

PLANT RESEARCH CENTERS OF EXCELLENCE AS DRIVERS OF THE EUROPEAN BIOECONOMY AND SOCIO-ECONOMIC DEVELOPMENT

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Abstract

The bioeconomy is a key driver of sustainable regional development, as it fosters innovation and promotes the efficient resource use. The bioeconomy and Centers of Excellence are closely connected, as Centers of Excellence serve as knowledge hubs that advance the bioeconomy while generating positive socio-economic impact and supporting sustainable development at the regional level. The study aims to present a comparative analysis of four European Centers of Excellence specialising in plant research. The survey applies a comparative case study methodology to examine the Centers of Excellence, selected for their scientific impact and involvement in European research frameworks related to the bioeconomy. The findings show that all four centers are catalysts for the development of the bioeconomy by supporting value chains, fostering start-ups and spin-offs, and transferring results into applied solutions in the agro-food industry. In addition, they have a substantial socio-economic impact, related to job creation, investments and the support of innovation-friendly business ecosystems. By promoting collaboration between academia, industry, and public institutions, they contribute to economies that are more resilient and support Europe's transition towards sustainable models.

Key words: sustainability, knowledge transfer, new business models

INTRODUCTION

The European Commission updated Bioeconomy strategy in 2025 and the new framework is directed towards competitiveness, industrial decarbonization, and resilience. Key elements include scaling up innovation, market leadership for bio-based products, sustainable biomass supply, and strengthening global partnerships [7]. The updated document strongly emphasizes shifting research from laboratories to industrial applications. In addition, the strategy outlines the importance of regional and local approaches alongside with stronger coordination tools.

This institutional framework creates the conditions for interdisciplinary and long-term research, precisely characteristics that are critical for the transformation towards an inclusive bioeconomy. Such transformation is closely linked to the principles of sustainable development, which aim to balance economic growth, environmental protection and social

well-being [32]. The bioeconomy requires integration between biological sciences, engineering, economics, policy and social sciences, as well as investments in infrastructure and human capital. In this context, the Centers of Excellence (CoEs) have become an important part of European priorities for advancing higher education and research, mainly related to green transformation, innovations and bioeconomy development. CoEs are considered a key driver for improved institutional capability, scientific progress and financial benefits [2]. In addition, CoEs can help bridge the gap by linking academic field and external stakeholders such as industry, policymakers, and public institutions [28].

Number of studies analyse the role of Centres of Excellence in capacity building, interdisciplinary research, funding effects and improvement [11, 12, 13].

The aim of the paper is based on comparative case study analysis of leading European Centres of Excellence in plant science using

multi-dimensional criteria to assess their impact on socio-economic development and the broader advancement of bioeconomy in Europe.

The novelty of the study lies in integrating the analysis of Centres of Excellence within the broader framework of the bioeconomy. While most surveys have examined either the role of research centres or the development of the bioeconomy separately, this study combines both perspectives in a comparative framework.

In addition, the paper contributes by comparing four distinct institutional models and by extending the analysis beyond scientific impact towards socio-economic role, regional development and innovation ecosystems. This multi-dimensional approach provides a more comprehensive understanding of how Centres of Excellence contribute to sustainable development.

MATERIALS AND METHODS

The theoretical foundation of the study is based on a conceptual framework that explains the relationship between Centres of Excellence and bioeconomy development.

The framework positions Centres of Excellence as key actors between knowledge creation, innovation processes and socio-economic impact. The importance of this organization is closely linked to the question how scientific outputs are transformed into solutions.

The conceptual framework illustrates the role of Centres of Excellence as crucial element in the innovation system, transforming scientific knowledge into bioeconomy applications through knowledge and innovation.

The framework highlights the influence of policy environments, funding mechanisms and stakeholder linkages, as well as the socio-economic role and influence.

The survey is based on a comparative case study methodology [9, 31] and is applied to analyse four leading European Centres of Excellence in plant systems biology. They were selected because of their scientific impact, and the scope focused on molecular and systems approaches in plant biology.

