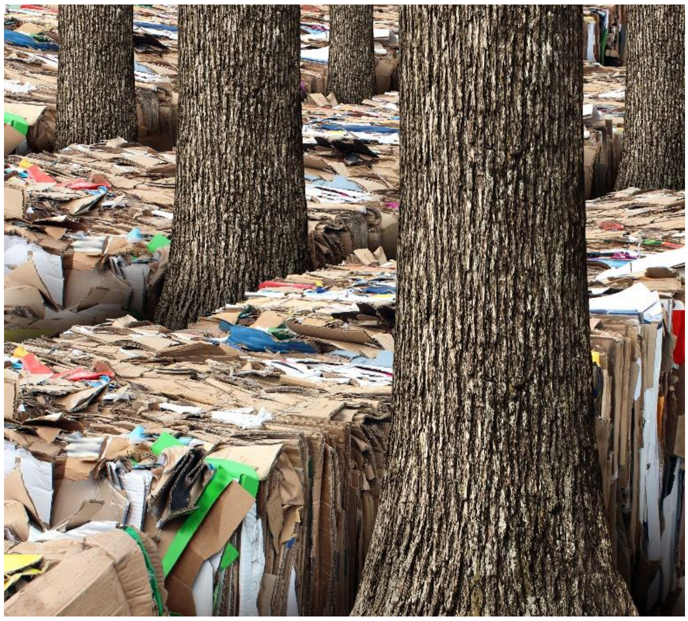
The numerous R&D projects (e.g. Carbon2Chem, BioRECO$_2$VER, BIOCON-CO_2, and BioCOnversion) focusing on the biotechnological use of CO_2 in the BIG-Cluster region also demonstrate the need for further development of existing processes and the establishment of new technologies and products. Within BIG-Cluster, an international and interdisciplinary think tank community is developing new ideas and creating new partnerships and consortia to further drive C1 utilization forward.

Aromatics from woody biomass – an infinite amount of possibilities

In the last few years, a lot of challenges have been tackled to exploit the enormous potential of lignocellulosic biomass, i.e. non-edible biomass such as wood, straw, corn stover, agricultural and forestry residues, and switch grass, as a feedstock to produce (bio-)aromatics, thereby stimulating the future bioeconomy. There is already a large existing market for phenolic compounds from fossil sources, which can be partly substituted by biobased aromatics, and additionally, bioaromatics provide new functionalities creating opportunities for new applications and markets.

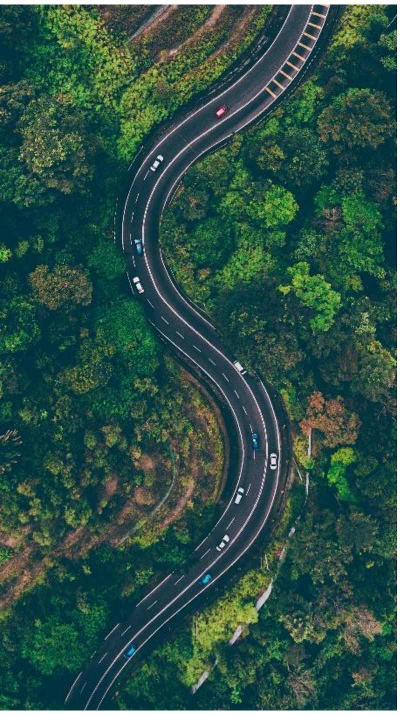
Given the diverse polymeric build-up of lignin, and the numerous technologies to convert this into useful chemical building blocks, the matrix of possibilities is virtually endless. On top of that, the information on the current state-of-the-art however is often scattered, making it difficult to assess the value, accessibility, or applicability of these bio-aromatics throughout the value chain. Therefore, a lot of effort has been invested in elaborating a norm for the different starting materials and products on the one hand, and mapping of the different technologies and feedstocks (Catalisti BAFTA project) on the other hand, which in the latter case has led to a comprehensive overview. And finally, different initiatives are running and on their way into upscaling of selected technologies (starting directly from woody biomass, from lignin coming from paper & pulp industry of bio-ethanol production, or even building up aromatics via sugar/furan chemistry) to provide industry with larger samples to assess the feasibility on a relevant industrial scale, which has been a severe bottleneck in most of the projects until now.

