

Bio Innovation Growth *mega* Cluster

BIG-C

Flanders, The Netherlands and North Rhine-Westphalia



An Initiative by BE-Basic, CLIB²⁰²¹ and FISCH

Supported by:

Biobased Delta, Biobased Economy Limburg, BioBase Europe, BIO.NRW, BioSC, CEF.NRW, CINBIOS, CleanTechNRW, Cluster Agrifood and Biobased Noord-Nederland, Dutch Regional Development Agencies, Flanders Bio, Ghent Bio-Economy Valley

The list above is not exclusive nor final.

1. Summary

The **Bio Innovation Growth mega Cluster (BIG-C)** is the cross-border Smart Specialization initiative aiming at transforming Europe's industrial mega cluster in the Belgium region of Flanders, The Netherlands and the German state of North Rhine-Westphalia into the global leader of biobased innovation growth. Due to its excellent position in the 4 Pillars of Competitiveness being institutions, infrastructure, macroeconomics and education the mega cluster, also known as Antwerpen-Rotterdam-Rhine-Ruhr (ARRR), has for decades been a powerhouse of industrial innovation in the chemistry sector. BIG-C proposes to join forces in moving towards renewable resources. By leveraging the ARRR in facing the upcoming transition towards the bio-economy, prosperity is secured and the most relevant societal challenges of industrial employment, raw material scarcity and climate change are addressed.

Building on existing national and regional strengths and biobased initiatives BIG-C will drive and leverage the national programs regarding for instance the Smart Specialisation Strategies as well as the European Horizon2020 strategy through workable and ready-to-implement sustainable flagship value chains. BIG-C will create the foundations to use so far neglected resources to produce chemicals up to consumer products and energy carriers in a cascading valorization process. Through implementing bio innovations it will fundamentally shift the base of our daily life from fossil to biobased and other renewable resources. At the same time BIG-C will strengthen the economy building on and further developing the 4 Pillars of Competitiveness by Smart Specialization.



2. Setting

The Bio Innovation Growth mega Cluster (BIG-C) coincides with Europe's strongest industrial mega cluster: the Belgium region of Flanders, The Netherlands and the German state of North Rhine-Westphalia. This cluster is in fact a well-known gateway to Europe and to the world, through the international ports of Antwerp and Rotterdam and the regions along the rivers Rhine and Ruhr – abbreviated as ARRR (this includes all other harbours of the same delta as Amsterdam, Ghent, Duisburg, etc.). ARRR is already leading in all 4 pillars of competitiveness: Institutions, Infrastructure, Macroeconomic Environment and Training & Education. Grouped around the Scheldt-Rhine river axis as its key logistic artery, ARRR benefits from an unparalleled density of top academic institutions, research institutes and industrial R&D centres. Despite the fierce competition, especially with emerging economies, the industrial sector in ARRR has grown in absolute numbers, due to its increased focus on high added-value products such as specialty chemicals and materials, and on continuous innovation.



Fig. 1 Flanders, The Netherlands and North Rhine-Westphalia form a mega cluster at the heart of Europe.

With 40.5 million inhabitants, the ARRR mega cluster represents the most populated European region and primary market. The cluster is home to 8.1% of the total European population but produces 12.2% of the European gross domestic product (GDP; the 27 European countries accounted for 12.9 trillion € in 2012). The GDP per capita in the cluster is about 29% higher than the European average (25,600 € in 2012). The cluster's industry share in gross added value ranges from 20 to 25% (2012) and the R&D intensity (the gross expenditure on R&D as share of the GDP) between 2 and 2.4%, thus revealing a strong coalition of equal and synergistic regions.

3. Unique Selling Point

Institutions, Infrastructure, Macroeconomic Environment and Human Capital (Training & Education): it is this powerful set of the four pillars of competitiveness that places BIG-C in pole position towards biobased innovation growth through smart specialization.

