Accelerating circular bio-based solutions integration in European rural areas

Guidelines for future Bioeconomy research and policy

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Executive Summary

The transition to a sustainable, circular, and inclusive bioeconomy is a cornerstone of the European Union's Green Deal, Bioeconomy Strategy, and long-term rural development goals. Yet despite strong political momentum and increasing innovation across sectors, rural communities — which are central to the bioeconomy — continue to face systemic barriers that prevent them from fully engaging with and benefiting from this transition.

The BioRural project, funded under Horizon Europe, aimed to close this gap by promoting the widespread uptake of innovative, small-scale, and locally embedded bio-based solutions in rural areas. Through a combination of multi-actor engagement, success stories, surveys, national grassroots workshops, innovation challenges, knowledge exchange initiatives and the creation of the European Rural Bioeconomy Network (ERBN), BioRural has identified both the structural challenges and the most promising pathways to support rural bioeconomy development across Europe.

This deliverable synthesises the project's main policy insights and offers targeted policy briefs on over 20 key topics. These include enabling frameworks for smart farming, circular business models, modular biorefineries, bioenergy villages, and urban-rural resource loops, as well as system-wide recommendations to align funding, governance, and regulatory instruments such as the Common Agricultural Policy (CAP), Waste Directive, and Renewable Energy Directive (RED III).

Each policy brief is structured around:

- *A clearly defined challenge, grounded in real-world barriers and rural stakeholder input;*
- *Supporting evidence from EU-funded projects, regional case studies, and stakeholder consultations;*
- *Specific and actionable policy recommendations at both EU and Member State levels;*
- *Expected environmental, economic, and social impacts;*
- *Key future research needs to strengthen the evidence base and support policy innovation.*

The findings demonstrate that rural bioeconomy development is not constrained by a lack of innovation and can be supported by the right policies, governance and effective communication of solutions. Addressing these issues requires not only increased investment and coordination but a shift in perspective: from top-down industrial bioeconomy growth to territorially embedded, community-driven transformation.

By supporting cross-sector collaboration, reducing regulatory and administrative barriers, and aligning funding mechanisms with circular and inclusive innovation models, policymakers can unlock the full potential of rural Europe to lead the bioeconomy transition. BioRural presents a practical and coherent set of policy briefs in this deliverable to do just that — ensuring that the benefits of the green transition are not only technologically feasible but also socially and geographically equitable.

Based on the extensive evidence gathered through stakeholder surveys, expert interviews, national workshops, and the development of 23 targeted policy briefs outlined in this deliverable, the BioRural consortium also prepared a formal contribution to the European Commission's public consultation on the

revision of the EU Bioeconomy Strategy. This submission reflects the project's core findings and recommendations to support a more coherent, inclusive, and innovation-driven rural bioeconomy across Europe. The contribution was submitted to the Commission's "Have Your Say" portal. The full text of the submitted contribution is presented in Annex I of this report.

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1. Introduction

BioRural is a Horizon Europe Coordination and Support Action (CSA) project that aims to catalyse the necessary transition toward a circular and sustainable bioeconomy in rural Europe. Over its 36-month duration (Sept 2022–Aug 2025), BioRural facilitated a dynamic and inclusive exchange between diverse stakeholder groups—farmers, SMEs, researchers, policy actors, civil society, and innovators—through an intensive programme of co-creation and multi-actor engagement. At its core, the project recognises that unlocking the potential of rural bioeconomies is essential for achieving a green, resilient, and socially inclusive Europe.

This Deliverable consolidates the project's major policy outcomes and recommendations to guide national and EU-level decision-makers in strengthening enabling environments for the bioeconomy. These recommendations are grounded in robust evidence collected across a broad spectrum of activities: 43 national workshops, a pan-European innovation challenge, a dedicated Bioeconomy Conference, participation as an active member of the Rural Bioeconomy Alliance (RBA), and a targeted survey involving over 400 stakeholders across the rural innovation ecosystem. These actions enabled BioRural to identify barriers to circular bioeconomy development, identify successful bio-based practices, and highlight policy gaps at both regional and European levels. In addition, a cornerstone output of the project is the BioRural Toolkit—a curated, one-stop-shop online platform that aggregates tools, success stories, policy intelligence, and guidance to support stakeholders in adopting and scaling circular bioeconomy solutions. Together, these efforts inform the policy recommendations presented in this Deliverable, structured to support effective and inclusive policymaking.

The Deliverable is organised into the following sections:

- Chapter 1 – Introduction: Overview of the project's rationale, objectives, and methodology.
- Chapter 2 – Methodology: Description of the approach used to extract and synthesise policy-relevant insights from project activities.
- Chapter 3 – Key Results: Highlights of actionable findings and successful practices contributing to the policy recommendations.
- Chapter 4 – Policy Recommendations/Briefs: Targeted briefs outlining key recommendations, linked to specific challenges, gaps, and policy recommendations.
- Chapter 5 – Conclusions
- Chapter 6 – Annexes

This document aspires to equip policymakers, rural actors, and innovation intermediaries with the knowledge and tools necessary to accelerate Europe's transition toward a vibrant, inclusive, and circular rural bioeconomy.

2. Methodology for the integration of results

2.1 Process for the Integration of Results

BioRural is a Horizon Europe CSA project that adopts a multi-actor approach to foster the transition toward a sustainable, circular bioeconomy in rural areas. The methodology for deriving the policy recommendations and compiling them into accessible briefs was based on the systematic integration of outcomes across various project activities and work packages. The project applied a bottom-up, evidence-based process combining stakeholder engagement, analytical assessments, and innovation support tools at both national and EU levels.

The methodology consisted of the following core components:

1. Assessment of the Current Performance of the EU Rural Bioeconomy
   An extensive literature review and data analysis were conducted to evaluate the current status of the rural bioeconomy across the EU. This included mapping structural, technological, economic, and regulatory conditions in rural regions, along with the identification of major gaps, limitations, and opportunities for the uptake of bio-based innovations.

2. Identification of Factors Affecting Adoption and Diffusion of Bio-Based Solutions
   A targeted survey involving over 400 stakeholders (including farmers, SMEs, researchers, advisors, and policy actors) provided detailed insights into the factors influencing the adoption of bio-based solutions in different rural contexts. The survey results enabled the identification of key barriers (e.g. lack of awareness, insufficient financing, low perceived feasibility) and enablers (e.g. knowledge transfer, local networks, supportive policies).

3. Evaluation of Success Stories
   The project systematically identified and assessed 43+ rural bioeconomy success stories from across 12 EU countries. These included diverse types of initiatives—technological, social, and organisational—that successfully implemented bio-based solutions in real-world rural contexts. The success stories served as empirical reference points to understand the conditions under which barriers were overcome and innovations scaled.

4. Creation of the European Rural Bioeconomy Network (ERBN)
   A dedicated European Rural Bioeconomy Network was established to facilitate continuous dialogue and cooperation among key stakeholders. Through 43 national workshops, bilateral interviews, and regular engagement in the Rural Bioeconomy Alliance (RBA), the project built a common understanding of rural bioeconomy needs and co-developed potential policy directions.

5. Knowledge Exchange and Capacity Building
   43 national workshops were held that asked grassroots stakeholders to redesign linear value chains to circular value chains, this allowed the project to capture grassroots opinions on the barriers and potential solutions to circular bioeconomy development. In addition, a series of regional and EU-wide activities were held to promote mutual learning and co-creation. These included a EU-wide Challenge for Rural Bioeconomy Innovators, a Bioeconomy Conference, and transnational workshops, all of which helped validate policy gaps and collect stakeholder-driven policy suggestions.

