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The Role of Entrepreneurial Clusters in Advancing Circular Bioeconomy and Innovation: A Case Study from Romania

Boglárka Vajda [1,2,*], Gabriela Drăgan [1], Lajos Vajda [2], Mária-Magdolna Gáspár [2] and Miklós Levente Bagoly [2]

[1] Faculty of International Business and Economics, The Bucharest University of Economic Studies, Piața Romană 6, 010374 Bucharest, Romania; gabriela.dragan@rei.ase.ro
[2] Asociatia Green Energy, Asociatia Asimcov, Presei 4, 520064 Sfantu Gheorghe, Romania; vajdalajos@greencluster.ro (L.V.); gaspar@asimcov.ro (M.-M.G.); info@greencluster.ro (M.L.B.)
* Correspondence: vajdaboglarka@gmail.com; Tel.: +40-749-096726

Abstract: This paper explores how bioeconomy-specialized clusters function as systemic intermediaries that support innovation, coordination, and business transformation in the transition to a circular bioeconomy. Using a qualitative case study methodology, we analyze how bioclusters in Romania enable SME development, knowledge transfer, and cross-sector innovation, ultimately strengthening regional entrepreneurial ecosystems. Findings highlight the role of clusters in supporting innovation management, access to financing, and policy alignment in the transition toward a circular bioeconomy. By fostering entrepreneurial networks, facilitating skill development, and supporting SME-driven innovation, clusters act as catalysts for inclusive and resilient business growth. This study highlights how clusters create an enabling environment by providing access to financing, technology, and market expansion opportunities. Although focused on a specific regional biocluster ecosystem, the findings underscore the scalability and replicability of this model across Europe, reinforcing its contribution to entrepreneurship, innovation, and regional economic development. This study contributes to the literature on entrepreneurial ecosystems and circular bioeconomy governance, emphasizing the role of clusters as intermediary organizations that facilitate business-led sustainability transitions. The findings offer practical insights for policymakers, industry leaders, and researchers, outlining strategies to strengthen cluster-based innovation, enhance SME competitiveness, and embed circular practices into national and regional bioeconomy strategies. This paper's added value lies in combining the Technological Innovation Systems (TIS) framework with empirical evidence from Romanian clusters—a context underexplored in current literature on circular bioeconomy transitions.

Keywords: circular; bioeconomy; cluster; networking; innovation; intermediaries

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1. Introduction

Ensuring sustainable food production, environmental protection, and economic competitiveness while improving quality of life is one of the most pressing challenges of our time. The increasing pressure on natural resources has exceeded sustainable levels, raising concerns about the long-term viability of food, raw materials, and energy supplies. The European Union (EU) has set ambitious climate goals, aiming to reduce greenhouse gas emissions by 55% by 2030 and achieve climate neutrality by 2050 [1]. Meeting these objectives requires fundamental restructuring of how economies extract, convert, distribute, and manage resources. The circular bioeconomy has emerged as a key driver of change, offering a pathway to economic growth while addressing environmental and social challenges [2].

As an EU member state, Romania is actively engaging in the transition to a circular bioeconomy. The country possesses significant bioeconomic potential, with abundant agricultural, forestry, and bio-based resources [3]. However, despite its high biomass availability, Romania faces structural challenges, including limited value-chain integration, insufficient policy coordination, and fragmented stakeholder engagement [4]. The slow development of bio-based networks and innovation ecosystems is often attributed to the absence of strong intermediary organizations [5].

To bridge these gaps, regional clusters serve as dynamic entrepreneurial ecosystems that drive bio-based business innovation, facilitate SME growth, and strengthen the circular bioeconomy. Clusters act as intermediaries that connect businesses, research institutions, policymakers, and civil society, fostering cross-sector cooperation, research-driven innovation, and SME competitiveness [6]. Their importance is particularly significant in rural and underdeveloped regions where they facilitate technology adoption, knowledge transfer, and market access for bio-based enterprises.

The success of this transition will depend on sectoral articulation among businesses, policymakers, research institutions, and civil society in order to establish new bio-based value chains. Therefore, the exchange of knowledge, the co-creation of solutions together with shared problems, and a coordinated effort that transcends sectors is crucial in fostering innovation and fostering systemic transformation towards environmental sustainability. In this regard, intermediating organizations play a critical role in facilitating collaborations, serving as a bridge between producers and users, entrepreneurs and adopters, and researchers and policymakers [7]. Thereby, bioeconomy cluster initiatives are the key intermediaries. These initiatives facilitate interaction among enterprises, research groups and public agents, and a range of other stakeholders. In acting as systemic enablers of cluster developments, bioclusters may foster value-chain formation, technology transfer, innovation, and internationalization, which is necessary for advancing the circular bioeconomy [8].

While it is true that bioeconomy clusters enhance innovation, competitiveness, and sustainability, their effectiveness is very often dependent on the presence of strong intermediary mechanisms [9]. As systemic intermediaries, clusters help businesses adopt sustainable practices, access funding and expertise, and comply with policy objectives [4]. They also facilitate joint research projects, market access, and internationalization, and serve as platforms to aid skills development and business incubation [6].

This research paper draws on the Technological Innovation Systems (TIS) framework [10] to examine how Romanian bioclusters contribute to the circular bioeconomy transition. Specifically, it explores their intermediary role in fostering key innovation system functions: guidance of the search, resource mobilization, and legitimation. The central research question guiding this study is: How do some bioeconomy-specialized clusters in Romania act as systemic intermediaries in advancing the circular bioeconomy?

Therefore, the central objective of this study is to investigate how these clusters facilitate circular innovations and what challenges they face in fulfilling their intermediary role. While prior studies have examined innovation intermediaries in Western European contexts, this study contributes to the literature by applying the TIS framework to a multi-sectoral case study of Romanian clusters—an empirical landscape largely neglected in bioeconomy transition research.

The remainder of the paper is organized as follows: Section 2 presents the theoretical framework on bioeconomy transitions and intermediary roles, Section 3 details the research methodology, Section 4 discusses the empirical findings from five Romanian bioclusters, and Section 5 concludes with key implications for policy and practice.

2. Theoretical Framework

2.1. Bioeconomy, Circular Economy, and Circular Bioeconomy

The concept of the bioeconomy has become increasingly relevant due to its potential to transform biological resources, waste, and side-streams into value-added products, including bio-based materials and bioenergy [11]. According to the European Commission [12], the bioeconomy encompasses all sectors and systems that depend on biological resources, including agriculture, forestry, fisheries, aquaculture, and bio-based industries. This framework integrates these sectors into a unified system that prioritizes sustainability, efficient resource use, and circular production and consumption processes [13].

The bioeconomy offers a route to more sustainable production and consumption on the basis of renewable and biological resources and not fossil-based resources [14]. One of the key elements of the EU Bioeconomy Strategy is its integration with the Circular Economy, an economic system that aims to maintain the value of products, materials, and resources for as long as possible while minimizing waste [15]. The circular bioeconomy is positioned at the intersection of the bioeconomy and circular economy concepts, emphasizing the sustainable and efficient management of bio-based materials. The European Commission [16] defines the circular bioeconomy as a systemic approach aimed at reducing dependency on finite natural resources, reshaping industrial processes, and fostering the sustainable production and conversion of biological resources into bio-based products and bioenergy. Additionally, this model is intended to create employment opportunities and drive innovation. D'Amato et al. [17] further refine this definition, describing the circular bioeconomy as the practical integration of circular economy principles into the bioeconomy, ensuring the responsible use and regeneration of renewable biological resources.