Infrastructure

The mega cluster's lifeline is the Scheldt-Rhine river axis which provides in its area not only a highly developed infrastructure in highways, railways, and aviation, but also facilitates the high-volume shipping of feedstock and manufactured goods. In parallel to the river, a complex system of pipelines starting from sea ports connects industrial production sites with each other, especially those of the chemical industry. This extremely versatile logistic system not only serves the mega cluster itself but runs further down the river to the Rhine-Main area around Frankfurt, Ludwigshafen (home of BASF) and finally to the Swiss chemical industry around Basel as well as linking up with the French Lyon Area (Fig. 2).

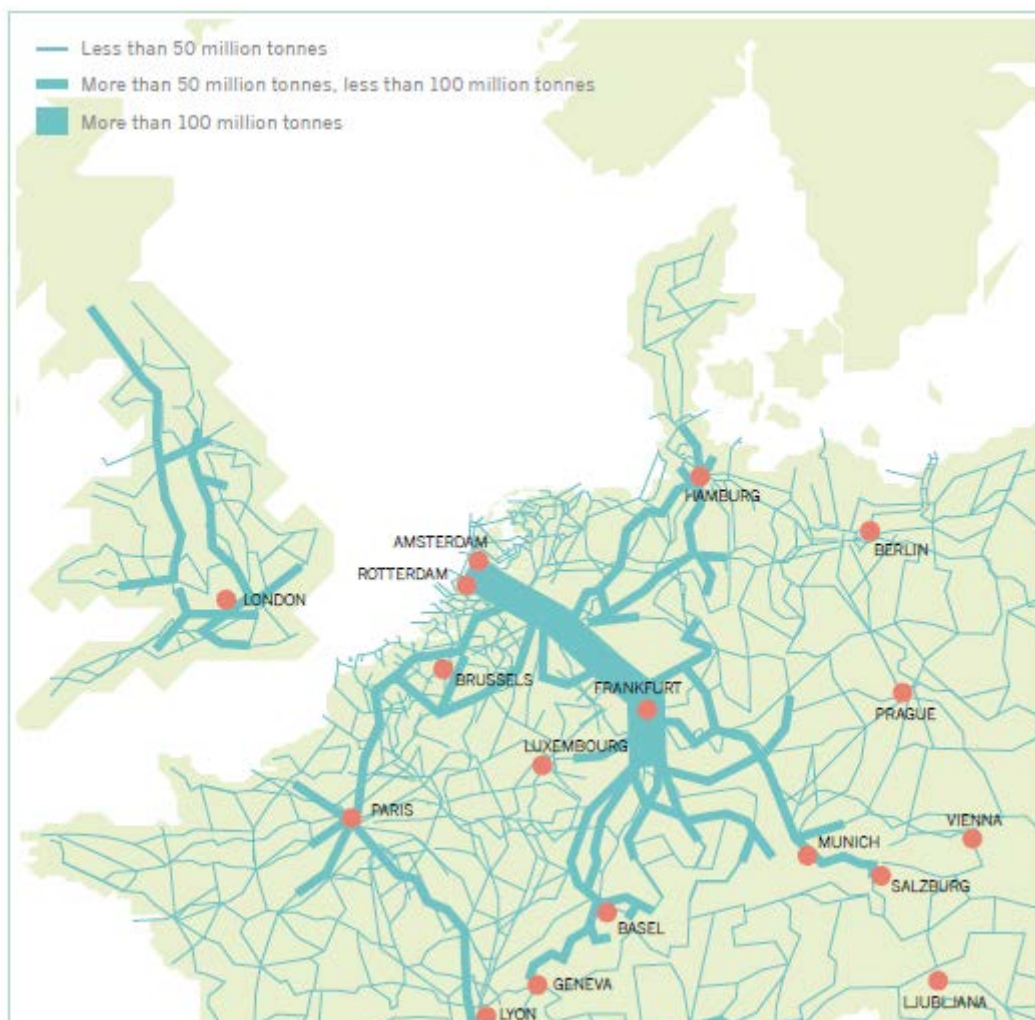


Fig. 2 Accumulated yearly volumes in European logistics (incl. pipelines), differentiating between <50 million tonnes/year (thinnest lines), 50 – 100 million tonnes/year (medium thickness) and >100 million tonnes/year (thickest lines). [Dutch Inland Shipping Information Agency (BVB), The power of inland navigation, April 2009]