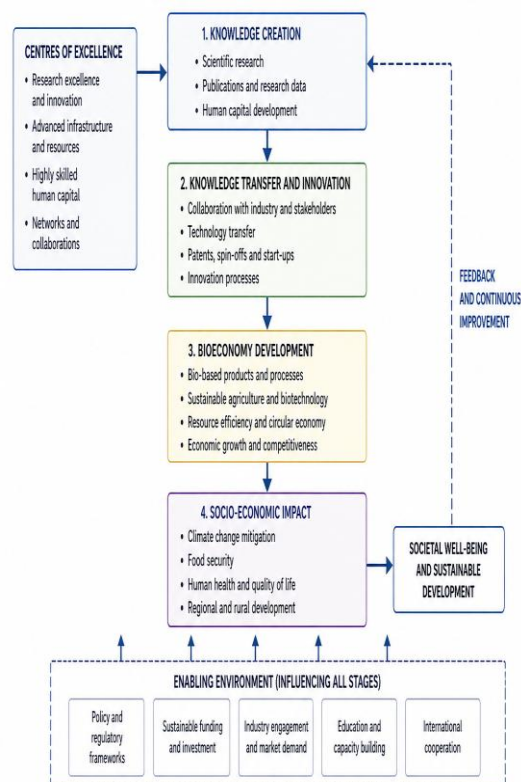


Fig. 1. Relationship between Centres of Excellence and Bioeconomy

Source: Own interpretation based on [1, 2, 7].

The selection of the four Centres of Excellence follows a purposive sampling approach, aimed at ensuring analytical comparability rather than statistical representativeness. The selected cases meet several key criteria: (1) high scientific relevance in plant systems biology; (2) active participation in European research and innovation frameworks, (3) diversity of institutional models, including public research institutes, university-based centres and hybrid public-private structures; and (4) representation of different stages of development, ranging from emerging centres to globally established institutions.

This approach allows for analytical generalization and identification of patterns across different institutional and policy contexts. (Table 1).

It should be noted that the selected centres are not intended to be statistically representative of all Centres of Excellence in Europe. Instead, they are designed to capture the diversity of institutional models, funding structures, and strategic orientations within the European research landscape. This

approach allows for analytical generalization and the identification of broader patterns regarding the role of Centres of Excellence in the development of the bioeconomy.

Table 1. Selected Centres of Excellence

CoE	Country	Founding Year
CPSBB	Bulgaria	2015
JIC	UK	1910
MPI-MP	Germany	1994
VIB-UGent	Belgium	2002

Source: Own survey based on [4, 16, 22, 30].

The methodological framework is adapted from the surveys of [3, 5, 27]. The analysis combines case description with cross-case synthesis [25]. Results are presented in a cross-case comparative matrix, enabling pattern identification and formulation of conclusions.

Data is collected based on a combination of document analysis and secondary sources, including institutional strategies, annual reports, research data, project participation, and policy and funding analysis.

RESULTS AND DISCUSSIONS

CoEs can be viewed as institutional environments designed to foster high-quality research, stimulate innovation, and advance education [17]. The size and scale of CoEs can vary widely [11]. Even though the CoEs are different, they are aligned not only with scientific and technological advancement and progress but as well as with achieving wider societal and policy related objectives [1,18]. CoEs are focused on high potential and innovative fields in science and industry [8, 21]. In addition, some CoEs also have social objectives and serious regional and local impact [18]. Organisational structure of the CoEs, teams, and collaboration are essential [29]. Regarding funding, some studies outline resource resilience and flexibility as drivers for research results [10, 14, 20]. In addition, some authors stated that the funding has a secondary effect, as measured by publications, citations, and human capital development [19, 33]. The OECD report [26] remarks that CoEs with larger budgets are more focused on

external cooperation. The funding links positively with interdisciplinary collaboration that directs to opportunities for higher scientific impact and long-term goals [26]. On the other hand, the effect of the fund concentration does not necessarily lead to excellence [18]. Resources, skills, and organisational structure can be considered as key factors in CoEs' development.