The successful development of a circular bioeconomy necessitates the active participation of a diverse set of stakeholders, including businesses, consumers, policymakers, researchers, and civil society organizations. Collaborative efforts are essential for fostering innovation, knowledge exchange, and policy alignment. The BIOEAST initiative emphasizes that the expansion of the bioeconomy relies on multi-actor engagement, cross-sector collaboration, and targeted investments to accelerate sustainable transformation [18]. Despite the increasing momentum to expand the bioeconomy, significant disparities persist across Europe. A key barrier to bioeconomy development is the slow emergence of new bio-based networks, even in regions with strong bioeconomic potential. This challenge is largely attributed to the absence of intermediary or bridging organizations, as well as institutional lock-in to pre-existing markets, relationships, and knowledge systems [5].

2.2. Clusters as Facilitators and Intermediaries

A well-functioning circular bioeconomy depends on an interactive, multi-actor environment that facilitates continuous knowledge exchange and cooperation. Multi-stakeholder alliances play a crucial role in connecting key actors—including government agencies, businesses, research institutions, and civil society—to mobilize knowledge, resources, and expertise in pursuit of shared objectives [19]. Within this ecosystem, intermediaries act as enablers by bridging gaps between stakeholders, mitigating transaction costs, reducing information asymmetries, and overcoming communication barriers that often hinder collaboration [9]. Intermediary organizations fulfill multiple functions within the circular bioeconomy, including knowledge transfer [20], technological and financial support [21], fostering trust and knowledge exchange, and driving collaborative innovation [22].

The role of intermediaries varies depending on the needs and expectations of different stakeholder groups [6].

- For businesses, intermediaries provide access to broader networks, funding opportunities, and technical expertise;
- For academic institutions, they serve as a bridge between theoretical research and practical applications while also influencing policy development;
- From the perspective of public authorities, intermediaries play a key role in regional economic development and the enhancement of innovation ecosystems.

As Barrie et al. [8], Laur [6], Blankenship et al. [23], and Kivimaa [7] suggest, intermediary organizations can take various forms: triple helix innovation systems, cluster initiatives, and business incubators. Among these, cluster initiatives have gained particular attention for their ability to facilitate innovation and productive knowledge interaction in bio-based industry sectors. Clusters operate not just as service providers, but also as platforms for strategic alignment and institutional support. Hermans [10] further emphasizes that bioclusters differ from traditional clusters by serving as both innovation ecosystems and transition arenas, making them especially relevant for addressing the systemic challenges of the bioeconomy transition.

2.3. Bio-Clusters as Intermediaries in the Bioeconomy

In this study, we use the term bioclusters to refer to entrepreneurial clusters that are specialized in the bioeconomy sector. These clusters integrate actors across research, business, and policy domains to support innovation and sustainability-oriented transformation within regional economies. Clusters constitute an important organizational arrangement for enhancing the performance of regional innovation systems [24]. They are essentially a network of stakeholders, businesses, research and innovation entities, financial sector organizations, and governance bodies, working together for some common or complementary strategic objectives. This facilitative environment allows the firms and other actors in it to exploit shared competitive strengths and synergies, hence promoting solidarity in problem-solving and capacity-building.

As dynamic and adaptive organizational structures, clusters facilitate both long-term strategic planning and short-term project-based collaborations. Consistent with the economic cluster theory [25], clusters are recognized for fostering industrial specialization, competitiveness, and innovation [26]. The growing prominence of bioeconomy and circular bioeconomy paradigms has further reinforced the importance of biocluster initiatives. These entities catalyze regional economic cooperation, support cross-sectoral knowledge flows, and facilitate sustainable transformation by aligning actors and building supportive institutional environments.

Whereas traditional industrial clusters concentrate on competitiveness and innovation, bioclusters integrate additional objectives such as environmental responsibility and socio-economic resilience. In line with EU Green Deal priorities [27], bioeconomy clusters act as territorial platforms for mainstreaming circular bioeconomy principles and creating new bio-based value-chains. Bio-clusters operate as systemic intermediaries [28] within the TIS framework. They contribute to core innovation system functions such as resource mobilization, legitimation of emerging technologies, and guidance of the search [29]. As they evolve from project facilitators into agents of structural change, bioclusters influence regional development trajectories, foster institutional innovation, and enhance the legitimacy of sustainability-oriented practices [7,10]. Through these mechanisms, bioclusters simultaneously fulfill operational mandates and contribute to the structural transformation of the innovation system.

3. Materials and Methods

3.1. Research Design

This study adopts a qualitative case study approach [30] to examine the role of bioclusters as intermediaries in Romania's circular bioeconomy. Specifically, the analysis focuses on a biocluster ecosystem of five clusters spanning bioenergy, agro-food, forestry, textiles, and balneology.

The selection criteria for these five clusters were based on the following.

- Their economic relevance and maturity within Romania's regional bioeconomy;
- The need for sectoral diversity to ensure coverage of multiple industries engaged in bioeconomic innovation;
- Their integration of circular bioeconomy principles within strategic operations.

While this in-depth approach limits generalizability to other regions, the insights obtained offer replicable strategies that may inform similar bioeconomy cluster initiatives in Europe and beyond.

3.2. Data Collection

The study employs a multi-method qualitative approach to gather comprehensive data and ensure methodological triangulation. The following three main data sources were used.

- Semi-Structured Interviews: Ten key stakeholders—cluster managers, SME representatives, policymakers, and funding institutions—were interviewed to discuss cluster structures and strategic objectives, stakeholder roles, collaboration mechanisms, and challenges such as policy coordination and financing.
- Document Analysis: Over 50 reports, policy documents, and strategic plans from clusters and public institutions were reviewed. These documents provided contextual background on cluster evolution, funding mechanisms, and policy alignment.
- Direct Observation: The research team conducted field visits and virtual observations of cluster activities and stakeholder meetings, focusing on decision-making processes, internal communication channels, and policy engagement efforts.

3.3. Semi-Structured Interviews and Data Coding

To gain deeper insights into the challenges and opportunities faced by these five bioclusters, the research team conducted ten semi-structured interviews from 10 January to 1 February 2025. The interviewees were chosen for their flexibility; each participant could elaborate on experiences specific to their cluster role, while the questions ensured that core topics—clusters' intermediary roles, financing mechanisms, collaborative strategies, and innovation practices—were consistently addressed.

Table 1 below provides an overview of the interview participants. Anonymized codes (P1, P2, etc.) were assigned to safeguard confidentiality. Interviews were conducted by telephone, or in person, with durations ranging from 30 to 60 min. All interviewees provided informed consent and received explanations about the study's purpose, scope, and data handling procedures.

Data from interviews were audio-recorded, transcribed verbatim, and imported into NVivo 15 [31] for coding. A preliminary coding framework was developed based on the research objectives—intermediation, collaboration, innovation practices, financing, and policy alignment—and refined iteratively as transcripts were analyzed.

Table 1. Overview of the semi-structured interview participants (N = 10).

Interview Code	Position/Role	Type of Organization	Date of Interview	Duration (min)	Method
P1	Cluster manager	Bioenergy Cluster	10 January 2025	45	Face-to-face
P2	SME representative	AgroFood Cluster	12 January 2025	40	Face-to-face
P3	Cluster expert	Balneo Cluster	15 January 2025	35	Telephone Call
P4	Cluster manager	Textile Cluster	16 January 2025	50	Face-to-face
P5	SME representative	Wood Cluster	20 January 2025	30	Telephone Call
P6	Cluster expert	Bioenergy Cluster	21 January 2025	40	Face-to-face
P7	SME representative	Textile Cluster	25 January 2025	45	Face-to-face
P8	Cluster manager	AgroFood Cluster	27 January 2025	60	Face-to-face
P9	Cluster manager	Wood Cluster	30 January 2025	35	Face-to-face
P10	Consultant	Consultancy Organization (SME)	1 February 2025	50	Face-to-face

3.4. Data Analysis

Two researchers independently applied the coding framework to each transcript, following a thematic analysis approach. They met frequently to reconcile minor discrepancies, ensuring a consistent interpretation of the codes. After finalizing all thematic categories, Cohen's kappa was calculated at 0.82, indicating a high level of inter-coder reliability. Data saturation was deemed to have been reached when no new themes or insights emerged, reflecting a redundancy of perspectives on the clusters' intermediary roles and bioeconomic challenges. To strengthen validity, the study applied methodological triangulation, cross-referencing interview findings with the insights from document analysis and direct observation. This approach minimized subjectivity by confirming patterns across different data sources.