Macroeconomic environment

The true strength of the tri-national mega cluster is formed by its skilled workers: technicians, engineers, industry managers, and scientists. Because of its century long industrial tradition a unique culture has evolved with a track record in overcoming technical, economical and ecological challenges by adapting its industrial processes and value chains. It is this responsiveness of the whole society, which qualifies this tri-national cluster to pioneer the bioeconomy. When industrialization started 150 years ago the mega cluster's key to success was the availability of feedstock (coal). Now that local mining has come to an end and fossil feedstocks are being imported, it is the outstanding industrial competence that has kept the mega cluster in the lead. As fossil feedstock is becoming scarce and fossil-based emission needs to be reduced, another fundamental change is at the horizon, requiring preparations and strong management. To prepare for the future, it is essential to:

- use as much as possible the carbon sources that are available in the region, as one of the main pillars of a harmonized biomass feedstock policy,
- to combine these local resources with import fossil and biobased feedstock from international providers,
- develop and install suitable biobased industrial processes,
- maintain the lead in plant innovations,
- build sustainable value chains from a variety of feedstock up to consumer products,
- create not only new value chains but also new chemicals leading to innovative, more sustainable and more performing materials.

BIG-C proposes a powerful strategy by integrating new and established value chains from the very beginning. This can be achieved by:

- working with bio- *and* fossil-based feedstock in order to reach feedstock-flexibility,
- using sustainable and recycled feedstock available in the regions,
- integrating bio-based intermediates into synthetic chemistry,
- intensifying the processes.

The complexity of new complete value chains – whether rooted in biorenewable feedstock, CO₂ or other C1 streams – cannot be solved by a single industry. Not even the large players have all the required expertise, research, pilot facilities, and other resources (both in human and financial capital) under a single roof. This realisation came about in the past years when the initial investments were made in (national) public-private partnerships (PPP's) such as BE-Basic (Netherlands, since 2004), CLIB2021 (Germany, since 2008) and FISCH (Flanders, since 2012). BIG-C builds on these and other investments, thus capitalizing on ongoing national and European programs.

Institutions

The existing PPP's (fig. 3) provide a proven framework for research collaborations, technology development, and human capacity building, with operationalized agreements on IP-ownership, publication strategies that control confidentiality as well as high-quality scientific publications. Additional elements of the innovation infrastructure include cost, risk and resource sharing in (pilot) facilities (fig. 5). These pillars of BIG-C were realized through the efforts and support of the various national chemistry and energy coordination bodies such as Regiegroep Chemie (Netherlands; now TKI-BBE), VCI.NRW (North Rhine-Westphalia) and essenscia (Flanders). Together these bodies succeeded in delivering on

strategic targets such as doubling the sector’s contribution to national GDP and half the sector’s emissions.

Finally, the high concentration of top-level general universities, universities of technology, pilot facilities, incubator organisations, and polytechnics illustrate the cluster’s educational/training capacity, which is essential in order to develop the new workforce for the new industry.

A schematic overview of the PPP-network, a selection of the universities, knowledge institutes and pilot facilities that make up the BIG-C mega cluster as well as some economic data is given below.



Fig 3. The PPP and industry cluster-network in the mega cluster.

Population: 40,5 M
 GDP: 1.372 Bn Euro
 GDP/capita: 33.586 Euro
 Industry: ca. 25 % contr. GDP
 Agro&Food: 150 Bn Euro
 Chemical: 168 Bn Euro