6. Development of the BioRural Toolkit
   A central outcome was the BioRural Toolkit, an open-access online platform that consolidates success cases, technical solutions, policy references, financing options, and training resources. Offering a mix of different support such as videos, articles, academic approach papers, in order to reach a large panel of stakeholders.

2.2 Integration of Results into Policy Recommendations

The policy briefs presented in this Deliverable are the result of synthesising findings from the above activities. The process integrated:

- Quantitative and qualitative data from surveys and workshops;
- Learning from success stories and case studies;
- Thematic input from national and EU-level events;
- Feedback loops through stakeholder interactions in the ERBN;
- Practical knowledge embedded in the BioRural Toolkit content.

The identification of policy gaps and recommendations followed a triangulated process: comparing perceived needs from grassroots actors with institutional frameworks, identifying mismatches between solution maturity and policy readiness, and highlighting systemic enablers and blockers. BioRural consortium partners, with topic-specific expertise, took the lead in drafting specific policy briefs which then went through various rounds of revision and refinements.

The next chapter summarises the key findings from the project activities that underpinned this policy-oriented synthesis.

3. Key BioRural Results that feed into the Policy Briefs and Research Gaps

3.1 Assessment of the Current Performance of the EU Rural Bioeconomy

An extensive literature review and data analysis were conducted to evaluate the current status of the rural bioeconomy across the EU. This included mapping structural, technological, economic, and regulatory conditions in rural regions, along with the identification of major gaps, limitations, and opportunities for the uptake of bio-based innovations

This review highlights the critical role of the circular bioeconomy in delivering on the EU's long-term policy ambitions, including the European Green Deal, the Circular Economy Action Plan, and the Bioeconomy Strategy as well as supporting the EU's strategic autonomy and long term competitiveness. The circular bioeconomy, as understood in this context, merges the principles of biological resource use with those of circularity—creating regenerative, closed-loop systems that minimize waste, preserve natural capital, and promote rural economic resilience. However, the evidence shows that the transition to a circular bioeconomy is still in its early stages, and its strategic integration into policy frameworks remains inconsistent across Europe.

One of the central findings is that conceptual clarity is lacking in how the bioeconomy is defined and applied. The terms "bioeconomy," "bio-based economy," and "circular bioeconomy" are often used interchangeably, contributing to confusion among stakeholders and misalignment in policymaking. While the bioeconomy is frequently treated as a broad concept encompassing any economic activity involving biological resources, this generality can obscure important distinctions—particularly between linear and circular production models. Without clear framing, there is a risk that bioeconomy development continues along extractive, linear pathways. Therefore, embedding circularity as a defining feature of bioeconomy policy is critical to ensuring alignment with sustainability objectives.

Sustainable feedstock supply emerges as a foundational element in the circular bioeconomy. Current biomass systems face multiple pressures, including competition with food production, land use constraints, and environmental degradation. The analysis points to the need for diversified, sustainable biomass sources, including underutilised feedstocks such as perennial biomass crops (PBCs), algal feedstocks, agricultural residues, and urban biowaste. Perennial crops like miscanthus and switchgrass offer high yields on marginal lands and can contribute to both energy and material value chains. However, despite their potential, such feedstocks remain marginal in EU agriculture and policy support mechanisms. In addition, there is significant room for improvement in the valorisation of biowaste, with current recovery levels far below their potential—pointing to a need for investment in collection infrastructure and market development for secondary bio-based raw materials.

The development of biorefineries and bio-based industries is a second major pillar of the circular bioeconomy, with considerable opportunity for rural innovation and job creation. The EU already hosts over 800 biorefineries, but regional disparities persist, and many facilities are still oriented towards traditional bioenergy outputs rather than diversified, high-value biobased products. Advanced biorefineries, capable of processing multiple feedstocks and generating a range of outputs, are essential for achieving circularity. The findings highlight the importance of decentralised, small-to-medium-scale

facilities that align with local resource availability, as opposed to large-scale operations dependent on long-distance biomass transport—which may undermine circular economy principles.

Despite growing technological capacity, systemic barriers remain. These include gaps in logistics infrastructure, difficulties in scaling up bioconversion technologies, and limited market demand for bio-based products. Retrofitting existing industries to integrate biobased processing is often complex and costly. Furthermore, market acceptance of bio-based products is still underdeveloped, constrained by price competitiveness and low consumer awareness. These barriers underline the importance of a policy environment that supports innovation uptake, de-risks investment in new value chains, and raises awareness of the benefits of bio-based alternatives.

Encouragingly, the BioRural project identified over 30 promising small-scale, circular bio-based solutions already operating across Europe, documented in the BioRural Toolkit. These include innovators like Staramaki (natural wheat-stem straws), ALGEN (algae treatment of wastewater, producing versatile algae-based feedstocks), and NaturePlast (bioplastics such as bio-sourced and/or biodegradable polymers). Although often small in scale, such initiatives demonstrate high replicability and potential for regional adaptation. Scaling them requires targeted support, including access to finance, enabling regulation, and capacity building. Importantly, future policy should prioritise networks of localised production units that respond to local needs and resource availability, rather than centralised systems that risk losing sight of environmental and social sustainability.

Lastly, the discussion identifies important directions for future research and policy alignment. These include better understanding of adoption drivers and barriers, harmonising protocols for the classification and certification of bio-based products across Member States, and improving regional equity in bioeconomy development. A more nuanced and sector-specific policy framework—explicitly centred on circularity—would enable more effective measurement of progress and more tailored support for emerging value chains. The findings strongly suggest that a well-defined circular bioeconomy concept—supported by favourable demand trends, consistent policies, funding mechanisms, and regional strategies—can serve as a cornerstone of Europe's green transition, particularly in rural regions where bio-based resources and innovation potential converge.

3.2 Identification of Factors Affecting Adoption and Diffusion of Bio-Based Solutions

A targeted survey involving 422 rural stakeholders—including farmers, SMEs, researchers, advisors, and policy actors—alongside 46 expert interviews, provided detailed insights into the conditions influencing the adoption of small-scale bio-based solutions across rural Europe. Conducted across five key bioeconomy themes, the BioRural study identified critical barriers such as limited awareness, inadequate financing, and low perceived feasibility, as well as key enablers including effective knowledge transfer, strong local networks, and supportive policy frameworks. Together, these findings form a robust evidence base for designing targeted policy interventions to foster innovation, uptake, and scale-up in diverse rural contexts.

A consistent message emerging from the surveys is that the adoption of bio-based solutions is significantly more successful when supported by multi-stakeholder collaboration. End-users who work closely with advisors, researchers, customers, and suppliers tend to adopt solutions that are not only technically sound

but also contextually relevant and socially accepted. Experts highlighted the importance of involving agricultural and scientific advisors at the early stages of solution design, emphasizing that co-creation, peer learning, and knowledge exchange mechanisms greatly enhance sustainability, replicability, and long-term success.

While economic incentives—such as cost savings or improved product functionality—are the leading motivators for end-users to adopt innovative bio-based practices, the surveys showed that financial drivers alone are insufficient. Experts stressed the importance of complementary non-financial incentives, including trusted advisory services, demonstration projects, peer-to-peer exchanges, and opportunities for knowledge sharing. These are especially critical in lower-capacity rural regions where financial support must be matched with confidence, awareness, and local examples of success.

Respondents identified several common barriers to adoption, chief among them being lack of access to capital, complexity or inadequacy of regulations, and insufficient technical skills or advisory support. Importantly, both adopters and non-adopters face different obstacles depending on their regional and sectoral context. This underscores the need for tailored policy approaches that consider local realities and differentiate between stakeholder types—particularly between adopters seeking scale and non-adopters requiring foundational support.