The coded data were ultimately grouped into core thematic categories (e.g., "financing challenges", "regulatory misalignment", "cross-cluster cooperation"), guiding the comparative analysis of the five bioclusters presented in the subsequent sections. Although the focus on five regional clusters limits the direct transferability of findings to other contexts, the in-depth examination of their intermediary role offers valuable insights for practitioners and policymakers seeking to strengthen cluster-based innovation strategies in the bioeconomy sector across Europe.

4. Results and Findings

4.1. The Growth of a Biocluster Ecosystem in Romania

Michael Porter's definition of clusters as geographic concentrations of interconnected companies and institutions remains foundational to Romania's industrial policy [25]. The European Commission's Communication on Competitiveness and Industrial Policy further refines this concept by describing clusters as dynamic economic ecosystems that bring together enterprises, institutions, and regional actors to foster specialization and boost competitiveness [32]. Clusters in Romania are officially recognized under Government Decision 918/2006—Impact Programme, which defines clusters as groupings of producers, users, and/or beneficiaries that aim to transfer EU best practices to enhance industrial competitiveness. As of early 2024, the Ministry of Economy, Trade, and Business Environment recorded 78 cluster initiatives, reflecting the expansion of collaborative innovation structures within the country. Among these, 54 are members of CLUSTERO, Romania's

national cluster association that unites the most active clusters in sectors such as renewable energy, textiles, wood and furniture, and agro-food [33].

Figure 1 illustrates how clusters function as collaborative ecosystems, integrating key stakeholders across multiple sectors. The model underscores the importance of synergistic interactions among businesses, research institutions, public authorities, and support organizations. By fostering cooperation, these clusters enhance knowledge transfer, technological development, and economic growth while ensuring alignment with regional and national development strategies. The integration of the four-clover model further reinforces their role in driving sustainable innovation and long-term competitiveness.

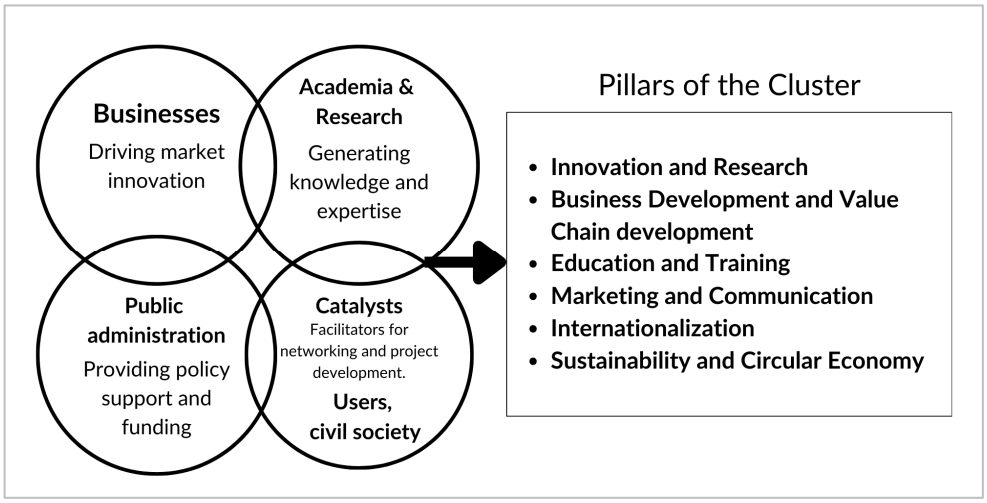

Figure 1. Clusters as collaborative ecosystems, integrating diverse stakeholders. Source: Compiled by the authors based on Carayannis et al. [34].

A cluster is defined as an integrated system of multiple actors—businesses, academia, public authorities, and catalyst organizations—that collaborate to enhance competitiveness and innovation in a specific field [35]. The cluster concept in Romania follows the four-clover model, expanding upon the triple-helix framework [36]. This model integrates businesses, academic institutions, government bodies, and financial/innovation intermediaries, enabling long-term sustainability and cross-sector collaboration.

The regional biocluster ecosystem has evolved progressively, shaped by structural and economic policies that foster innovation. Its origins can be traced to the establishment of the Business Incubator of Sfântu Gheorghe in 2006, supported by the United Nations Development Programme. Initially designed as a business accelerator, the incubator has since transformed into a multifunctional hub offering incubation programs, coworking spaces, digital innovation support, and capacity-building initiatives. Between 2007 and 2024, the incubator has played a pivotal role in supporting 146 companies, with 63 businesses still active today. Additionally, it serves as a platform for 21 non-governmental organizations and other entities, reinforcing its long-term contribution to regional economic development and cluster sustainability (Table 2).

Table 2. Sfântu Gheorghe Business Incubator evolution (2007–2025).

Entity Type	2007–2024	2025
SMEs	146	63
NGOs and other entities	20	21
Cluster management entity	5	5

Source: authors' own elaboration based on data provided by ASIMCOV.

Figure 2 visually represents the biocluster ecosystem, illustrating its role in fostering sustainability and innovation through a structured approach. The diagram's roof highlights the overarching goals—sustainability and the Sustainable Development Goals (SDGs)—which serve as the foundation for all activities within the ecosystem.

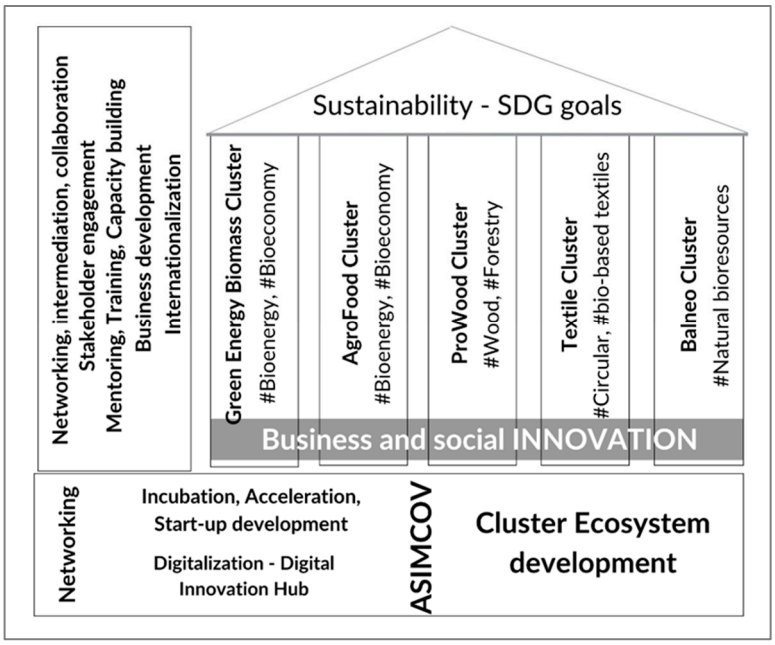

Figure 2. The biocluster ecosystem and its contribution to sustainability. Source: authors' own elaboration.