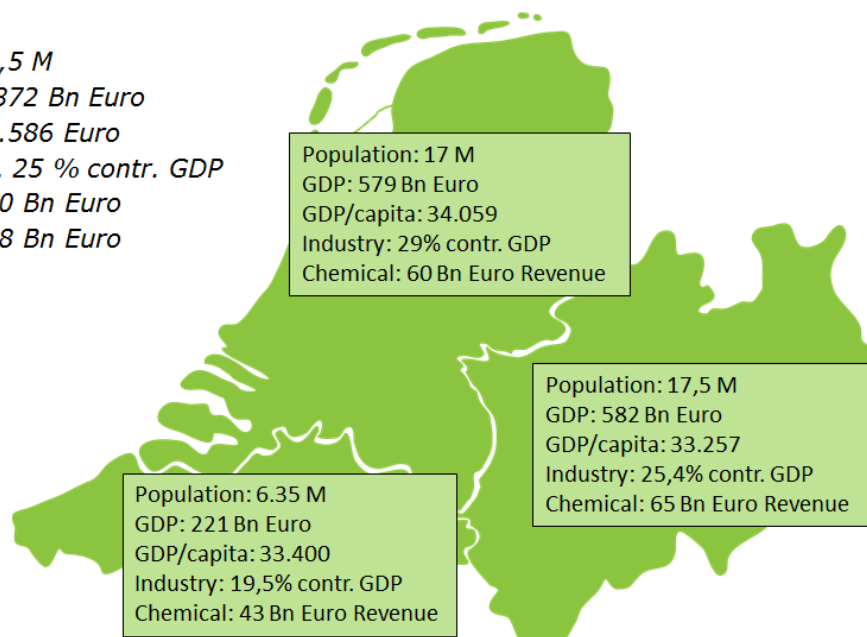


Fig. 4 Economic data of the mega cluster



Fig. 5 Knowledge institutes and pilot facilities in the mega cluster.



Fig. 6 Selection of universities involved in bio innovations in the mega cluster.

Realizing the mega cluster's major potential requires investments and patience. Therefore, the development of a sustainable bio-economy needs substantial care from all stakeholders, especially governments and industries, due to the large scale of capital requirements and long developmental times of mature chemical and energy industries (Figure 7).

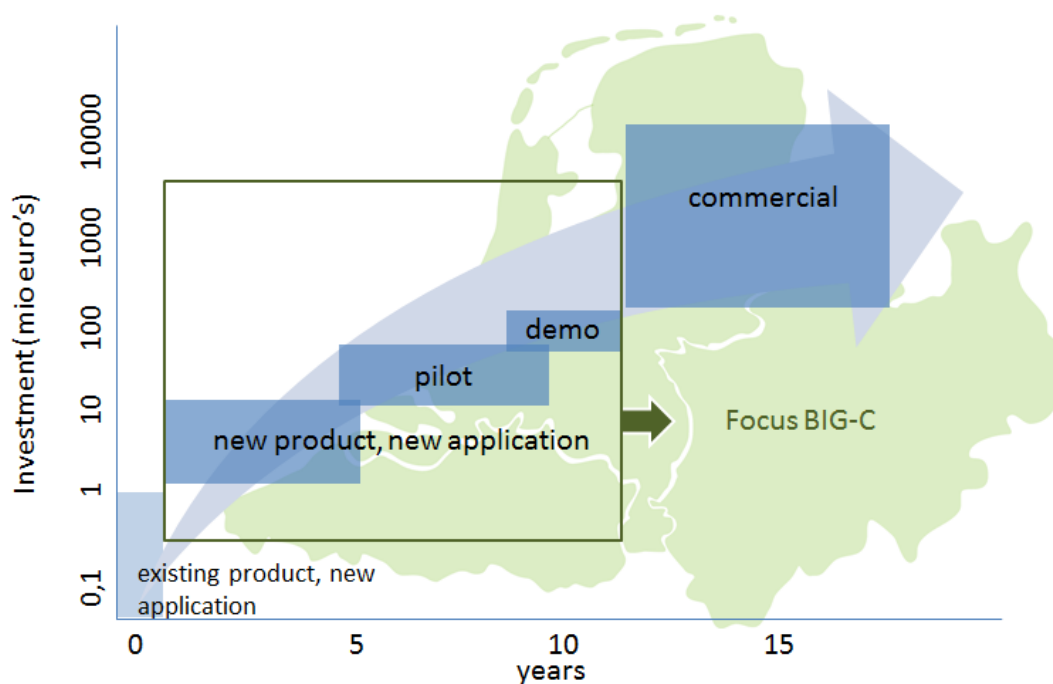


Fig. 7 Typical trend in capital requirements and development times as seen in emerging biobased industries (based on industry experience).