Based on the methodological framework the CoEs are compared in several direction: (1) institutional focus and bioeconomy relevance (Table 2); (2) funding sources (Table 3); (3) socio-economic role (Table 4).

The Max Planck Institute of Molecular Plant Physiology (MPI-MP), the Centre of Plant Systems Biology and Biotechnology (CPSBB), VIB-UGent Plant Systems Biology Centre and the John Innes Centre (UK) have similarities in some aspects; however, they differ in scale, institutional integration, strategic priorities. The MPIMP is divided into three departments and supplemented by various independent research groups, as well as affiliated university units. Approximately 400 people from over 30 countries work at the institute [22].

As a center of plant biotechnology, VIB-UGent specializes in research and innovation as well as capacity-building and collaborations. Ghent University has over 50,000 students and 15,500 staff, which offers an ecosystem for scientific excellence [30]. The UGent fosters cross-disciplinary collaborations. The international cooperative partnerships in plant biotechnology give the organization a dynamic profile of social responsibility and academic leadership.

The John Innes Centre is a leading UK center of excellence in plant science, known internationally as an independent institute. JIC has spent well over a century making significant contributions to evolutionary scientific knowledge and its many branches, from basic research to practical innovations in agriculture, health, and biotechnology. JIC is organised into over 40 research groups, led by Group Leaders across five departments [16]. The institute is well-known for translating research into widely adopted products and commercial ventures.

Table 2. Comparative matrix based on institutional model, strategic objective and bioeconomy role

Dimension	CPSBB (Bulgaria)	MPI-MP (Germany)	VIB-UGent (Belgium)	John Innes Centre (UK)
Institutional Model	Independent institute, public-private, based on EU projects	Public-funded; Independent under Max Planck Society	Public-funded; Collaboration with Ugent	Public research institute under UKRI/BBSRC
Core Research Focus	Applied plant biology, Biotechnology Bioinformatics, Metabolomics, Plant breeding, Plant genomics, Plant stress biology, Systems biology,	Applied plant biology, Biotechnology Bioinformatics, Metabolomics, Plant genomics, Plant stress biology, Computational biology	Applied biology, Biotechnology Epigenetics Genomics, Metabolomics, Plant biotechnology, Plant breeding, Plant genomics, Plant stress biology, Systems biology	Applied plant biology, Biotechnology Bioinformatics Crop genetics, plant-microbe interactions, synthetic biology, Plant breeding, Plant genomics, Plant stress biology
Strategic Objectives and main goals	Regional bioeconomy transformation and capacity building	Scientific excellence and fundamental research	Scientific innovation and industry engagement	Food security, agricultural sustainability, crop improvement
Role in Bioeconomy	Focus on plant-based innovations, capacity building in the region	Indirect via fundamental science underpinning bio-based R&D	Integration into bioeconomy via biotech spin-offs and applied projects	Direct impact on sustainable agriculture and plant breeding for bioeconomy
Stage of Development	Emerging and rapidly growing	Mature and globally recognized	Mature and internationally competitive	Long history, high global impact

Source: Own survey based on [4, 6, 15, 16, 22, 23, 30].

CPSBB structure is organized in administrative, technical, and IT units, as well as research and service Departments. The CPSBB Administration manages the administrative and financial management of CPSBB. It also takes care of communication with national and EU authorities and the doctoral program in Biotechnology. Among the huge workload is also the management of many national and international projects, supporting in this way the fundamental and applied research conducted by the CPSBB Departments [4].

Based on the data, it can be concluded that CPSBB is a newly established private independent research center. MPI and John Innes are excellence-based institutes that are independent public institutes, integrated into the national framework presented by the Max Planck Society and CPSBB, respectively. The VIB-UGent is a collaboration between a research institute and a university.