At the core of the ecosystem are five distinct bioclusters, each specializing in different sectors of the bioeconomy and circular economy.

- Green Energy Biomass Cluster (#Bioenergy, #Bioeconomy)—focused on renewable energy solutions, biomass utilization, and decarbonization;
- AgroFood Cluster (#Bioenergy, #Bioeconomy)—promoting sustainable agricultural practices, waste valorization, and food innovation;
- ProWood Cluster (#Wood, #Forestry)—concentrating on sustainable forestry management, wood processing, and eco-friendly furniture production;
- Textile Cluster (#Circular, #bio-based textiles)—advancing circular fashion, bio-based materials, and low-impact textile manufacturing;
- Balneo Cluster (#Natural bioresources)—leveraging Romania's natural balneological resources for health tourism and wellness innovations (Table 3).

Table 3. Composition of key bioclusters.

CLUSTER ORGANIZATION	Year Established	Total Members	Composition of Clusters			
			Businesses	Research, Universities, Education	Public Authorities	Others
PROWOOD	2010	81	60	4	6	11
AGRO-FOOD	2011	117	60	39	13	5
TEXTILE	2012	47	44	1	1	1
GREEN ENERGY	2011	80	49	14	14	3
BALNEO	2014	43	23	9	5	6
TOTAL		368	236	67	39	26

Source: Data provided by the clusters.

Each biocluster is committed to networking, business development, knowledge transfer, and internationalization, ensuring alignment with the principles of the bioeconomy and circular economy. Their activities are strategically designed to enhance sustainable value chains and innovation, contributing to the long-term resilience of the Romanian biocluster ecosystem. The development of this ecosystem has been supported by a network of local and regional institutions, including public authorities, research centers, and private stakeholders.

One of the key contributors to this framework has been the Association for Small and Medium Enterprises of Covasna County (ASIMCOV), established in 1996 with 21 members and now representing nearly 500 businesses [37]. ASIMCOV has played a central role in facilitating collaboration between public and private actors by working closely with local and regional authorities to create a supportive infrastructure for entrepreneurship and cluster development. By actively engaging in policy discussions and regional strategic initiatives and representing SME interests, ASIMCOV has contributed to the development of smart specialization strategies aligned with EU sustainability goals. Additionally, through programs such as the Digital Innovation Hub (DIH), it provides technology transfer, business incubation, and start-up acceleration services to ensure that SMEs can integrate digital transformation solutions and enhance their competitiveness. This broad-based partnership among public institutions, industry representatives, and intermediary organizations is essential in shaping the long-term sustainability and effectiveness of the biocluster ecosystem [38].

Based on both existing literature [6,7] and insights from our interview data (see Table 1 in Section 3.3), we identified six main categories of stakeholders that frequently interact within these Romanian bioclusters. While Figure 2 illustrates the ecosystem visually, Table 4 below provides a concise overview of how each stakeholder group contributes to, and benefits from, the cluster environment.

Table 4. Summarizing stakeholder roles in the Romanian biocluster ecosystem.

Stakeholder Category	Typical Examples	Main Roles/Contributions
Cluster Management Entities	Cluster coordinators, cluster managers, steering boards	• Oversee strategic direction and governance of the cluster • Facilitate networking, resource sharing, and joint project development • Communicate with public agencies to shape policy support
SMEs (Small and Medium Enterprises)	Agro-food producers, textile manufacturers, energy firms	• Develop new products, technologies, and services • Provide feedback on practical challenges (e.g., cost barriers, market demands) • Engage in joint innovation and knowledge exchange
Research and Academic Institutions	Universities, R&D centers, vocational institutes	• Conduct applied research relevant to bioeconomy and circular processes • Offer training programs to enhance workforce skills • Collaborate on pilot projects and technology testing
Government/Public Authorities	Regional authorities, national ministries, local agencies	• Formulate and implement relevant policy frameworks • Provide funding opportunities and guidance via public grants • Ensure regulatory compliance and alignment with EU/national priorities
Funding Institutions and Investors	Banks, venture capital funds, private equity firms	• Offer financial capital for cluster-related innovations • Assess risk and viability of emerging technologies • Encourage sustainable business practices via financing terms
NGOs and Civil Society Organizations	Environmental advocacy groups, community associations	• Monitor environmental and social impacts of cluster activities • Facilitate stakeholder dialogue and community engagement • Promote ethical and inclusive governance

Source: Adapted from Porter [25] and Carayannis and Campbell [34,39].

As indicated by several SME representatives (P2, P5, and P7 in Table 1), financing schemes and resource-sharing platforms are vital for sustaining innovative ventures. Meanwhile, cluster managers (P1, P4, and P8) pointed out that strong policy engagement with

regional authorities often helps overcome bureaucratic hurdles and align cluster activities with wider sustainability goals. These stakeholder roles underpin the multi-actor collaboration that, as discussed next, characterizes the five major bioclusters in Romania's bioeconomy.

4.2. The Five Major Bioclusters: Critical Analysis and Challenges

The biocluster ecosystem consists of five specialized clusters, each addressing different sectors of the bioeconomy and circular economy. These clusters, which emerged due to Romania's bioeconomic potential, specialize in various fields, from forestry and bioenergy to agro-food innovation and textile sustainability. Fragmented collaboration, regulatory barriers, and access to funding are among the most significant impediments to sustained development. Many SMEs within the clusters continue to operate independently rather than fully leveraging intra-cluster synergies. While these clusters have successfully stimulated regional economic growth, several key challenges persist.

4.2.1. Green Energy Biomass Cluster

The Green Energy Biomass Cluster, established in 2011, focuses on renewable energy production, biomass utilization, and decarbonization, significantly fostering regional energy independence and driving bioenergy development.

Notable projects include [40] the following.

- BioEnergyTrain and Phoenix, funded by EU Horizon 2020: Aimed at enhancing human capital in the bioenergy sector, this project developed specialized curricula in bioresource management and biorefinery, bridging the gap between academia and industry through interdisciplinary training programs and facilitating international researcher exchanges via Horizon Marie Curie RISE actions.
- InnoEnergyHub, funded by EIT Energy: Provides mentorship, training, and financial support for start-ups in bioenergy and circular economy solutions; through a network of industry experts and investors, it helps early-stage companies refine their business models, secure funding, and expand market opportunities.
- Cosmenerg and Cosmenerg4i, funded by EU COSME: Expanded eco- and bio-energy cluster networks across Central and Eastern Europe, fostering collaboration among businesses, technology providers, and research institutions in the fields of renewable energy, environmental technologies, and the circular economy.
- P2GreenEst, funded by EU COSME: Provided crucial support for green SMEs, helping them expand into non-EU markets, integrate into international supply chains, and participate in sustainable public procurement processes.
- Smart Post-Industrial Regenerative Ecosystem—SPIRE, funded by Urban Innovation Action: Promotes regenerative bio-industrial ecosystems by integrating circular economy principles into regional development.
- BioVill, funded by EU Horizon 2020: Facilitates the development of decentralized biomass-based energy models for rural communities by offering technical assistance and knowledge-sharing platforms, enabling villages to establish biomass heating systems using locally sourced raw materials and to implement regulatory frameworks for the transition from fossil fuels to sustainable bioenergy solutions.
- AgroBioHeat, funded by EU Horizon 2020: A project that promoted the use of agricultural residues and biomass for clean heating solutions, helping local communities adopt sustainable bioenergy technologies and integrate them into existing energy infrastructures.