Survey outputs also highlighted the role of demand-side dynamics. End-users pointed to supplier and customer demand as a major driver of adoption, often superseding public incentives. Experts echoed this, calling for stronger downstream demand for sustainable bio-based products through tools such as green public procurement, sustainability labels, and consumer education campaigns. Stimulating this kind of market pull is key to creating viable business models in rural settings.

End-users expressed a clear preference for locally adapted solutions. Nearly four out of five respondents emphasized the need for small-scale technologies and practices that align with local feedstock availability, supply chain infrastructure, and community needs. This finding supports the broader argument that circular bioeconomy initiatives should be place-based, rather than dependent on large-scale systems or long-range biomass logistics that conflict with circularity principles.

Both expert and end-user surveys converged on a set of enabling conditions for accelerating small-scale bio-based innovation in rural areas. These include: the provision of targeted regulatory and economic support for producers and green industry transitions; sustained awareness and training initiatives focused on rural actors; incentives for consumers to adopt sustainable behaviours; and the strengthening of advisory and brokerage services to bridge the gap between available innovations and rural adopters. In particular, non-adopters expressed a need for tailored support mechanisms, simple access to advice, and confidence-building measures before considering uptake.

Finally, the evidence strongly suggests that uniform policy approaches will fall short in enabling a just and effective rural bioeconomy transition. Instead, successful policy must be locally grounded, stakeholder-specific, and multidimensional, combining direct financial support with ecosystem-level interventions such as capacity building, knowledge systems, regulation streamlining, and innovation-friendly procurement and market strategies.

3.3 Evaluation of Success Stories

As part of its efforts to support the European Rural Bioeconomy Network (ERBN), the project assessed 8 rural bioeconomy success stories drawn from across the EU. These stories highlight the practical experiences of entrepreneurs and organisations that have successfully translated bio-based innovations into functioning products and services across the five core bioeconomy themes. The objective of this analysis was not only to showcase inspirational examples, but to extract actionable insights from the innovation processes that can inform policy, replication, and scale-up across other rural regions.

The assessment revealed that successful bioeconomy initiatives consistently share six core characteristics, which together define a roadmap for the development of effective circular bio-based ventures. These include: (1) genuine and sustainable biomass management, (2) alignment with niche markets and specific value chains, (3) a focus on practical, tailor-made solutions, (4) implementation of an adaptive and sustainable growth strategy, (5) reliance on research and experimental pilots, and (6) strong collaboration with local stakeholders.

Across all successful cases considered , the use of sustainably managed local biomass emerged as a foundational principle. Rather than simply leveraging technological innovation, these cases demonstrate environmentally and socially grounded approaches to resource management. Local sourcing of raw materials and ecological stewardship are central to building both credibility and long-term resilience. Simultaneously, most of the success stories targeted underserved or niche markets, where competition is lower and solutions can be highly customised to user needs. This strategic positioning often enabled companies to reshape value chains and improve access to previously untapped markets.

Another recurring trait was the emphasis on practicality and localisation. The most effective innovations were those that addressed real and present challenges in their regions, offering solutions that could be easily adopted and integrated into existing workflows. This helped build trust and engagement with end-users. Equally important was the presence of an adaptive growth strategy—where companies were prepared to evolve their business models in response to changing regulations, consumer preferences, or environmental factors. This ability to remain flexible while keeping a strong sustainability focus proved essential for long-term success.

One of the clearest success factors identified was the early use of research and pilot testing. The featured companies did not leap directly into market-scale operations but instead built their offering through small-scale experimentation, iterative improvement, and evidence-based decision-making. This stepwise innovation process not only reduced risk but also increased credibility with customers and funders. Combined with strong engagement of **local actors—including municipalities, research centres, support organisations and civil society—**these pilots benefited from local expertise, trust, and co-ownership. Stakeholder collaboration was repeatedly shown to enhance problem-solving, unlock infrastructure, and improve access to regulatory, financial and market insights.

Collectively, these case studies demonstrate that successful circular bioeconomy initiatives are deeply embedded in their local contexts—economically, socially, and environmentally. They respond to regional challenges with rooted solutions and are supported by an ecosystem that values both traditional knowledge and new innovation. Importantly, this research suggests that the transition to a circular bioeconomy is not just a technological or commercial process, but one grounded in inclusive participation, long-term vision, and systemic alignment across policy, market, and community actors.

For policymakers, the success stories analysed provide a strong empirical basis for supporting purpose-driven, locally adapted business models. These models tend to operate in low-competition, high-impact spaces and thrive when given targeted support in the form of capacity building, regulatory clarity, financial tools, and infrastructure for piloting and collaboration. Facilitating such innovation ecosystems will be key to achieving a circular bioeconomy that is both scalable and socially equitable across Europe's diverse rural regions.

This assessment identified over 20 additional rural bioeconomy success stories across 12 EU countries, showcasing a range of technological, social, and organisational innovations successfully implemented in real-world rural contexts. Featured within the BioRural Toolkit, these case studies serve as empirical reference points to illustrate how key barriers were overcome and under what conditions bio-based innovations were able to scale.

3.4 Creation of the European Rural Bioeconomy Network (ERBN)

A central outcome of BioRural's network-building efforts is the establishment and rapid scaling of the European Rural Bioeconomy Network (ERBN)—a pan-European structure built on four Regional Rural Bioeconomy Platforms (RBPs). By month 36, BioRural had identified 1,212 key actors, with 36% actively participating in project activities and over 616 individuals formally joining ERBN through subscription via the BioRural Toolkit—well beyond the initial target of 280 members. ERBN success is built on high-quality engagement: 229 key actors now routinely collaborate on workshops, success story documentation, liaison with other projects, and event organization.

In the policy context, ERBN has functioned as more than a network—it serves as a strategic interface between grassroots actors and decision-makers. The network facilitates cross-country coordination and creates space for rural voices to influence policy design, through shared experiences and thematic input. BioRural's engagement within the Rural Bioeconomy Alliance (RBA) further enhanced this institutional relevance, linking ERBN with broader EU bioeconomy initiatives and ensuring alignment with flagship frameworks such as the Green Deal and the Circular Economy Action Plan.

ERBN also established structured collaboration with related EU and national bioeconomy projects and networks, including EU-Farmbook, modernAKIS, Tools4CAP, and the EU CAP Network. To be highlighted the agreement to connect BioRural toolkit with EU-Farmbook, which started with BioRural in 2025, and will be continued with the thematic network of thERBN project after BioRural finishes. From a strategic governance perspective, ERBN is designed to endure beyond the project lifespan. By embedding thematic boards (e.g. bioenergy, agroforestry, aquatic systems) within its governance structure and developing a participatory governance model via local and regional actors, ERBN is laying the groundwork for long-term sustainability and adaptability of the network.

Why these findings matter for policy:

- ERBN provides a scalable model for stakeholder-driven policy engagement—enabling rural sustainability pathways to be shaped directly by those who deliver them.
- The network demonstrates how structured regional platforms can support capacity building, policy uptake, and diffusion of innovation through sustained partnerships and digital infrastructure.

- By formalising liaison with key EU networks and projects, ERBN ensures continuity of knowledge flows and alignment between local practice and high-level policy instruments.

These insights highlight the potential of network-based governance as a policy instrument in its own right. ERBN exemplifies how multi-actor, cross-border structures can amplify the impact of rural bioeconomy initiatives and serve as a strategic lever for cross-sectoral, evidence-based policymaking.

3.5 Knowledge Exchange and Capacity Building Workshops

A series of national, regional and EU-wide activities were held to promote mutual learning and co-creation. These included 43 national workshops, regional and EU-wide Challenges for Rural Bioeconomy Innovators of which helped gather stakeholder policy insights and collect stakeholder-driven policy suggestions.