Human Capital

BIG-C benefits from the inclusion of some of the best ranked universities in the field of biobased science and bioprocess and agricultural engineering. A transition as proposed crucially needs a well-trained and educated workforce. Several programs are running. However at this point a complete inventory has not been conducted in the three regions yet. Two examples of running programs:

BE-Basic recently launched a substantial program for improved education in the area of the bio-based economy, led by Delft University of Technology and based on an inventory of existing modules and industrial needs. This program covers the whole learning trajectory from primary school to post-graduate training including hands-on training at the Bioprocess Pilot Facility in Delft and the Biobased training centre in Terneuzen.

Already since 2010 CLIB2021 runs in North Rhine-Westphalia Europe's biggest Graduate program. It welcomes graduates from all over the world to Bielefeld University, Technical University Dortmund and Heinrich-Heine-University in Düsseldorf. More than 100 graduates study the science fields of polyomics, expression, biocatalysis and downstream processing. The program puts a special focus on technology transfer through academic annual retreats, interdisciplinary cooperation and industrial internship.

Extension of the existing programs and initiatives in the regions based on the needs, will provide the necessary attention for the Human Capital Agenda and will provide solutions to ensure the strongest possible knowledge infrastructure.

4. Objectives

The mission of BIG-C is to stimulate bio-economical development in the industrial mega cluster in a comprehensive way – not just with regional but with European and worldwide reach. BIG-C will not only transform technical value chains, but will prepare and develop ARRR's 4 Pillars of Competitiveness to be ready for implementing bioeconomy value chains. Through these activities BIG-C will have an additional transforming impact on society as a whole by changing the general understanding of the possibilities and industrial value of re-using used consumer products, thus changing consumer behavior. In other words, BIG-C targets technical system solutions concerning the grand societal challenges which inherently affect society itself.

Technically, BIG-C will address the holistic production, processing and utilization of various regional resources of carbon whether its primary origin is the region itself (e.g. agro- or silvicultural biomass) or whether it is consigned to regional recycling in the sense of a cascade usage (e.g. municipal waste or industrial side streams incl. CO- and CO₂-emission). It will leverage its accomplished logistical infrastructure whenever additional resources need to be imported for this goal.

BIG-C will work on Institutions, Infrastructure, Macroeconomic Environment and Human Capital through:

- joint public/private cooperative research, development and demonstration including sharing of pilot and demonstration facilities,
- development of logistics and infrastructure for cross-border biobased value chains and clusters including cross-border investments and funding, especially stimulating participation of small and medium sized companies,
- joint realization of flagship value chains under special consideration of promoting small and medium sized companies (being a majority in the industrial mega cluster landscape),
- a joint Human Capital Agenda focused on education and vocational training of skilled workforces and cross-border academia exchange included adapted curricula at schools and universities,
- leveraging critical mass in the regions to build knowledge and to be able to really speed up the process.

In addition to industrial aspects in the strict sense, BIG-C will address the necessary infrastructure as well as funding by:

- offering the tri-national point of expert contact for governments, authorities and public administration,
- capitalizing on earlier investments in well-functioning public-private partnerships,
- synergy and harmonisation to support biobased transition of and across strong industry sectors (agri/chem/energy/engineering/etc) e.g. by uniform certification schemes, regulations, physical infrastructure, and transparent markets;
- a joint focus on internationalisation beyond Europe,
- joint strategy towards European funding such as Horizon 2020, BBI, SPIRE,
- leveraging national funding by joint cross-border funding schemes,
- joint tri-national inter regional funding of major initiatives, to achieve what a single region cannot.



5. Stakeholders

BIG-C builds on the excellent foundations present in the three regions. By starting from the proven specialty of the ARRR region, being chemical industry and related industries, and moving to renewable feedstock, new opportunities will emerge. BIG-C offers a single joint strategy on carefully selected value chains, pooling its resources down to the research level and pilot facilities. In this way BIG-C moves from current strengths to long-term economical, ecological and societal sustainability.