- BioRural, funded by EU Horizon Europe: Plays a crucial role in engaging rural stakeholders and policymakers, fostering knowledge exchange and co-creation processes to accelerate the deployment of bioenergy-based solutions tailored to local needs.
- thERBN, funded by EU Horizon Europe: Aims to strengthen small rural farms and foresters in transitioning to sustainable and climate-neutral operations by facilitating the adoption of innovative circular bioeconomy practices.
- Greet CE, funded by EU Interregional Innovation Investment I3: Focuses on enhancing SME innovation and access to EU funding by providing specialized training and funding application support; it also integrates policy recommendations to create an enabling environment for green SMEs.

A key initiative in the community-driven bioenergy solutions has been the "One Village—1 MW" concept [40]. This project aims to create self-sufficient rural energy solutions by utilizing local residual biomass for energy generation. The initiative (Figure 3) follows a structured approach: (a) identification and collection of biomass sources such as forestry residues, agricultural waste, and urban trimmings; (b) processing and conversion into briquettes, pellets, compost, and biofertilizers for various applications including heating, agriculture, and energy production; and (c) energy generation and distribution to power public buildings and residential areas (to generate 1 MW of power per village, supplying energy to public buildings like schools, kindergartens, town halls, and residential areas, ensuring energy security and sustainability). This initiative, implemented in over 45 villages with a combined capacity exceeding 30 MW, highlights the role of bioenergy in fostering energy resilience and sustainability. The BioVillMap platform [41] developed by the cluster actively tracks and highlights the rural municipalities engaged in bioenergy production, showcasing how local communities are transitioning to sustainable, bioenergy-driven economies.

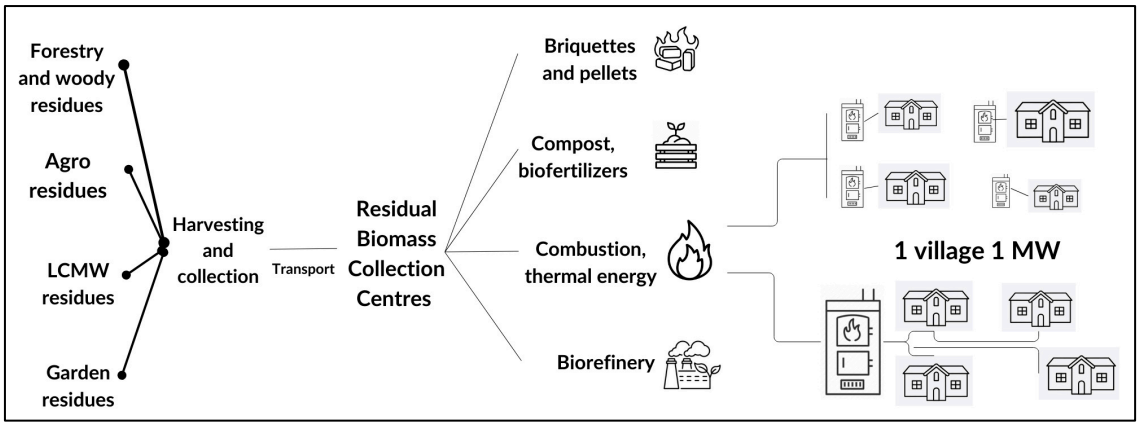

Figure 3. The "One village 1 MW concept". Source: authors' own elaboration 2025.

Critical Analysis: Despite its progress, the Green Energy Biomass Cluster faces significant policy and infrastructure barriers that limit the scalability of biomass-based energy projects. One of its primary strengths lies in its robust collaboration with research institutions, as demonstrated by projects such as BioEnergyTrain, which fosters specialized curricula and facilitates international research exchanges. Moreover, the cluster benefits from extensive access to EU funding mechanisms that enhance SME innovation and financial stability. The alignment with the European Green Deal further solidifies the cluster's long-term viability by ensuring consistent policy support for renewable energy expansion. However, several limitations persist. The underdeveloped infrastructure for biomass processing restricts the scalability of promising initiatives like the One Village—1 MW Initiative, while heavy reliance on government incentives introduces financial vulnera-

bility and susceptibility to regulatory shifts. Fragmented stakeholder coordination also undermines the effectiveness of knowledge-sharing platforms, such as BioVill, even though BioVill offers a viable blueprint for scaling biomass-based solutions in rural communities.

Additionally, strengthening international collaborations through initiatives like Horizon Marie Curie RISE could further accelerate technological advancements and knowledge transfer in bioenergy research and development. Nonetheless, the cluster must contend with persistent threats, including competition from fossil-based energy sources that benefit from established infrastructure and government subsidies, as well as inconsistencies in national energy policies and delays in the implementation of green energy subsidies, which together create a volatile investment landscape. Market uncertainties surrounding fluctuating biomass costs further complicate the financial feasibility of large-scale bioenergy projects.

4.2.2. AgroFood Regional Cluster

The AgroFood Cluster, founded in 2011, supports sustainable agricultural practices, waste valorization, and innovation in food processing. This cluster advances sustainable agricultural practices and waste valorization.

Relevant projects include [42] the following.

- STRING—Strategies for Regional Innovative Food Clusters—Contributed to aligning regional policies with circular bioeconomy principles, securing funding access and regulatory support for agro-food SMEs.
- TRACE-KEI—Strengthened SME capabilities by developing sustainable business models, supporting digitalization, and fostering collaboration among agriculture, food technology, and renewable energy sectors.
- Sustainable Dairy Innovations—A research-driven project focused on reusing whey by-products to create probiotic beverages, demonstrating industrial symbiosis in the food industry.
- Turning medicinal mineral water into a gluten-free functional drink—Transforming therapeutic water into a gluten-free, fiber-enriched functional beverage, supporting digestive health and preventive well-being.
- Valorization of Apple Pomace—A waste valorization initiative transforming apple processing by-products into high-fiber flour for gluten-free baking, integrating circular economy principles into food production.

The cluster plays a pivotal role in promoting bioeconomy principles, yet faces challenges in supply chain integration and regulatory barriers.

Critical Analysis: While playing a pivotal role in promoting sustainable agricultural practices and waste valorization, the AgroFood Cluster confronts significant structural and financial challenges that impede its long-term viability. Although robust industry–academia partnerships have fostered food sustainability innovations, the uneven integration of sustainable processing technologies and supply chain inefficiencies create hurdles for market adoption.

Moreover, regulatory discrepancies in food packaging and circular production, coupled with limited consumer awareness of circular food products, restrict the cluster's impact. On the other hand, expanding waste-to-value initiatives and digital precision farming, as well as strengthening international collaborations, could enhance resource efficiency and funding diversification, addressing the systemic challenges identified. Additionally, strengthening international collaborations in sustainable food systems can help address knowledge gaps and improve funding diversification. Recent reports from the European Commission [43] emphasize the necessity of stronger policy incentives and technological investments to drive systemic transformation in food clusters.

4.2.3. ProWood Cluster

The ProWood Cluster, created in 2010, fosters sustainable forestry management, eco-friendly wood processing, and innovation in furniture manufacturing. This cluster focuses on sustainable forestry and wood processing [44].

Key projects include the following.

- ROSEWOOD and ROSEWOOD 4.0—Facilitated ICT integration in sustainable forest management, optimizing timber value chains and enhancing digital transformation in the sector.
- FORESDA—A project that played a key role in fostering cross-sector collaboration in the Danube region, linking the wood processing, furniture production, and bio-based industries to create more resilient and innovative value chains.
- Furniture Go International—FGOI—Provided export-readiness support, allowing SMEs to expand into global markets while adopting sustainable production methods. The cluster has actively promoted Smart Furniture Remanufacturing initiatives, integrating circular economy principles into furniture production through eco-design, resource efficiency, and product lifecycle extension.
- Smart Furniture Remanufacturing Initiative—Focused on circular production in the furniture industry, promoting eco-design and lifecycle extension.
- Bio Wood Net—Established a distributed industrial research network aimed at fostering sustainable development, the creation of new bio-based materials, and the application of digital technologies in wood processing.
- Student-Entrepreneur in the Centre Region and Digital Skills Development in the Centre and West Regions—Provides training programs that enhance technical expertise, digital competencies, and entrepreneurial skills among young professionals and industry workers.