The LignoValue pilot project (coordinated by VITO) for example, will be a huge step towards a demonstration line. This mobile and flexible pilot line planned to be operating in 2021 will enable research and industry in the BIG-Cluster region to further develop industrial-scale bioaromatics applications. All these actions should ultimately lead to reduce the risk for companies to invest in a future bioaromatics demonstration plant in the BIG-Cluster region – a region with an ample supply of feedstock – and establishing a full value chain.



The development of many innovative biobased aromatic molecules will lead to innovative materials in many sectors with a strong focus on construction and automotive sectors, where a large transition is needed to make housing and mobility more sustainable.
Especially in the case of lignin-valorization, the competitive use of lignocellulose will strongly be increased as it was shown that the single use of the sugar fraction or cellulose-fiber fraction of lignocellulose was not economically viable.

Alternative fuels – contributing to sustainable long-distance transport



Alternative fuels are typically able to reduce the CO_2 output of the energy carrier by 50 - 100% compared to fuels made from fossil feedstock[5,6]. This is crucial for sectors that have no option to use electricity or fuel cell technology in the foreseeable future such as long-distance trucking, shipping and aviation.
For trucking **biodiesel** is expected to remain the energy carrier of choice.

There are two routes developed at large commercial scale i.e. fatty acid methyl esters (FAME) and hydrotreated vegetable oils (HVO). Biomass feedstock ranges from first generation oil (vegetable oil) to second generation oil (tall oil from the pulp and paper industry, waste oils from animal fat processing or cooking oils). The latest trend is to also use (mixed) plastic recycle streams and convert these into pyrolysis oil, which is subsequently blended with the vegetable oils for hydrotreating and a mixed HVO/renewable diesel is produced. Other biodiesels are produced via BTL (Biomass to liquids), gasification of (woody) biomass or municipal solid waste (MSW, then called refuse-derived fuel (RDF)) to syngas and converted via Fischer-Tropsch or GTL (gas to liquids), the latter technology can also produce **biokerosene.** Next to Fischer-Tropsch alternative C1 chemistries have been developed via methanol-to-gasoline technology (MTG).

[5] https://www.biofuel-express.com/en/hvo/
[6] E. Bouman et al, Transportation Research, Part D (2017), 408-421

The current route for **biokerosene** production is via waste oils as feedstock. In the BIG-Cluster region a production line with a designed capacity of 100,000 tons and planned startup in 2022 is set up. Alternative routes next to oils-to-jet plus syngas-to-jet involve alcohols-to-jet and sugars-to-jet.

Various partners in the BIG-Cluster region are active in the field of **biobunker oil**, notably Vertoro, Progression Industries, and Goodfuels. There is a good link with the lignin valorization activities for the bioaromatics from the woody biomass program. Lignin residues that remain from high(er) end molecular targets can qualify for the biobunker application.
When properly hydrotreated, polished or upgraded, the biofuels lend themselves equally well to be used as bio- or renewable **naphtha** in steam crackers. This fits well with strategies of major commodity producers like SABIC, DOW and BASF via a material balance approach[7].

The BIG-Cluster region with its high population, high industrial density, and a strong infrastructure needs robust alternative fuel options able to compete with fossil-based fuels. The BIG-Cluster network with high level academic research and chemical and energy industry working together forms a perfect ecosystem to develop improved biofuel options, which fulfill all demands.

[7] https://www.basf.com/global/en/who-we-are/sustainability/we-drive-sustainable-solutions/circular-economy/mass-balance-approach/biomass-balance.html

Challenges ahead for a European bioeconomy

Europe as a whole is well positioned to pioneer a global biobased transformation. Its combination of top-level science, leading industries, governments pushing sustainable developments, and receptive societies puts Europe in a unique and responsible position. Especially the Green Deal will make Europe the first continent that is fully climate neutral and circular. The bioeconomy will play an important role in this strategy by using renewable resources and milder processes. The Circular Economy Action Plan offers new opportunities to biobased chemicals and materials in function of recycling and, even better, circular use.