Science, industry (incl. SME), authorities and the civil society are stakeholders and at the same time beneficiaries of this concept. Their active involvement is essential when it comes to realizing the 4 feedstock-to-product value chains we focus on:

- Research Institutes deliver the basic science to be turned into disruptive technologies in industrial application.
- Industries, especially the large companies, in various sectors invest in and open doors to the markets of sustainable feedstock, energy carriers as well as bulk and platform chemicals.
- SMEs play a central role in three ways: I) The biobased economy will develop a decentralized infrastructure based on biorefineries of SME-scale, II) SMEs can play an important role as technology providers for extraction and conversion technologies and III) the large diversity of consumer products brought to market are to a large extent developed and produced by SMEs.
- Authorities support and steer the unfolding of the biobased infrastructure, explaining the importance and potential of this Smart Specialization to the general public.
- Vocational and academic institutions educate and train technicians and experts of biobased production facilities.
- The general public – whether directly involved in biobased value chains or representing the consuming beneficiary – must not only accept but support BIG-C's concept and targets.

6. Flagship Value Chains and Key Performance Indicators

BIG-C aims to realize value chains, starting from renewable feedstock via building blocks to polymers or materials for consumer products. This will be achieved by consortia of companies that cover the entire value chain: at the feedstock level, the conversion to basic building block level, and the use of these blocks in polymer or material production (including blending and product design). A smart specialisation plan will only be successful if the last step, the consumer product, is integral part of the ambitions. It allows innovation to be fully implemented and adds value. This is, what BIG-C makes a Smart Specialisation Initiative.

BIG-C addresses four feedstock-to-product (F2P) value chains, inoculated on SPIRE and BBI value chains: lignocellulose, agro-based, CO₂ and organic waste (Figure 8).

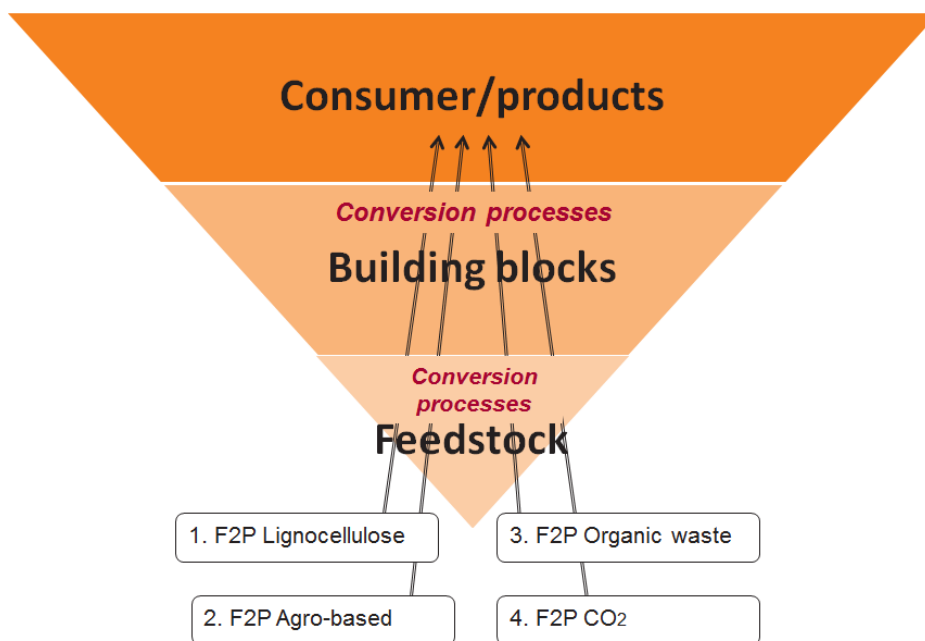


Fig. 8 Schematic overview of the four Feedstock-to-Product value chains as addressed by BIG-C.

The highly industrialised profile, including the logistic systems of the mega cluster offer great potential moving towards using renewable feedstock, waste streams and CO₂ and other gases.

In cooperation with the stakeholders, BIG-C will identify the projects under each Feedstock to Product Value Chain.

Feedstock to Product Value Chain 1:

From green (lignocellulosic) resources to biobased chemicals, materials and advanced biofuels

The limited availability of biomass and its sustainable use will drive the conversion of e.g. agricultural waste, short rotation wood, landscape material and greenery cuttings into cost-competitive bio-based chemicals, materials and advanced biofuels.