Critical Analysis: While the ProWood Cluster boasts high export potential, challenges persist regarding resource availability and workforce retention. Although the ProWood Cluster has successfully promoted sustainable forestry practices and industrial innovation, challenges related to supply chain fragmentation and inconsistent sustainability policies remain pressing concerns. The high costs of digitalizing forestry operations and transitioning to circular wood production create barriers for SMEs, limiting the scalability of sustainable initiatives. Although the cluster benefits from robust international partnerships, including ROSEWOOD 4.0, the lack of skilled labor and fluctuating timber market conditions pose threats to long-term sector growth. Future strategies should prioritize policy alignment with European sustainability directives and digital transformation investments to enhance competitiveness. Expanding cross-border collaborations in forest monitoring technologies and circular wood product certification can further mitigate industry risks. The European Forest Institute [45] identifies gaps in sustainable forestry governance, emphasizing the need for circular wood supply chains. The cluster's reliance on traditional timber-processing techniques presents an obstacle to meeting EU climate neutrality targets.

4.2.4. Textile Cluster

The Textile Cluster, established in 2013, promotes circular fashion, bio-based materials, and sustainable textile manufacturing [46].

Aimed at advancing circular fashion and bio-based textiles, this cluster has benefited from the following.

- DE-MA-CO Project—Improved cooperation and competitiveness within the textile industry, laying the foundation for sustainable development.

- Competitive Advantage through Innovation—Enabled textile manufacturers to integrate sustainable materials and eco-friendly production techniques.
- Local Sustainable Fashion Week —Raised awareness about circular textiles, ethical fashion, and responsible consumerism.
- EcoTexHoReCa Expo & Conference—Supported sustainable textile integration in the hospitality industry, promoting eco-certified materials.
- Digital Textile Waste Reuse Program—Developed a textile recycling initiative, enabling fiber-to-fiber recovery processes and reducing industry waste.

Critical Analysis: Despite its strong commitment to sustainable fashion, the Textile Cluster faces persistent challenges related to high production costs for eco-friendly materials and slow adoption of sustainability certifications among SMEs. The global competitiveness of Romanian textile manufacturers is hindered by price pressures from low-cost textile producers and fluctuating organic fiber supply chains. While EU-funded initiatives such as Competitive Advantage through Innovation and EcoTexHoReCa offer valuable financial support, a stronger focus on digital traceability solutions and blockchain-integrated supply chains could enhance transparency and sustainability in textile production.

Moreover, consumer education campaigns on sustainable fashion choices and policy incentives for circular textile adoption could further drive industry transformation. Despite EU Green Deal incentives, textile SMEs face barriers to adopting biodegradable and recycled materials due to cost limitations and market reluctance. Research from the United Nations Environment Programme [47] suggests increased government incentives could accelerate eco-certification adoption and competitiveness.

In line with recent findings [48], advancing sustainability in the textile sector requires coordinated action across the entire product life cycle—from fiber production to post-consumer reuse—supported by digital technologies such as blockchain, IoT, and AI platforms. These tools not only enable material traceability and life-cycle monitoring, but also support waste reduction and smarter resource management.

4.2.5. Balneo Cluster

The Balneo Cluster, founded in 2014, leverages Romania's natural balneological resources for health tourism and wellness innovation [49].

Specializing in health tourism and bioeconomic integration, this cluster has been supported by the following.

- InnovaSPA, funded by Interreg Europe—Innovative health solutions for thermal spa regions aiming for the improvement of development policies at a regional/national level, which support the transfer of technology and knowledge in order to accelerate the market launch of new products and innovative solutions for spa resorts.
- Digital Mapping of Romania's Therapeutic Resources—An interactive database featuring over 500 mineral springs and health resorts to support strategic planning.
- Centru Region Balneological Strategy Development—Contributes to national health tourism policies, emphasizing sustainability and economic viability.
- Summer schools, conferences, and training programs—Enhance professional expertise in the sector. These educational initiatives help to ensure that traditional balneotherapy practices evolve in alignment with modern medical and wellness trends.

Critical Analysis: While Romania's natural balneological resources provide a competitive advantage for health tourism, the Balneo Cluster faces challenges related to outdated infrastructure, seasonal demand fluctuations, and low international brand recognition. While the Balneo Cluster benefits from strong governmental support, it remains affected by seasonal fluctuations and infrastructure challenges. Limited digitalization in spa management and inconsistencies in regulatory support further hinder the sector's expansion.

Despite these challenges, the cluster has demonstrated strong potential through initiatives like InnovaSPA and Digital Mapping of Romania's Therapeutic Resources, which integrate smart technologies into spa operations. Future strategies should focus on modernizing spa facilities and expanding Romania's presence in the European wellness tourism market. Strengthening cross-border collaborations with leading health tourism clusters could also enhance investment inflows and foster knowledge exchange. The European Travel Commission & Tourism Economics [50] notes that while Romania holds a competitive advantage in balneological tourism, underdeveloped infrastructure and lack of digital marketing strategies hinder international expansion.

Each of these clusters plays a critical role in shaping Romania's bioeconomy, being aligned with Romania's National Sustainability Strategy [51] and with Romania's National Circular Economy Plan [52]. However, their future growth depends on policy alignment, financial sustainability, and enhanced intra-cluster cooperation. Strengthening regulatory frameworks, facilitating investment in sustainable practices, and fostering cross-sector collaboration are crucial for ensuring the resilience and global competitiveness of these clusters.

These insights align with broader concerns raised by Craiut et al. [53], who argue that Romania's technology transfer system remains fragmented and lacks strong intermediaries to connect research, industry, and policy. In contrast, the bioclusters examined here—through collaborative projects, incubation programs, and regional partnerships—offer practical examples of how these gaps can be addressed. By creating platforms for innovation and exchange, they show how place-based ecosystems can help turn sustainability goals into actionable outcomes.

Western European bioclusters offer useful reference points for Romania's evolving bioeconomy landscape. Szarka and Kittler [54] describe how transnational initiatives like 3Bi and BIG-C connect regions across Germany, France, Belgium, and the Netherlands, fostering shared infrastructure and joint innovation agendas. Kirchgeorg [55] similarly highlights how the Bioeconomy Cluster Central Germany leverages smart specialization and structured governance to build competitive, cross-sector value chains. Stegmann et al. [56] add that while many clusters are advancing circular principles—such as biorefineries and resource-efficient biomass use—challenges remain in fully integrating cascading use and product design for circularity. Together, these examples underscore that biocluster success relies not only on innovation and funding, but also on long-term coordination, inclusive governance, and commitment to systemic circularity.

4.3. Challenges in Biocluster Development: Insights from Interviews

To assess the challenges and opportunities facing the five bioclusters, we conducted ten semi-structured interviews with cluster managers, SME representatives, policymakers, and funding institutions (see Table 1 in Section 3.3). Following thematic analysis in NVivo 15, three dominant categories emerged—(1) fragmented collaboration among SMEs, (2) over-reliance on EU funding, and (3) regulatory/administrative barriers—each of which relates to functions within the TIS framework [29] and the intermediary roles highlighted by Kivimaa [7].