Policy and Regulatory Challenges Identified in BioRural National Workshops

The national workshops conducted under BioRural brought together a wide range of stakeholders and revealed persistent policy and regulatory challenges that are hindering the development and scaling of circular bioeconomy value chains. Participants consistently pointed to regulatory uncertainty, policy fragmentation, and technological gaps as barriers to innovation, investment, and implementation at the local and regional levels.

A key regulatory barrier repeatedly raised by stakeholders relates to the unclear classification of bio-based residues under existing EU waste legislation. Current interpretations of the EU Waste Framework Directive and End-of-Waste Criteria lack sufficient clarity regarding when biological residues can transition from being considered “waste” to being treated as valuable byproducts or secondary raw materials. This ambiguity discourages investment in circular processes, as companies are uncertain about the legal and economic feasibility of reusing materials. Participants strongly recommended clarifying and streamlining waste classification rules, including providing more practical and sector-specific criteria for determining end-of-waste status.

Another significant challenge is the inconsistency of policies across EU regions and sectors, which creates confusion and inefficiency for bio-based innovators. Diverging waste management standards, environmental regulations, and product certification procedures between Member States make it difficult to scale circular solutions or operate transnationally. For instance, stakeholders expressed frustration with how the REACH regulation treats bio-based and fossil-based chemicals identically, without acknowledging the often lower environmental footprint of the former. Such blanket regulatory approaches limit the competitiveness of bio-based alternatives and stifle innovation. The workshops revealed broad support for harmonized, cross-border policies and certification frameworks, especially for bio-based products and packaging materials.

A third recurring issue was the absence of EU-wide harmonized standards for bio-based products. Stakeholders noted that without such standards, it becomes difficult for bio-based producers to demonstrate environmental performance, achieve regulatory recognition, or compete on equal footing with fossil-based products. This lack of clarity was particularly problematic in sectors like food packaging and bioplastics. As a solution, participants advocated for EU-level standardization of sustainability criteria and performance benchmarks to help build trust, attract investment, and ease integration into established supply chains.

Additionally, existing agricultural and food safety regulations were identified as obstacles, especially when it comes to the use of agricultural residues in food-related or energy applications. While the Common Agricultural Policy (CAP) includes sustainability goals, some of its provisions were seen as restrictive, limiting the flexibility of farmers and businesses to valorise byproducts. Likewise, stringent health and safety rules from the European Food Safety Authority (EFSA) can complicate efforts to reuse food system waste. Workshop participants recommended greater regulatory flexibility in agriculture and food policy to unlock waste-to-product innovations, provided that food safety and environmental standards are maintained.

Beyond regulatory issues, the workshops highlighted that technological gaps remain a major bottleneck. Many regions lack the infrastructure and technology needed to process diverse biomass streams efficiently and cost-effectively. There is a clear need for further investment in R&D, particularly in the development of advanced biorefineries, residue valorisation processes, and scalable, modular bio-based processing systems. Stakeholders emphasized that EU funding mechanisms—such as Horizon Europe and the Bio-based Industries Joint Undertaking (BBI JU)—should continue to prioritise innovation that lowers costs and improves performance in these critical areas.

Finally, the workshops revealed strong support for the development of local bioeconomy hubs and regional clusters. Stakeholders recognised that high costs and logistical challenges associated with biomass collection and transport can be overcome through the geographic concentration of bio-based industries and the integration of complementary processing activities. These local clusters—featuring shared infrastructure, integrated biorefineries, and multi-sector partnerships—were seen as key to achieving economies of scale, improving logistics efficiency, and facilitating the circular use of residues. Such regional innovation ecosystems would also help rural areas capture more value from their natural resources while fostering job creation and cross-sector collaboration.

Taken together, the findings from the BioRural workshops clearly show that the transition to a circular bioeconomy requires an enabling regulatory environment, targeted investment in infrastructure and technology, and stronger regional coordination. Policy coherence at the EU level—especially in waste legislation, product certification, and support for local innovation ecosystems—will be crucial to unlocking the full potential of rural bio-based solutions.

3.6 Development of the BioRural Toolkit

A central outcome was the BioRural Toolkit, an open-access online platform that consolidates success cases, technical solutions, policy references, financing options, and training resources. Designed as a "one-stop-shop" for rural bioeconomy stakeholders, the toolkit supported the identification of high-potential interventions and informed the development of practical policy guidance.

Role of the BioRural Toolkit in Supporting the Circular Bioeconomy Transition

The BioRural Toolkit serves as a central pillar of the project’s knowledge infrastructure, functioning as a one-stop interactive repository designed to empower rural bioeconomy stakeholders across Europe. Hosted online and integrated with the European Rural Bioeconomy Network (ERBN), the Toolkit connects farmers, innovators, SMEs, policy actors, and researchers through shared resources, collaboration tools, and actionable insights.

The Toolkit's user-oriented design addresses multiple needs: it hosts factsheets summarising the bioeconomy status at EU, national, and regional level; a searchable inventory of research outputs, commercial bio-based solutions, and funding opportunities; and a curated collection of 30+ audio-visual success stories drawn from BioRural's thematic work, including Natureplast, Staramaki and ALGEN. These resources enable users to access practical case studies, evidence-based policy intelligence, and replicable business models in an easily digestible format.

Another key feature is the interactive network map, which allows registered stakeholders to locate, filter, and connect with partners across bioeconomy themes and EU regions. This strengthens cross-border cooperation and facilitates bottom-up innovation and consortium-building within the ERBN. The Toolkit also provides geospatial layers (e.g. biomass and waste potential) that help stakeholders assess resource availability and plan context-specific interventions.

In addition, the Toolkit hosts online tutorials, capacity-building recordings, practice abstracts, policy guidance, and business model blueprints tailored to each of the five bioeconomy themes: Food & Agriculture, Forestry & Natural Habitat, Aquatic Systems, Bioenergy, and Biochemicals & Biomaterials. These materials support stakeholder learning, project design, and uptake of circular solutions, bridging the gap between grassroots innovation and institutional policy frameworks.

Through its comprehensive offering, the BioRural facilitates knowledge exchange, fostering co-design, and accelerating innovation within rural bioeconomies. It delivers a practical and scalable infrastructure for evidence-driven policy design, stakeholder networking, and regionally adapted bio-based solution deployment.

4. Policy Briefs

Drawing from the key BioRural results outlined in the previously chapter, the following policy briefs represent the consortium's consolidated recommendations for supporting the development of a sustainable, inclusive, and innovation-driven rural bioeconomy across Europe. These briefs have been developed with input from project partners and external experts participating in various BioRural activities. They are grounded in the evidence gathered through surveys, stakeholder workshops, success story assessments, and thematic analyses.

Each policy brief follows a common structure:

- A clear articulation of the challenge, supported by evidence from the BioRural project and broader EU context
- A targeted set of policy recommendations, accompanied by their expected impacts
- A short section on future research needs to support implementation and fill knowledge gaps

To enhance clarity and usability, the policy briefs are organized into two main categories:

- Horizontal Policy Briefs
  These address cross-cutting recommendations that are relevant across the entire bioeconomy. They focus on systemic issues such as governance, funding, definitions, and coordination, and are primarily aimed at improving the coherence and strategic alignment of the EU Bioeconomy Strategy with other related frameworks (e.g., Green Deal, CAP, Circular Economy Action Plan).
- Sector-Specific Policy Briefs
  These focus on particular sectors or value chain segments within the bioeconomy—such as agriculture and food, forestry, aquatic resources, bioenergy, and biomaterials. They offer practical policy insights tailored to specific production systems, technologies, or thematic areas (e.g., biomass logistics, value chain integration, digital tools, market access).