Such lignocellulosic biomass still needs an improved digestion and fractionation process followed by a full biorefinery approach, thus also providing fertilizers or energy carriers in addition to high-value basic chemicals. These biorefineries will create jobs in rural regions,



add income to farms, improve the efficiency of disclosure systems and secure the economics of regional production. This covers valorisation of C5-, C6-sugars, lignin and other compounds.

Feedstock to Product Value Chain 2:

The next generation agro-based value chains

In order to increase and broaden the product portfolio and to create new markets, new technologies and applications will be developed based on current and future breded crops. This can be done either by cultivating dedicated crops, by developing special crops producing chemicals or by crops that can be disclosed more economically or that lead more easily to specific molecules such as aromatics, surfactants or resins.

Special emphasis will also be given to soil carbon depletion including nutrient recovery and return to the land in a structured and economically feasible way.

Feedstock to Product Value Chain 3:

New value chains from organic side streams

Many current industrial side streams offer potential for further valorisation into higher added value bio-products. These types of side streams come for example from the agro industry, the food processing industry, oleochemistry and the bio-energy sector. In addition, industrial biotechnology and green chemistry offer possibilities for re-thinking current processes in bio-based industries to obtain a better valorization of the complete biomass into new applications.

By realising cost-effective value chains for added-value molecules out of (small) dedicated streams and platform molecules out of general waste streams the pressure on the environment and on virgin resources will be reduced. For example, the resulting protein source from agro-industrial streams may replace soy in feed, thus reducing the need for importing soy-based proteins (and the accompanying nitrogen).

Again, BIG-C aims to combine added-value molecule production with bioenergy generation in a biorefinery concept, thus enabling sustainable and economically feasible approaches. It includes also high added value compound extraction whether or not followed by further conversions.

Feedstock to Product Value Chain 4:

CO₂ and exhaust gases to chemicals

Biomass is seen as a renewable resource as it takes CO₂ from the air and transforms it into all kinds of molecules that form the basis for value chain 1, 2 and 3. However, the direct capture of CO₂ from industrial processes (from different sectors) combined with cost- and energy-efficient conversion methods is a more direct way of bringing CO₂ into a cyclic approach and leads to a C1-chemistry approach in first instance. The combination of this approach with exhaust gases such as CO and H₂ can become an extra route to make renewable, (non-) biobased molecules. Moreover, not only waste (after gasification) or waste gas (produced by industry) can be used but also waste energy. Indeed, peaks of energy production can be stored in the form of chemicals through a power-to-gas (methane production) or power-to-chemicals approach. This is a combination of different sectors leading to more sustainable re-use of CO₂ and other waste gases.

While the power-to-gas approach is already in full development, there is a need for demonstrations of smaller units transforming less purified gases into chemicals in robust

systems resistant to strong fluctuations in amount and composition (including quality) of gases.

Key Performance Indicators

BIG-C will continuously evaluate the effectiveness of its Smart Specialization measures from the overarching view of economical, ecological and societal sustainability along the following 4 Pillars of Competitiveness key performance indicators:

- Institutions implementing cross-border academic and industrial cooperation models in training and education, research and development, piloting and demonstration
- demonstration plants based on regional resources
- industrial utilization of regional resources
- industrial output based on the addressed resources
- employment related to these industries
- carbon footprint and greenhouse gas emission of these industries
- public acceptance of BIG-C results



7. Dissemination

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. However, Europe itself is diverse. Within this diversity the BIG-C mega cluster is blessed not only with excellent institutions generating know-how, global industries, strong SMEs, a regional feedstock base and critical markets, but also with a tradition of reaching out. The ARRR area as a whole has already proven to be a strong market place for trading goods and exchanging know-how with neighboring regions, other European countries and beyond. BIG-C will build on this tradition and develop specific dissemination measures for know-how in the 4 Pillars of Competitiveness:

1. Building and adapting bioeconomy Institutions
2. Developing the suitable Infrastructure
3. Providing the suitable Macroeconomic Environment including public acceptance
4. Implementing Human Capital training and education models

8. Governance

BIG-C proposes to build on and bridge between existing and proven national pre-competitive public-private partnerships (PPP's such as the research programs under CLIB2021, BE-Basic, FISCH and others), pilot and training facilities, demonstration plants and other assets from the ARRR-region on the one hand, and the Joint Technology Initiative in the field of Bio-based Industries (JTI-BBI) and PPP Sustainable Process Industry through Resource and Energy Efficiency (PPP-SPIRE) on the other. BIG-C intends to work on the 4 pillars of competitiveness and bridge towards and cooperate with initiatives like SPIRE and BBI and with the regional governments and organisations. The exact way in which to do this will be discussed with SPIRE, BIC and the regions.