Regarding research focus, all organisations are concentrated in the field of plant biology.

CPSBB focuses on biotechnology applications in the context of climate change resilience and bioeconomy.

On the other hand, MPI-MP scientific contributions are directed towards fundamental plant metabolism and systems biology.

John Innes Centre is focused on agricultural sustainability, microbial interactions, and synthetic biology.

In addition, the VIB-UGent scientific field is related to genomics and biotechnology for commercial use. Based on the comparison, it can be outlined that CPSBB orientation is more focused on bioeconomy and technology transfer, while others are with basic and translational research scope.

Regarding the strategic goals, CPSBB is still developing and oriented towards capacity building. On the other hand, MPI-MP's priority is scientific excellence. VIB-UGent, as a collaboration, is concentrated on innovation and industry engagement, while

John Innes focuses on food security and sustainability.

The four Centres of Excellence demonstrate different roles within the bioeconomy development.

CPSBB plays a transformational role in an emerging bioeconomy ecosystem. Its activities are related to plant stress biology, biotechnology that directly support sustainable agriculture and bio-based innovation. In addition, CPSBB contributes to knowledge transfer and the creation of regional innovation networks.

MPI-MPs contribution is primarily indirect. Its emphasis on systems biology, and multi-omics research generates foundational knowledge that creates opportunities for future applications in biotechnology and crop improvement [22]. Although not directly market-oriented, MPI-MP is supplying discoveries, methods, and highly trained researchers.

VIB–UGent presents integrated research and innovation bioeconomy model. By combining academic excellence with industry partnerships and biotechnology spin-offs, it actively implements scientific discoveries into commercial solutions. Its engagement in genomics and synthetic biology helps in bridging laboratory science and industrial biotechnology markets.

The John Innes Centre demonstrates bioeconomy model focused on global challenges such as food security, sustainable agriculture, and crop resilience. Its expertise directly supports the development of climate-resilient crops and sustainable production systems. Through international collaborations, it links fundamental science with real-world agricultural production, highlighting the bioeconomy’s social dimension.

In relation to funding, MPI-MP funding sources include the Max Planck Society and are supplemented by EU grants. The Max Planck Society is one of the world's most prestigious and well-funded research organisations, ensuring stable and substantial baseline funding. EU grants add competitive, project-based support, enabling collaborations [24].

CPSBB is linked to EU Teaming projects, national grants, and private funding. The funding relies on EU capacity-building programs to strengthen research excellence [6].

VIB–UGent Funding is a mix of Flemish government, European Research Council (ERC)/H2020, and industry. A substantial public investment from the Flemish government ensures balanced institutional support, while EU funding and industry partnerships support innovation and applied research [30].

John Innes Centre receives core financial support from national funding, EU projects and charities. This reflects research excellence and social impact, as charitable funds often back high-impact science [15, 16].

For the John Innes Centre, publicly available data indicate that government grants constitute the largest share of its budget. In the most recent reporting period, JIC received £33.7 million in government funding, which represents approximately 45.3% of its total income (£74.4 million) [15,16]. Contributions from charitable donors and philanthropic sources are minor. The remaining 54.5% derives from “other income”, which includes revenue from, trading operations, investments, and competitive research grants not classified as core government support. This structure highlights JIC’s strong reliance on public funding while also demonstrating a significant capacity to attract diverse non-governmental revenue streams through partnerships, scientific services, and externally funded projects.

In contrast, the funding model of VIB-PSB reflects its position within a highly integrated regional research ecosystem in Flanders.

The center receives 70–90% of its resources from public sources, primarily through operational support from the Flemish government and competitive European funding programs such as Horizon 2020 and Horizon Europe.

Industry collaboration accounts for 5–20% of its budget, originating from joint research agreements, technology transfer activities, and targeted innovation partnerships in the biotechnology and agritech sectors.

Philanthropic funding plays only a minor role, estimated at 1–5%, typically supporting specific initiatives rather than core operations. This diversified yet predominantly public

model underpins VIB-PSB’s dual mission of fundamental research and high-impact innovation [30].