Together, these policy briefs aim to support policymakers at EU, national, and regional levels in designing more coherent, innovation-enabling, and inclusive bioeconomy policies.

Based on the extensive evidence gathered through stakeholder surveys, expert interviews, national workshops, and the development of 23 targeted policy briefs outlined in this deliverable, the BioRural consortium also prepared a formal contribution to the European Commission's public consultation on the revision of the EU Bioeconomy Strategy. This submission reflects the project's core findings and recommendations to support a more coherent, inclusive, and innovation-driven rural bioeconomy across Europe. The contribution was submitted to the Commission's "Have Your Say" portal. The full text of the submitted contribution is presented in Annex I of this report.

4.1 Horizontal Policy Briefs

Policy Brief 1: Enhancing Policy Coherence Across Governance Levels to Accelerate the Circular Bioeconomy

Challenge

The success of the EU's transition to a circular bioeconomy relies on policy coherence across strategies, sectors, and governance levels. However, evidence from the BioRural project and stakeholder consultations across Europe highlights significant misalignments at different levels of governance that hinder effective implementation and the scaling of small-scale bio-based solutions in rural areas.

At the EU level, overlapping yet unaligned strategies may lead towards conflicting objectives between sectoral policies. The Bioeconomy Strategy promotes innovation and sustainability through biological resources, while the European Green Deal emphasizes reducing agrochemical inputs and achieving climate neutrality. For instance, the Green Deal's target to significantly reduce the use of pesticides may conflict with the Bioeconomy Strategy's emphasis on biotechnology innovation for crop resilience—highlighting a need for integrated planning.

Similarly, the EU's Vision for Agriculture and Food Systems places strong emphasis on food security and competitiveness, potentially clashing with bioeconomy goals centered on ecosystem restoration, carbon neutrality, or marginal land use for non-food biomass. Without coordinated prioritisation, strategies risk pulling in different directions.

Sectoral fragmentation also undermines synergies. The Circular Economy Action Plan focuses largely on manufacturing and waste, while the Bioeconomy Strategy is more agriculture- and biomass-oriented. Stakeholders from BioRural workshops noted missed opportunities in aligning agricultural side streams with broader circular value chains, due to siloed planning.

Further, funding misalignment between instruments such as the Common Agricultural Policy (CAP) and national innovation funds limits support for innovative, high-risk bio-based business models. In many Member States, CAP continues to fund conventional farming methods with limited incentives for circular or regenerative practices [1].

At the regional level, industrial and innovation policies are often working in silos and are often not harmonised with bioeconomy objectives, leading to uneven implementation. Some regions prioritise traditional industrial development over sustainable rural transitions. Administrative complexity—particularly the fragmentation of funding streams and overlapping regulatory obligations—adds an additional layer of friction, particularly for SMEs and rural actors without the capacity to navigate bureaucratic systems.

Policy Recommendations and Expected Impacts

- Strengthen cross-sectoral coordination body at the EU level (including Commission representatives from DG AGRI, DG CLIMA, DG RTD, DG GROW, and DG ENV), as well as at the Member State level, , alongside national and regional policy leads. The task force should regularly review and align key policy frameworks (e.g. CAP, Bioeconomy Strategy, Green Deal, Circular Economy Action Plan) to ensure coherence, consistency, and mutually reinforcing targets.

[1] European Court of Auditors. *Special Report No. 17/2023: Circular Economy – Slow Transition by Member States despite EU Action.* Luxembourg: European Court of Auditors, 2023. https://www.eca.europa.eu/ECAPublications/SR-2023-17/SR-2023-17_EN.pdf.

Expected Impact: Reduces regulatory conflict, improves strategic coherence, and enables joint interventions across sectors.

- Introduce Integrated Policy Programming at National and Regional Levels
  Support Member States in developing joint action plans that align the Bioeconomy Strategy with other strategies, such as the CAP Strategic Plans and Smart Specialisation Strategies (S3). This should include dedicated funding envelopes for cross-cutting bioeconomy initiatives.
  Example: Finland's Bioeconomy Strategy (2022) includes inter-ministerial steering and funding mechanisms aligned with national climate and circular economy goals.
  Expected Impact: Increases policy complementarity, maximizes funding efficiency, and accelerates deployment of cross-sectoral projects.
- Mandate Regional Policy Coherence Reviews in EU Programme Evaluations
  As part of the mid-term and ex-post evaluation of CAP and cohesion programmes, require a policy coherence assessment to identify misalignments and recommend adjustments to support bio-based transitions.
  Expected Impact: Identifies region-specific gaps and enables course correction to support more consistent national roll-out of circular bioeconomy actions.
- Align CAP and Innovation Funding through Bioeconomy Windows
  Encourage Member States to earmark dedicated CAP Pillar II funding and Horizon Europe missions (e.g. Soil, Climate-Neutral Cities) to small-scale, high-TRL rural bioeconomy solutions.
  Best Practice: Ireland's Bioeconomy Demonstration Initiative combines rural development and R&D funds to support place-based innovation hubs.
  Expected Impact: Directs public investment toward high-impact, scalable innovations in rural areas and supports SMEs.
- Streamline Administrative Processes through One-Stop-Shops
  Support the creation of regional bioeconomy one-stop-shops to coordinate permitting, access to funding, and regulatory guidance. These entities should consolidate services across multiple policy areas.
  Example: The Flemish "Green Deal" one-stop model supports agro-ecological transitions through consolidated advisory and administrative support.
  Expected Impact: Reduces administrative burden, accelerates project delivery, and increases SME participation.

Future Research Needs

To support improved policy coherence and unlock the full potential of the bioeconomy, further research should focus on:

- Effective models for policy integration, particularly institutional mechanisms that align environmental, agricultural, industrial, and innovation policies in support of bio-based transitions.
- Comparative regional studies examining where policy coherence has led to successful bioeconomy outcomes—helping identify transferable best practices and structural barriers.
- Optimisation of funding instruments, including how to better coordinate CAP, Horizon Europe, LIFE, and regional development funds to support high-impact, cross-sectoral initiatives.
- Administrative streamlining, with evidence-based proposals for reducing complexity in project implementation—especially for SMEs and multi-actor consortia.

- Impact frameworks that assess synergies and trade-offs between overlapping strategies (e.g. the Green Deal, CAP Strategic Plans, Bioeconomy Strategy), ensuring integrated approaches also deliver measurable outcomes at local and national levels.

Policy Brief 2: Harmonise classification and certification protocols for biobased products

Challenge

Despite the EU's ambition to lead in the global bioeconomy, the growth of bio-based product markets continues to be hindered by regulatory fragmentation and a lack of harmonisation in classification and certification. Stakeholders engaged through BioRural workshops and surveys consistently identified inconsistent definitions and diverging criteria as key barriers to market development and trust-building.

Currently, there is no universally accepted definition of what constitutes a "bio-based product" across EU Member States or sectors. Some national authorities and industry actors base definitions on carbon origin, others on lifecycle assessment or environmental impact, leading to considerable variation. In addition to lack of transparency and confusion among consumers, this definitional inconsistency obstructs effective policymaking, inhibits cross-border trade, and hampers the development of common sustainability benchmarks.

Similarly, classification protocols diverge across product categories and sectors — from packaging to textiles and construction — reducing transparency and making it harder for bio-based products to enter mainstream markets. In the absence of EU-wide criteria, certification schemes have proliferated independently. While well-intentioned, this patchwork of eco-labels has sown confusion among both producers and consumers. Many stakeholders, especially SMEs, face heavy administrative burdens in complying with multiple schemes, while consumers struggle to assess the credibility of claims. This creates space for greenwashing, undermining genuine innovation.