However, although biomass is renewable, it remains a finite resource whose availability is limited primarily by the amount of available land and water. There is currently no consensus on the amount of annually available biomass in the EU, as estimates vary depending on assumptions, models and the stringency of sustainability criteria used. The Commission's Joint Research Centre has recently been mandated to provide data and analysis on biomass supply and demand. The estimates show that around 1.2 billion tonnes of biomass is supplied and used in the EU and 1 billion tonnes is imported[8]. For the imported stream in particular, the criteria for sustainable biomass should be well defined on the basis of strongest arguments and most credible science. As the annual availability is limited, a sustainable use needs to be further developed.

There is a common agreement that intensive agriculture must deliver the needed food and feed for our society under the boundary conditions of land, water, nutrient, and biodiversity limitations. Residues of agriculture, crop processing and post-consumption need to be used as feedstock and energy for the bioeconomy. The other biomass group is lignocellulose coming from forestry and nature, grown under less stringent land-water-nutrient needs, but with a high impact on CO_2 capture and even nature restauration (e.g. for abandoned land). As biobased resources are limited, biobased value chains must fit in a circular economy as well. The effort to maximize re-use and recycling of materials through circular value chains is a basic condition for a sustainable bioeconomy. Technologies to produce biobased chemicals and fuels from primary biomass, processing by-products and residuals including carbon dioxide as well as products after use need to be developed.

The coming 20 - 30 years the European society will move from a fossil-based to a renewables-based economy. This means that recycling and re-use will be challenged by mixtures of plastics/polymers of both origins with over time increasing amounts of renewable carbon.

[8] 25 September '19 high-level debate EU Research & Innovation Days, Brussels

Digitalization and industrial symbiosis are important enabling technologies and business models for these developments.

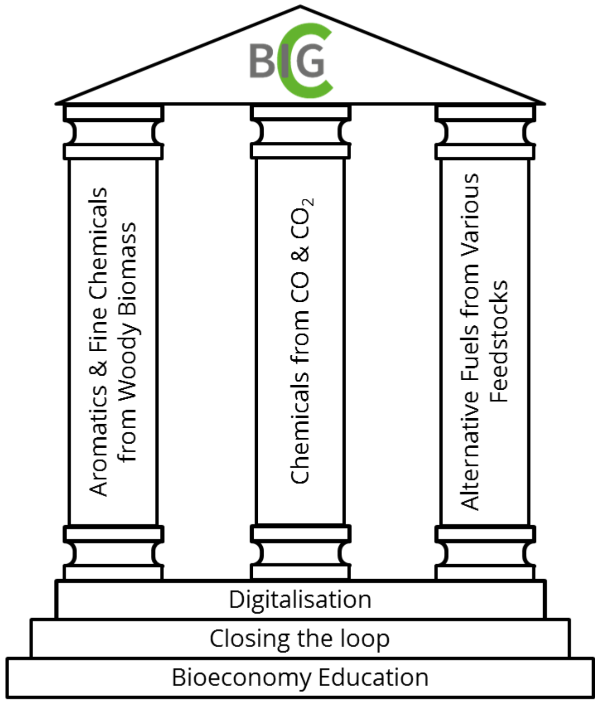
Other challenges relate to scale-up, which takes a lot of money for piloting and demonstration and a long time (typically 10 years) for biobased products and materials: In competition with established fossil-based products, developing and scaling-up of biobased processes depends therefore on suitable funding models. Financial instruments and financing are key for the implementation of plants, and growing innovative SMEs to cross the well-known valley of death. In BIG-Cluster, as a cross-border initiative, there is the need for an efficient system of co-funding of cross-regional innovation projects.

On market demand, a lot still needs to be developed with players at the end of the value chain, typically brand owners and retailers. Brand owners with their strong link to consumers increasingly ask for (biobased) products of high performance, safety and sustainability. We think we can offer the components for such products by biobased materials.

The growing bioeconomy-industry will need skilled and well-trained employees to meet the demand for sustainable chemicals and products. Curricula educating bioeconomists and entrepreneurs will be of high importance in the future.

Also, governments (local, regional, national) and public agencies have a role to play in boosting the biobased product markets through their own procurement processes. And last but not least, consumer awareness and public acceptance need to be much improved beyond the current situation.

The well-established and experienced BIG-Cluster network is ideally suited to tackle the challenges bioeconomy is facing. We are going to base our updated agenda on developments summarized in this document and define clear topics to tackle in the future.



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