4.3.1. Fragmented Collaboration Among SMEs

Seven out of ten interviewees explicitly cited fragmented collaboration as a pressing issue. Although bioclusters are designed to foster synergy, the P9 observed: "We only really cooperate when we go for EU calls; the rest of the time, each firm follows its own strategy". Meanwhile, the P5 (Cluster Manager) explained that smaller firms often worry about "larger players dominating decision-making", which inhibits open knowledge exchange. From a TIS perspective, insufficient collaboration reflects a gap in knowledge diffusion

and network formation—key functions that normally benefit from cluster intermediation. Lacking strong "organizational" intermediary support [7], SMEs fail to pool resources or leverage each other's expertise, thereby hampering innovative capacity.

4.3.2. Heavy Reliance on EU Funding

An equally prevalent theme—mentioned by eight participants—was the over-reliance on EU grants. While programs like Horizon Europe, Interreg, and COSME provide vital infusions of capital, the P6 noted: "There's a need for more diverse funding sources—not just from the EU, but also national, regional, and private. Otherwise, we risk building systems that only work as long as the funding lasts". Several respondents, including the P10 (Consultant), pointed out that national funding remains "sparse and unpredictable", while private investment is hindered by perceived risks in emerging bio-based technologies. In TIS terms, this indicates a shortfall in resource mobilization beyond project-driven mechanisms. Clusters might act as systemic intermediaries by lobbying for stable national co-financing programs or by cultivating investor networks to reduce this vulnerability.

4.3.3. Regulatory and Administrative Barriers

Six interviewees singled out regulatory complexity as a critical barrier, especially the misalignment between national legislation and EU-level directives. The need to simplify procedures was emphasized. The P1 (Cluster Manager) highlighted the challenge of demonstrating that legislation can be changed. Without clear policy signals, cluster members remain cautious about scaling up or adopting advanced technologies, as each shift can trigger unanticipated compliance hurdles. Such disparities hamper legitimation and guidance of the search [29], which are crucial for de-risking innovative bio-based solutions.

4.3.4. Connecting Insights to Eastern Europe's Bioeconomic Context

The challenges revealed by these interviews reflect broader structural and institutional constraints typical in Eastern European countries undergoing a shift from traditional industries to sustainable, knowledge-based models [57]. Limited domestic funding channels, persistent bureaucracy, and a less mature innovation culture complicate cluster-led transition. While triple-helix interactions [36] exist nominally, the synergy among universities, industry, and government is often constrained by fragmented policy frameworks and a low emphasis on commercializing R&D.

4.3.5. Strategies for Overcoming Challenges

Despite these hurdles, interviewees offered several potential solutions.

- Strengthening Cluster Intermediation: Many participants (e.g., P3, P8, P10) emphasized a need for centralized coordination that better aligns cluster goals with regional or national policy agendas;
- Diversifying Funding: Half the interviewees recommended encouraging private–public partnerships, venture capital, or regional funding schemes to reduce the dependence on EU project cycles;
- Deepening Cross-Cluster Collaboration: By broadening membership (to include AI and digital solution providers) and hosting joint training initiatives, clusters can enhance both organizational and systemic intermediary functions [7];
- Policy Advocacy: Some managers (P1, P4) called for a more formal policy role for clusters, possibly through regional committees or national councils, to ensure new regulations support eco-innovation.

In TIS language, these recommendations target the "Resource Mobilization", "Guidance of the Search", and "Legitimation" functions—aiming to reduce institutional friction and empower clusters as catalysts for sustainability.

4.3.6. Conclusion of Interview Findings

In summary, the interviews emphasize that fragmentation, funding vulnerability, and regulatory ambiguity hinder cluster development as intermediaries in Romania's circular bioeconomy. By expanding membership to emerging tech sectors and forging tighter public–private collaboration, clusters may improve their intermediary capacity to unify stakeholders, boost resource flows, and lobby for supportive regulations. These insights further confirm that organizational and systemic intermediation must work in tandem to navigate the unique institutional environment of Eastern Europe.

To visualize how these challenges manifest across the five bioclusters, the next subsection presents Table 5, offering a comparative overview of each cluster's membership, financing approaches, policy engagement level, and key obstacles—integrating the interview findings outlined here.

Table 5. Comparative overview of the five Romanian bioclusters.

Cluster	Sector and Focus	Total Members	Key Financing Sources	Core Activities /Projects	Policy Engagement	Interview-Based Challenges
Green Energy (established in 2011)	Bioenergy, Biomass Residues	80	EU Horizon, COSME, Interreg	BioVill, AgroBioHeat BioRural Greet CE thERBN	Medium (Local/regional partnerships)	- Underdeveloped biomass infrastructure - Reliance on project-based funding - Fragmented SME collaboration
AgroFood (established in 2011)	Sustainable Agriculture, Agro-Food	117	EU Horizon COSME, Interreg,	STRING, TRACE-KEI, CEE2ACT	Medium (Close ties with agri depts)	- Supply chain issues - High dependency on EU grants - Regulatory misalignments (food safety vs. sustainability)
ProWood (established in 2010)	Forestry, Wood Processing, Furniture	81	EU Horizon, COSME, Interreg national schemes	ROSEWOODFORESDA Smart Furniture BioWoodNet	Medium (Regional cross-border projects)	- Skilled labor shortage - Fluctuating timber market - Complex digital transformation
Textile (established in 2012)	Circular Textiles	47	EU projects, national schemes	Digital Textile Waste Reuse, EcoTex HoReCa	Low–Medium (Minimal direct policy input)	- High cost of eco-friendly materials - Limited consumer awareness - Slow adoption of certifications
Balneo (established in 2014)	Balneo-tourism	43	Interreg Europe, local, regional funds	InnovaSPA, Digital Mapping of Mineral Resources	Medium (Regional engagement)	- Outdated spa infrastructure - Seasonal demand fluctuations - Limited brand recognition

Source: Data compiled from official cluster documents, interviews (P1–P10), and direct observations (2025).

4.4. Cross-Cluster Comparison: Linking Documentary Evidence and Interview Insights

Having explored the individual clusters' characteristics (Section 4.2) and the overarching challenges identified through stakeholder interviews (Section 4.3), this subsection consolidates both documentary data and empirical insights into a comparative overview. Table 5 juxtaposes the five bioclusters' key attributes—such as membership, financing, policy engagement, and main challenges—alongside the recurrent themes that emerged from the interviews (e.g., fragmented collaboration, heavy reliance on EU funding, regulatory hurdles).

Key Observations and Transition to Future Prospects

Table 5 reveals both commonalities and differences among the five clusters. Combined with the insights from stakeholder interviews (Section 4.3), the analysis in Section 4.2 highlights recurring structural barriers to Romania's bioeconomy potential—namely insufficient cross-sector collaboration, excessive reliance on EU grants, and bureaucratic inefficiencies [58].

- Financing: All clusters depend heavily on EU-level funding (Horizon, COSME, Interreg), confirming interviewees' concerns (P2, P6) that such dependence undermines long-term sustainability. Although Green Energy and AgroFood show slightly more diverse financing, they still rely on project-based support.
- Innovation Activities: From bioenergy (Green Energy) to circular textiles (Textile), each cluster pursues distinct projects. Yet SMEs (P5, P7) described these efforts as "one-off" or "short-term", echoing the fragmentation theme in Section 4.3.
- Policy Engagement: Clusters' influence on regional or national policies stands at a medium level. While engagement exists, it remains limited in impact, pointing to the need for stronger, unified efforts. As the P3 remarked, for balneology, "legislative action—is essential". The P1 argued for adequate regulations in the bioenergy field.
- Key Challenges: Interviews underscore that infrastructure gaps, administrative hurdles, and unstable funding consistently hinder each cluster's intermediary capacity. For instance, Green Energy faces an inadequate biomass supply (P1), while Balneo struggles with outdated spa facilities (P3).