Table 3. Comparison based on funding and scientific influence

Institute	Funding Sources	Global Scientific Relevance
MPI-MP	Federal and regional governments (83%), EU and other project funding (17%)	Top-tier globally in European plant science
CPSBB	Project funding (85%), economic activities and other own sources (15%)	Emerging Southeast European plant science Institute
VIB–UGent	National (Flemish) government (70%), project funding (20%), funding from industry (5%)	Top EU player in plant biotechnology
John Innes Centre	National government funding (45%), project activities (55%), donations (0.2%)	World leader in plant-development science

Source: [4, 6, 15, 16, 23, 24, 30].

The Max Planck Institute of Molecular Plant Physiology presents a third model typical of the Max Planck Society’s funding architecture. Approximately 80% or more of the institute’s budget comes from public sources, primarily federal and state government allocations. Private sector funding represents an estimated 10–15%. Philanthropic contributions constitute 5–10%, reflecting donor support for scientific advancement, infrastructure, and early-stage research. This structure confirms MPI-MP’s strong foundation in public investment, complemented by strategic private-sector partnerships and philanthropic support [23, 25].

Approximately 85% of CPSBB budget comes from competitive project funding—primarily EU programs such as Horizon Europe and national operational programs, reflecting its strong integration into European research networks. The remaining 15% is generated through economic activities and other own sources, including services to local SMEs, training programs, and technology transfer initiatives. This structure highlights both the rapid development of CPSBB and its growing role as a regional driver of scientific capacity, innovation, and economic modernization [4]. The comparison shows different types of funding from public to project-oriented, which reveals the diversity of centres of excellence and the various opportunities for research and innovation in the EU.

The socio-economic role of the institutions is also essential, especially for boosting local

economics and contribution for overcoming social challenges at regional level.

The John Innes Centre generates significant socio-economic value through its research, innovation, and educational activities. Over 25 years, JIC’s total estimated contribution to the global economy is £54.2 billion, with £5.95 billion accruing to the UK alone. The research return on investment (RoI) is high - 29:1 in the UK and 264:1 globally [15,16]. JIC supports around 881 full-time equivalent jobs in the UK, including direct employment, supply chain, and induced effects. The centre’s operations and scientific activities contribute £42.5 million in annual Gross Value Added to the UK economy [16]. Productivity gains arise primarily from agricultural innovations and bioengineering applications that enhance efficiency and sustainability in the agri-food sector. Health-related research contributes £6.3–28.2 billion globally by advancing nutrition, antibiotic resistance solutions, and bio-based materials. JIC’s environmental research supports biodiversity, carbon reduction, and sustainable crop production, leading to measurable ecological benefits valued at over £35 million [16]. JIC’s training and education programmes generate around £180 million in socio economic value, equipping students and researchers with advanced bioscience and biotechnology skills. These activities strengthen the UK’s innovation ecosystem and global research leadership [16]. While the UK gains directly from employment and innovation, more than 80% of JIC’s economic

impact occurs internationally, particularly in low- and middle-income countries that benefit from food security, improved crop yields, and

environmental resilience. The Centre's international collaborations amplify the global impact of UK-funded science.