Market fragmentation is the end result. Without common classification and certification frameworks, producers cannot scale across EU markets, and consumers lack the trust and information needed to shift demand toward sustainable, circular products.

Policy Recommendations and Expected Impacts

- Adopt a Common EU Definition for Bio-based Products
  Develop and formalise a single, EU-wide definition for bio-based products, grounded in scientific evidence and developed in consultation with industry, certification bodies, and civil society. This would provide legal clarity, reduce regulatory overlap, and improve consistency across sectors.
- Standardise Classification Criteria Across Sectors
  Establish a harmonised classification framework that includes clear thresholds for biobased content, sustainability attributes, and lifecycle metrics. This framework should be adaptable to sector-specific contexts but rooted in shared principles, like those developed by CEN/TC 411 on bio-based products.
- Introduce EU-wide Certification Standards and Governance
  Promote a pan-European certification system for bio-based products, overseen by a single governing body (e.g. an ECHA or JRC-led platform), building on best practices from schemes such as the German DIN CERTCO or Italy's ReMade in Italy. Certification should be rigorous yet accessible, especially for SMEs.

- Combat Greenwashing through Stronger Verification Protocols
  Require third-party verification of environmental claims, with transparent criteria and auditing processes. Tie this to clear penalties for non-compliance, building consumer confidence and protecting the credibility of sustainable markets.
- Create a Unified Eco-labelling Scheme for Bio-based Products
  Develop a recognisable EU label — similar to the EU Ecolabel — for bio-based products, providing consumers with trustworthy, comparable, and easily interpretable information. Simplified, visual communication of biobased content and sustainability performance will drive more informed purchasing.

By implementing these measures, the EU can reduce administrative complexity, protect consumers, and unlock greater competitiveness and cohesion in the bio-based product sector.

Future Research Needs

- Best practices in standardisation: Identify successful national classification and certification systems and assess how they can inform an EU-wide framework.
- Consumer perception analysis: Understand how certification schemes and eco-labels affect purchasing decisions across EU markets, especially in low-awareness regions.
- Certification costs and barriers: Explore how to make verification schemes cost-effective and accessible, particularly for small-scale rural producers.
- Governance models: Examine options for managing and updating harmonised certification protocols at the EU level, including stakeholder involvement mechanisms.
- Prevention of greenwashing: Investigate enforcement mechanisms that balance legal certainty with flexibility for innovation, avoiding over-regulation while ensuring accountability.

Policy Brief 3: Develop (public) market information systems

Challenge

Accurate, accessible, and integrated market information is a cornerstone for scaling the rural bioeconomy in Europe. However, current data systems for biomass availability, by-product flows, and market dynamics remain fragmented and inconsistent, particularly at the regional and local levels. Stakeholder consultations held within the BioRural project, including national workshops and survey responses from over 400 stakeholders, highlighted this information gap as a critical bottleneck.

One major issue is the lack of reliable, standardized data on biomass availability — including primary production from agriculture and forestry, as well as secondary sources such as agri-food processing by-products and residues. Unlike in the waste management sector, where operators are required to report waste flows, there is no obligation to declare biomass by-products. As a result, these potentially valuable resources remain underutilized, and resource planning is hindered by uncertainty[2] .

The market remains highly fragmented, particularly for small-scale biomass providers and processors. These actors face systemic disadvantages due to limited access to pricing information, supply-demand forecasts, or opportunities for collaboration. Administrative barriers and technical complexity further compound the issue — for instance, the absence of harmonized standards for bioenergy systems and the complexity of certification and permitting procedures deter new entrants and raise transaction costs.
Digitalization presents a powerful lever, but current initiatives lack integration, interoperability, and a governance framework that ensures public benefit. A publicly managed, harmonised at EU level, if possible, biomass market information system would address these challenges, support efficient resource allocation, and empower rural actors to participate in the growing bioeconomy.

Policy Recommendations and Expected Impacts

- Introduce mandatory reporting of by-products in the biomass sector
  Establish legal obligations for biomass producers and processors to report by-product volumes and types, following the example of the EU's waste reporting framework. This will increase data transparency, improve traceability, and enable better resource planning.
- Create centralized, open-access databases on biomass availability
  Develop a Europe-wide, publicly accessible database that consolidates information from primary production, processing industries, and national inventories. Data should be standardized and geo-referenced to enable planning at the regional level. A case of good practice in this respect is Finland's BIOSAT tool, which integrates forest and agricultural biomass data at national level.
- Promote market integration through interoperable digital tools
  Invest in the development of interoperable digital platforms — either EU-led or supported via national Smart Specialisation Strategies — that allow stakeholders to share, visualize, and update biomass availability and demand data. This will improve coordination between sectors and reduce market inefficiencies.

[2] Caldeira, C., V. De Laurentiis, S. Corrado, F. van Holsteijn, and S. Sala. "Quantification of Food Waste per Product Group along the Food Supply Chain in the European Union: A Mass Flow Analysis." *Resources, Conservation and Recycling* 149 (2019): 479–488. https://doi.org/10.1016/j.resconrec.2019.06.011.

- Simplify administrative and technical procedures
  Align and standardize permitting, compliance, and technical requirements across Member States, especially for bio-based heat and energy systems. Streamlined procedures will accelerate deployment and reduce entry barriers for SMEs and community-based initiatives.
- Develop targeted support for small-scale operators
  Provide rural operators and cooperatives with access to training, digital tools, and tailored financial instruments to improve their ability to access markets and supply chains. For example, Germany's Bioeconomy Innovation Spaces provide technical assistance and matchmaking services to small bio-based businesses.
- Introduce digital passports for bio-based raw materials
  Pilot digital tracking tools that record sustainability attributes, traceability, and end-use potential of biomass. This will build confidence among industrial users and regulators, while simplifying compliance with environmental and social standards.
- Establish digital biomass trading platforms
  Support the creation of regionally embedded trading platforms that connect biomass providers with buyers in real time. These platforms should include logistics coordination, sustainability information, and automated contracting functionalities to reduce transaction costs and improve market liquidity.

By implementing these recommendations, the EU and Member States can unlock significant resource efficiencies, reduce barriers for rural actors, and support the transition toward a circular, inclusive bioeconomy.

Future Research Needs

- Data systems and integration: Research into scalable models for integrating biomass data from public, private, and academic sources, including remote sensing and farm-level data (eg. LPIS).
- By-product reporting: Pilot studies to test cost-effective, digital reporting systems for by-products at farm and processing levels, linked to regulatory oversight.
- Small-scale market access: Case studies examining what types of market information (price signals, demand forecasts, quality standards) are most valuable to small operators and how best to deliver them.
- Digital traceability systems: Feasibility studies on digital passports for bio-based materials, including blockchain or QR-based solutions and their uptake across different supply chains.
- Governance and interoperability: Research on the institutional frameworks needed to govern publicly managed biomass information systems, ensuring data quality, privacy, and interoperability across EU Member States.

Policy Brief 4: Integrating Rural Circular Bioeconomy Models into the EU Carbon Removal Certification Framework (CRCF)

Challenge

The EU Carbon Removal Certification Framework (CRCF), introduced under Regulation (EU) 2024/3012[3], is a key instrument for certifying high-quality carbon removals from activities such as carbon farming, soil management, and product-based carbon storage. However, many circular bioeconomy practices, particularly those rooted in small-scale, rural contexts—remain largely excluded or insufficiently supported by the current certification logic.