Viewed through the TIS lens [29], these findings suggest that Resource Mobilization and Guidance of the Search remain underdeveloped, limiting the scalability of eco-innovations. Clusters could strengthen their systemic intermediary role [7] by coordinating policy inputs, diversifying financial channels, and fostering cross-cluster synergies. Although each biocluster uniquely contributes to Romania's circular bioeconomy, shared structural weaknesses hamper long-term resilience.

Ultimately, these challenges reinforce the urgency for a national coordinating entity that aligns existing initiatives, promotes research–industry collaboration, and harmonizes policies with EU directives [49]. The next section (Section 5) builds on this comparative analysis to propose policy and managerial recommendations aimed at fortifying bioclusters' intermediary capacities and addressing the core barriers identified in the interviews.

4.5. Future Prospects: Establishing the National Bioeconomy Hub

4.5.1. Identifying Priorities for National Bioeconomic Integration

Building on the challenges identified in Sections 4.2 and 4.3—such as fragmented collaboration, dependence on EU project-based grants, and regulatory misalignments—there is growing consensus on the urgent need for a coordinated national strategy. According to the BIC Country Report [59], key national priorities for Romania's bioeconomy revolve around the following.

- Enhancing research and innovation in bio-based industries to boost EU-level competitiveness;
- Developing sustainable agricultural, forestry, and food-processing systems to optimize resource use;
- Stimulating cross-sectoral collaboration among industry clusters, academia, and public authorities;
- Fortifying regulatory frameworks that enable circular production models and low-carbon solutions.

Sector-specific gaps underscore this urgency: For instance, Green Energy grapples with underdeveloped biomass supply chains, while AgroFood struggles with supply chain inefficiencies and cost barriers. Meanwhile, ProWood contends with workforce retention and patchy sustainability policies, Textile battles high eco-material costs and slow certification uptake, and Balneo faces seasonal demand fluctuation and outdated infrastructure. Addressing these barriers requires a central coordinating mechanism that unifies stakeholder efforts, aligns policy instruments, and fosters deeper innovation partnerships [59].

4.5.2. Establishing a National Bioeconomic Integration

Recognizing the need for an integrated national platform, Romania has advanced the CEE2ACT project (Empowering Central and Eastern European countries to develop circular bioeconomy strategies), channeling EU funding to create the National Bioeconomy Hub (NBH). This newly established entity is envisioned as a dynamic coordination platform, linking the following.

- Government Institutions (e.g., the Ministries of Agriculture, Environment, and Research);
- Regional Development Agencies;
- Research and Academic Centers focused on bio-based R&D;
- Industry Clusters (Green Energy, AgroFood, ProWood, Textile, Balneo, as well as other bioeconomy-based clusters);
- Funding and Investment Bodies (public/private investors, venture capital);
- SMEs and other networks of bioeconomy actors (farmers, foresters, rural actors).

The core mission of the NBH is to drive Romania's transition toward a circular and knowledge-based bioeconomy by implementing targeted actions that include establishing public–private dialogue mechanisms to improve policy coherence and reduce bureaucratic barriers for bio-based businesses, organizing capacity-building programs and training workshops to enhance market readiness among SMEs, hosting networking events and promoting research collaborations to foster interdisciplinary innovation, and facilitating investments to attract both national and foreign capital for bioeconomy projects (Figure 4).

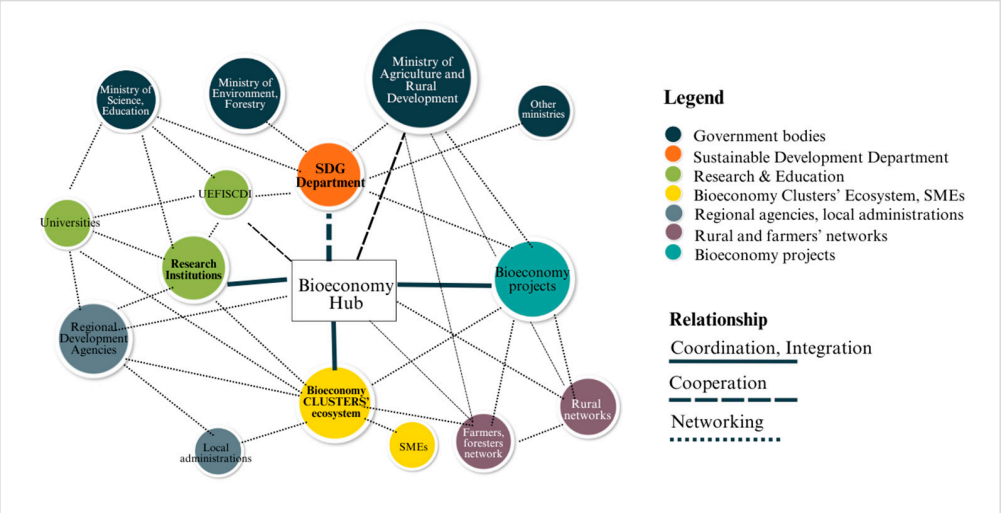

Figure 4. Bioeconomy Hub—ecosystem mapping. Source: Compiled by the authors.

By targeting the structural gaps identified across the five bioclusters, the NBH aims to unify local efforts under one strategic umbrella, amplifying Romania's integration into the EU bioeconomy ecosystem [59]. This approach aligns with the TIS principles, wherein a robust intermediary can bolster resource mobilization, legitimation, and collaborative learning—factors seen as critical for scaling circular bio-based ventures (Sections 4.2 and 4.3).

The establishment of the NBH represents a transformative milestone in Romania's sustainable development strategy, as it leverages EU funding, strategic partnerships, and cross-sectoral collaboration to serve as a catalyst for scaling bioeconomic initiatives, ensuring investment security, and enhancing the global competitiveness of Romanian bio-based industries. As the bioeconomy sector continues to expand, sustained commitment from government institutions, industry leaders, and research organizations will be essential for ensuring the long-term success of the hub. Looking ahead, the integration of Romanian bioclusters into EU-wide research consortia and international bioeconomy initiatives will play a critical role in securing Romania's position within the bio-based economy [59,60].

5. Conclusions

In conclusion, this study highlights the pivotal role played by Romania's bioeconomic clusters—spanning bioenergy, agro-food, forestry, textiles, and balneo-tourism—as intermediary organizations that connect SMEs, policymakers, and research institutions to foster circular bioeconomy innovation. By bridging sectoral gaps, these clusters facilitate knowledge exchange, financing opportunities, and policy support, thereby helping SMEs overcome structural challenges such as fragmented collaboration and over-dependence on EU grants. Nonetheless, the generalizability of our findings is constrained by the focus on five regional clusters and the predominantly qualitative methodology; additional research involving more regions and quantitative metrics could yield a fuller understanding of the clusters' long-term impact. The newly established National Bioeconomy Hub offers a promising avenue for unifying stakeholders across sectors and strengthening Romania's position in the broader European bioeconomy. Ultimately, sustained policy coordination, diversified funding strategies, and deepened collaboration between public and private actors will be crucial to ensuring that cluster-driven eco-innovations achieve meaningful scale and resilience.

This study is not without limitations. Its focus on a single biocluster ecosystem restricts the generalizability of the findings. Future research should incorporate comparative analyses across multiple European regions to identify common success factors and challenges. Incorporating quantitative assessments to measure economic, environmental, and social impacts—as well as adopting a longitudinal approach to track cluster evolution—would offer deeper insights into the long-term contributions and adaptability of bioclusters. Furthermore, exploring alternative governance models that enhance cluster intermediary functions could yield practical recommendations for designing more effective bioeconomy support mechanisms.

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Abbreviations

The following abbreviations are used in this manuscript:

SME	Small and Medium-sized Enterprises
TIS	Technological Innovation System
NBH	National Bioeconomy Hub

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