Given the broad diversity in legal form and nationalities of the involved organisations, we propose a federative form of public-private partnerships. A non-for-profit form such as a foundation allows for clear responsibilities and liabilities, with a Board that has clear mandates, and a Supervisory Board that represents the most important stakeholder groups with an independent chair-person. The Innovation Advisory Panel is composed of the Leadership (directors) of the individual PPP's, or an elected fraction thereof. The organizations involved already invest in this initiative (in kind).

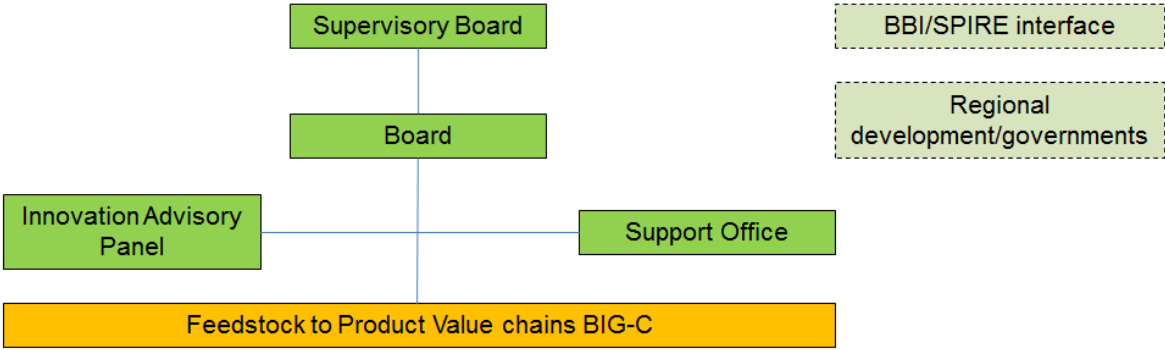


Fig 10. Proposed governance structure for the BIG-C Foundation.

9. Financial aspects

The European Commission recently initiated large-scale stimulus programs such as BBI and SPIRE to facilitate the development of the biobased economy (EU contribution respectively 1 billion and 0,9 billion euro).

The ARRR chemical sector currently has a 30% overall share of the European chemical sector. Also 30-40% of the members of SPIRE and BBI belong to the BIG-C regions. Hence, BIG-C targets to attract 30-40% of the BBI-programming to the mega cluster as well as SPIRE programming and possible others. Considering BBI this translates into € 1.2 bn of programs and facilities for a 10-year period. Considering SPIRE this translates into € 600 mio of programs and facilities for a 10-year period.

BIG-C has the ambition to attract a more than proportional share of the European support to the mega cluster given the strong role of the ARRR region in the Chemicals, Energy and Food industry.

To allow substantial fractions of this massive European support to specifically benefit green innovation growth in the BIG-C mega cluster, we see a continued key role for the participating governments to actively support and preferably further stimulate the development of a competitive, robust and sustainable biobased economy in their region. The underlying initiative BIG-C provides a framework for such a role, building on earlier investments in (now) proven, strong public-private partnerships.

BIG-C proposes to follow the BBI budget composition, of which approximately 2/3 is provided by industry and financial sector (venture and more senior capital), and 1/3 by government, matching the European rules for state support. This would translate into the following impact, assuming that BBI and SPIRE investments are attracted and additional funding is generated by the proposed BIG-C program:

Initiative	Contributor	Amount (€ mio/10 yr)
BIG-C	BIG-C (public)	400
	BIG-C (private)	800
Proposed ARRR fraction of BBI	BBI (EC)	400
	BBI (industry)	800
Proposed ARRR fraction of SPIRE	SPIRE (EC)	200
	SPIRE (industry)	400
	Cumulative	3.000