Practices such as composting, residue valorisation, short-rotation coppicing, and agroecological soil restoration often deliver measurable climate and environmental benefits yet face major barriers to CRCF integration. The current methodologies emphasize permanence, intensive Monitoring, Reporting, and Verification (MRV), and scalability—criteria that are not well-suited to regionally embedded and biologically complex systems typical of the rural circular bioeconomy.

BioRural's findings from stakeholder consultations and national workshops confirm these challenges, especially for smallholders and cooperatives operating at the margins of carbon markets. In many cases, participants reported that high upfront costs, lack of technical capacity, and limited verifier availability prevent their participation in CRCF-aligned initiatives. Furthermore, the CRCF does not yet accommodate non-soil carbon storage in long-lived biobased materials—excluding innovative value chains and products with real mitigation potential.

Key constraints include:

- Biophysical complexity in measuring carbon changes in soils with high spatial and temporal variability.
- Administrative burden for smallholders with limited capacity to meet complex MRV obligations.
- High transaction costs for third-party verification, often unaffordable without financial support.
- Lack of policy coherence, particularly with CAP Strategic Plans, which rarely align support for CRCF-aligned carbon farmingClick or tap here to enter text..
- Missing recognition of carbon stored in bio-based products and materials, despite their relevance in rural innovation.

Without reform, the CRCF risks reinforcing centralised, large-scale carbon removal models and missing the opportunity to scale inclusive, circular, rural climate solutions.

Policy Recommendations and Expected Impacts

- Introduce tiered MRV protocols within the CRCF to accommodate low-input, small-scale systems. Use pre-approved default values or proxy indicators for practices like composting, short-rotation coppicing, and biochar application.

[3] European Union. *Regulation (EU) 2024/3012 of the European Parliament and of the Council of 27 November 2024 establishing a Union certification framework for permanent carbon removals, carbon farming and carbon storage in products.* OJ L 2024/3012, 6 Dec. 2024. https://data.europa.eu/eli/reg/2024/3012/oj.

Impact: Broadens CRCF accessibility, especially for smallholders and rural cooperatives; reduces administrative hurdles; encourages uptake of low-tech carbon farming models.

- Promote cooperative or regional certification schemes where farmers can share monitoring infrastructure and verification services. Support the creation of regional MRV platforms with digital tools and local outreach.
  Impact: Reduces per-farm certification costs, facilitates capacity building, and strengthens rural innovation ecosystems.

- Leverage CAP instruments to offer training, MRV guidance, and onboarding grants or vouchers for first-time CRCF participants, especially targeting remote and under-resourced areas.
  Impact: Increases participation in CRCF from rural and marginalised communities, strengthens the data base for future methodologies, and improves long-term engagement.

- Develop certification methodologies for carbon stored in long-lived biobased products (e.g. bio-based construction materials, wood-based textiles). Invest in material tracking systems to verify product lifecycle storage.
  Impact: Incentivizes innovation in rural biorefineries and material-based carbon sinks; stimulates rural industrial value chains aligned with net-zero goals.

Future Research Needs

- Develop reliable, cost-effective tools for measuring short-term and product-based carbon storage in rural settings. This should include hybrid systems that combine remote sensing with simple field-based assessments.

- Evaluate the effects of CRCF[4] adoption on rural economies, especially on farm income, access to finance, and attractiveness for youth and innovation actors. Include case studies of regions where carbon farming[5] has complemented local development.

- Test and scale low-cost digital MRV systems, including satellite data, administrative data, mobile apps, and blockchain tools suited for cooperative-level use. Explore their integration into regional MRV platforms.

[4] Carbon Market Watch. "Overview of the Carbon Removals and Carbon Farming Certification process." n.d. https://carbonmarketwatch.org/wp-content/uploads/2025/03/AGRI.pdf

[5] Weinreb-Willard, M. *Carbon Farming: Stakes, Issues and Alternatives*. Brussels: ARC2020, 2022. https://www.arc2020.eu/wp-content/uploads/2023/02/ARC2020_Carbon_Farming_Stakes_issues-and-alternatives.pdf.

Policy Brief 5: Embedding Circularity in Innovation: Making Circular Bioeconomy the Norm, Not the Exception

Challenge:

Despite growing policy momentum behind the circular bioeconomy, circularity is still not systematically embedded within innovation processes across Europe. Evidence from BioRural fieldwork, stakeholder engagement, and success stories demonstrates that new products and technologies are often designed without full consideration of their environmental footprint, end-of-life handling, or potential for reintegration into circular systems. Instead, innovation frequently prioritises short-term functionality, cost-effectiveness, or technological novelty—leaving circularity as an afterthought rather than a core design principle.

One key constraint is associated with additional costs. Innovators—particularly SMEs and rural entrepreneurs—often face pressure to minimise costs and bring products to market quickly ,[6]. The inclusion of circular design features typically requires additional research, materials, or testing, which may delay time-to-market and reduce short-term profitability. These disincentives are compounded by the absence of regulatory or financial mechanisms that reward circularity.

Another challenge is the fragmented nature of value chains[7] and innovation ecosystems. Circularity can rarely be achieved by a single actor or at a single stage—it requires coordination across stakeholders, from raw material suppliers and manufacturers to recyclers and end users. However, many innovation processes operate in silos, lacking the horizontal collaboration or infrastructure required to close material loops. Early-stage innovators often do not have the resources or networks to engage with downstream partners or consider end-of-life reuse.

Infrastructure limitations further restrict the ability to pilot circular solutions in real conditions. Access to shared demonstration facilities, such as biorefineries[8], pilot processing lines, or test farms, is often limited or concentrated in specific regions. Without opportunities to experiment and validate circular processes in real-world environments, many innovations remain linear by design. Finally, weak regulatory incentives and the absence of harmonised eco-labelling systems leave circular bioeconomy products at a competitive disadvantage—facing higher costs but without commensurate market recognition or reward.

Policy Recommendations

- Establish a standardised eco-labelling scheme for circular bioeconomy products to build market trust and offer innovators clear design benchmarks.
- Facilitate access to shared pilot and demonstration infrastructure, including test farms, regional labs, and mobile processing units, particularly in rural areas.

[6] Kircher, M. "Bioeconomy – Present Status and Future Needs of Industrial Value Chains." *New Biotechnology* 60 (2021): 96–104. https://doi.org/10.1016/j.nbt.2020.09.005.

[7] Piantoni, G., M. Arena, and G. Azzone. "Exploring How Different Innovation Ecosystems Create Shared Value: Insights from a Multiple Case Study Analysis." *European Journal of Innovation Management* 26, no. 7 (2023): 206–232. https://doi.org/10.1108/EJIM-09-2022-0495.

[8] Faulkner, J. P., E. Murphy, and M. Scott. "Downscaling EU Bioeconomy Policy for National Implementation." *Cleaner and Circular Bioeconomy* 9 (2024): 100121. https://doi.org/10.1016/j.clcb.2024.100121.

- Support the scale-up of circular innovations through dedicated EU funding streams, innovation vouchers, or green procurement guarantees.
- Bridge to ease collaborative projects between academics, tech centers, and industrials through joint funding, supportive structure as clusters.
- Introduce tax benefits or trade incentives for certified circular products, recognising their added environmental value and stimulating early market demand.

Expected Impacts

- Better use of raw materials and by-products will enhance the profitability of primary producers and reduce waste-related losses.
- Circular innovation will decrease resource intensity, lower emissions, and support regenerative agricultural and industrial systems.
- Farmers and rural innovators will gain recognition as sustainability leaders, improving the image of the bioeconomy and encouraging youth engagement.
- Broader adoption of circular design will drive digitalisation, biotech development, and more efficient, data-rich processes across value chains.