Table 4. Comparison based on socio-economic role

Dimensions	CPSBB (Bulgaria)	JIC (UK)	MPI-MP (Germany)	VIB-UGent (Belgium)
Employment Impact	Scientific staff, local construction and service jobs	Scientists, support staff, and spin-off companies	Research staff, supporting industries	Scientists, startup staff, university collaborations
Business Ecosystem Support	Start-up support, public-private projects	Start-up incubator, agri-tech companies	Spin-offs, biotechnological collaborations	Incubators, seed funding, VIB bio-accelerator
Education and Skills Development	Research training, EU fellowships	Graduate schools, scientific outreach, technician training	PhD and postdoc programs, student internships	Graduate training, academic-industry programs
Economic Impact	Increased demand for services, skilled worker retention	Tourism, real estate, high-value job creation	Boost to real estate, transport	High-value added jobs, regional biotechnology visibility
Industry Collaboration	Regional agricultural and biotechnology firms	agriculture, biotechnological, pharma firms	partnerships with biotechnological and agricultural firms	agri-food, digital farming, biotechnology
Global Research Integration	Horizon 2020, Horizon Europe	UKRI, EU (pre-Brexit), and global research networks	Max Planck Network, EU projects, international visibility	EU-funded networks, global academic partnerships
Regional impact	Rising innovation hub in Southeastern Europe	Scientific leader of East England	Scientific leader for Golm/Potsdam	Bioeconomy driver for Flanders

Source: Own survey based on Own survey based on [4, 6, 15, 16, 22, 23, 30].

The VIB-UGent Center for Plant Systems Biology generates significant socio-economic value by advancing scientific innovation, strengthening agri-food systems, and enabling industrial competitiveness. At the core, its impact is the contribution to agricultural productivity and climate adaptation. Research in plant development, stress tolerance, gene regulation analysis helps unlock plants' biological potential, leading to improvements in crop productivity, drought resilience, nutrient efficiency. For example, new discoveries about the regulation of root development and the identification of transcription factors that control growth transitions open avenues for creating more climate-resilient crops. Such innovations reduce vulnerability to extreme weather, a driving factor of yield loss and income instability in agriculture. A major driver of PSB's socio-economic impact is its connection to entrepreneurship, industrial

partnerships, and regional economic growth [30]. Additionally, PSB contributes to socio-economic development by serving as a training hub for scientific talent. With 19 research groups and 258 staff members, the center plays a key role in educating future experts in plant biology, bioinformatics, genetics, and biotechnology. This enhances the region's human capital, developing skills needed for the green transition, sustainable agriculture, and advanced life sciences research [30]. Over the years, PSB has been the source of several successful biotech spin-offs, including notable examples such as CropDesign and Aphea.Bio, which have become important actors in the agri-tech and green biotechnology sectors. These companies not only translate scientific discoveries into practical agricultural solutions but also stimulate job creation, private investment, and technological competitiveness in Flanders. PSB also plays a key role in the development

of the Ghent Biotech Valley, serving as a leading institution that strengthens the region's position as a European hub for life sciences and sustainable biotechnology.

The Max Planck Institute for Molecular Physiology is part of the broader Max Planck Society (MPG), whose innovation and commercialisation ecosystem generates significant socio-economic impact. The Max Planck Society has produced a strong portfolio of knowledge-based companies, with 200 spin-offs created since 1990, generating approximately 9,500 jobs globally. MPI-MP contributes to this innovation ecosystem by generating foundational molecular and biochemical discoveries that seed new technologies, methods and industrial applications [23]. MPI-MP's research platform is built upon four main pillars: genetic diversity, phenotyping, gauntlets, and biomodeling. Although primarily focused on fundamental science, MPI-MP also advances plant biotechnology. MPI-MP produces highly trained PhDs and postdoctoral researchers who enter academia, biotechnology, pharmaceuticals and medical technology sectors. At the regional level, MPI-MP serves as one of the key institutions in the Potsdam-Golm Science Park, one of Germany's most dynamic innovation clusters [22]. Its presence enhances the park's scientific reputation, attracts investment, strengthens collaboration networks, and generates demand for specialized services. By stimulating innovation, the institute supports the expansion of high-skilled employment and improves the economic competitiveness of the Brandenburg region. The Max Planck Institute of Molecular Plant Physiology (MPI-MP) has played a central role in fostering innovation and entrepreneurship through the creation of several spin-off companies. In its early years, the institute helped establish two major R&D firms – PlantTec and Metanomics, both founded with significant involvement from MPI-MP scientists [22, 23]. In subsequent years, additional spin-offs emerged from the institute's research ecosystem. Together, these spin-offs illustrate the institute's strong capacity for translating fundamental research into commercial innovation and contributing

to the regional biotechnology ecosystem. MPI-MP's research platform is built upon four main pillars: genetic diversity, phenotyping, gauntlets, and biomodeling. Although primarily focused on fundamental science, MPI-MP also advances plant biotechnology. MPI-MP produces highly trained PhDs and postdoctoral researchers who enter academia, biotechnology, pharmaceuticals and medical technology sectors.

The Center of Plant Systems Biology and Biotechnology in Bulgaria has emerged as a key scientific institution generating strong socio-economic impact at both regional and national levels. By establishing a modern research infrastructure in Plovdiv, CPSBB creates high-skilled employment opportunities in Southern Bulgaria and significantly contributes to building local scientific capacity.

Through its training programs for young researchers, PhD students, and postdoctoral scientists, the center plays an important role in reducing brain drain and fostering the development of a new generation of specialists in plant biology and biotechnology. CPSBB is also an active driver of innovation. Through participation in EU-funded projects, including Horizon Europe and national operational programs, the center promotes technology transfer and supports the commercialization. Its collaborations with local SMEs in biotechnology and agriculture stimulate the adoption of innovative solutions, creating modern bioeconomy sector in Bulgaria [4, 6].

At the regional level, CPSBB supports economic development in the Plovdiv area. Its presence strengthens the city's role as an emerging innovation hub and enhances Bulgaria's integration into the European Research Area by fostering international partnerships and contributing to European research networks. Through its combined contributions in employment, innovation, regional development, and sustainability, CPSBB plays an increasingly important role in positioning Bulgaria as a competitive participant in European plant science and biotechnology.

The comparative analysis also highlights the significant role of national policy frameworks in shaping the performance and strategic orientation of Centres of Excellence. In countries such as Germany and the United Kingdom, strong and stable public funding systems support long-term scientific excellence and infrastructure development. In contrast, in emerging systems such as Bulgaria, Centres of Excellence rely more heavily on European funding instruments, particularly capacity-building programs.

Regional policy models, as in the case of Belgium, demonstrate how coordinated innovation strategies and public investment can foster strong links between research institutions and industry.

These differences illustrate that national policy environments influence not only funding stability but also the degree of industry collaboration, innovation capacity and overall impact on the bioeconomy.

CONCLUSIONS

Based on the comparative analysis it can be concluded that all four centers contribute significantly to Europe's plant science landscape, though with different scales and missions. JIC and MPI-MP benefit from long-term, stable funding that supports world-class infrastructures and high-impact fundamental research. VIB-UGent has hybrid university–institute model to drive one of Europe's biotech innovation ecosystems, linking academic excellence with industry collaborations. CPSBB, while the youngest, shows rapid development and an important regional role in bioeconomy innovations and technology transfer in Southeast Europe.

These institutional differences reflect national priorities and funding architectures but ultimately create a complementary ecosystem across Europe. MPI-MP and JIC lead in deep scientific discovery, VIB-UGent facilitates commercialization, and CPSBB strengthens capacity and innovation in emerging regions. Together, they advance climate-resilient agriculture, plant biotechnology, and green innovation, reinforcing Europe's leadership in the global bioeconomy.

Based on the findings of the study, several policy implications can be identified.

(1) The establishment of long-term and stable funding mechanisms is crucial for sustaining scientific excellence, enhancing institutional resilience and enabling strategic, forward-looking planning;

(2) There is a clear need for stronger policy incentives to foster collaboration between academia and industry, with a particular focus on improving knowledge transfer, innovation uptake and the commercialization of research results;

(3) Policy frameworks should actively support the development of regional innovation ecosystems by strengthening the alignment with smart specialization strategies and encouraging synergies between research institutions, businesses and public authorities;

(4) Targeted support for emerging Centres of Excellence is essential for reducing regional disparities, enhancing research capacity in less-developed regions and reinforcing the overall competitiveness of the European bioeconomy.

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