Future Research to Support the Recommendations and Impact

- Develop practical circularity assessment tools and early-stage screening methods for innovators to incorporate circularity in design and development phases.
- Investigate economic instruments—such as fiscal incentives or tax relief—for circular business models, with case studies from successful national pilots.
- Map regional disparities in pilot infrastructure access and identify priority investment zones to support rural innovation.
- Examine consumer and business attitudes toward circular products and labels to design communication strategies that increase market pull.
- Study mechanisms for value chain coordination and interoperability—digital platforms, governance models, and standards that enable circular practices across sectors.

Policy Brief 6: Support the Establishment of Local and Micro-Regional Biomass Storage and Logistics Centres to Enhance Supply Chain Efficiency and Sustainability

Challenge:

The lack of local infrastructure for collecting, storing, and valorising lignocellulosic biomass remains a major bottleneck in rural bioeconomy development. BioRural project findings confirm that a wide array of lignocellulose-rich biomass residues—such as garden trimmings, straw, husks, and pruning waste—are generated across diverse geographies and timeframes, yet their collection and consolidation are rarely coordinated or supported by appropriate logistics systems. In most regions, there are no intermediate depots or dedicated spaces for biomass storage, making it difficult for households, farmers, and public entities to safely and effectively manage these resources. The result is an inefficient and underutilised biomass flow, with significant volumes either improperly disposed of or burned[9] [10].

This fragmentation is exacerbated by misalignments between biomass generation and collection schedules. For example, seasonal pruning or storm damage often generates unexpected surges in biomass that municipal systems are not prepared to handle. In the absence of drop-off points or storage centres, this material is either left to decay, illegally burned, or collected with general waste—undermining both energy recovery and environmental goals.

At the regulatory level, biomass residues frequently fall into grey zones between agriculture, forestry, and waste regulation. These overlapping jurisdictions introduce uncertainty regarding transport permissions, classification standards, and end-use compliance. The absence of consistent legal definitions and transport documentation for different biomass types adds further complexity and raises transaction costs, especially for small operators. Without harmonised frameworks and infrastructure support, there is little incentive for private actors to invest in regional biomass trade or logistics hubs.

Establishing local or micro-regional Biomass Logistics and Trade Centres (BLTCs) could address these inefficiencies. Such centres[11] can act as aggregation points for biomass, offering storage, pre-processing, and quality control. When strategically located, they improve transport logistics, reduce illegal disposal, and enable year-round supply for decentralized energy production and circular material uses. However, without targeted policy support, the development of BLTCs will remain uneven and underexploited across Europe.

Policy Recommendations

- Support the development of local and micro-regional biomass logistics centres through rural development funds and public-private partnerships. These hubs should enable collection and storage of a wide range of residues including straw, pruning biomass, shells, and woodchips.

[9] Elbersen, W., et al. *To Be or Not to Be a Biobased Commodity: Assessing Requirements and Candidates for Lignocellulosic-Based Commodities.* Wageningen: Wageningen Food & Biobased Research, 2022. https://research.wur.nl/en/publications/to-be-or-not-to-be-a-biobased-commodity-assessing-requirements-an.

[10] Khawaja, C., and R. Janssen. *Sustainable Supply of Non-Food Biomass for a Resource-Efficient Bioeconomy: A Review Paper on the State-of-the-Art.* S2Biom, 2014. https://www.s2biom.eu/images/Publications/S2biom_review_state-of_the_art_Final.pdf.

[11] AGROinLOG, "Demonstration of Innovative Integrated Biomass Logistics Centres for the Agro-industry Sector in Europe," 2016. https://cordis.europa.eu/project/id/727961.

- Repurpose disused public or agricultural infrastructure—such as former CAP warehouses or municipal lots—for biomass storage, ensuring they meet basic standards for accessibility, safety, and environmental compliance.
- Enable flexible public access to centres, allowing households, farmers, and municipalities to deliver biomass beyond fixed collection days, especially after storms or seasonal surges.
- Invest in infrastructure such as covered depots, paved loading zones, weighbridges, moisture sensors, and secure fencing to ensure operational efficiency and quality control.
- Design behavioural and awareness incentives, including low-cost drop-off schemes and public information campaigns to discourage open burning and illegal disposal[12].
- Clarify and harmonize regulatory frameworks at national and EU levels to reduce legal ambiguity regarding biomass classification, transport, and valorisation. This includes:
    - A clear distinction between waste and secondary raw materials
    - Simplified transport permits for intra-regional biomass flows
    - Fast-track permitting for storage and logistics facilities
    - Alignment with RED III, Waste Framework Directive, and Circular Economy Action Plan

Expected Impacts

- Significant reduction in open biomass burning, which contributes to air pollution and wildfires. In countries like Portugal, open burning was linked to 26% of wildfire incidents in 2024. Improved collection and storage reduce environmental risks and contribute to climate and air quality goals.
- Improved feedstock quality and year-round supply for bioenergy plants and biorefineries. Supports substitution of fossil fuels and imported biomass with locally available resources.
- Job creation in biomass collection, processing, and logistics, particularly through cooperatives or SMEs. Offers new revenue streams for local actors.
- Enhanced citizen awareness and behaviour change around sustainable biomass use, aligned with EU waste and energy policy goals.

Future Research to Support the Recommendations and Impact

- Conduct feasibility studies[13] across different EU contexts to model investment, maintenance, and revenue scenarios for BLTCs in both high-density and remote rural settings.
- Evaluate environmental trade-offs between decentralized and centralized biomass supply models using comprehensive LCA methodologies that include transport emissions, storage losses, and energy recovery efficiency.

[12] Blair, D., P. Gagnon, and S. Klain. *Biomass Supply and the Sustainable Development Goals.* IEA Bioenergy, 2021. https://www.ieabioenergy.com/wp-content/uploads/2021/10/IEA-Bioenergy-SDG-Case-Study-Report-FINAL.pdf

[13] SUCELLOG Project. *Triggering the Creation of Biomass Logistic Centres by the Agro-Industry: Handbook for Agro-Industries Interested in Starting a New Activity as Biomass Logistic Centre: Carrying Out a Feasibility Study.* 2015

- Use GIS and spatial analysis tools to optimise siting of BLTCs based on local biomass availability, infrastructure access, and proximity to end users (e.g., heating plants, biogas units).
- Investigate the role of IoT, blockchain, and smart sensors in real-time biomass tracking, quality assurance, and logistics optimization, with pilot testing in rural areas.
- Assess public willingness to engage with decentralized biomass logistics systems. Identify effective incentives and communication strategies to increase voluntary participation and correct usage.

Policy Brief 7: Supportive framework for the development and operation of active and durable Rural Circular Bioeconomy Networks and Collaborative Schemes

Challenge: Weak Coordination and Limited Continuity Undermine Rural Bioeconomy Collaboration

The BioRural project has consistently highlighted that multi-stakeholder collaboration is essential for advancing a sustainable and circular rural bioeconomy. Collaborative networks that bring together small and medium enterprises, research institutes, farmers, cooperatives, local governments, and NGOs can play a transformative role in addressing systemic barriers—ranging from high upfront investment costs to fragmented logistics and lack of know-how. Findings from BioRural deliverables such as the "Bio-based Solutions Innovation Report" (D3.3) and the stakeholder consultation summary (D1.2) underscore that collaborative platforms are not only valuable for pooling resources and sharing knowledge but also for enabling innovation, disseminating best practices, and improving access to financial and technical support.

Despite these benefits, durable and effective collaboration remains a challenge. Many networks in the rural bioeconomy landscape face issues related to fragmented participation, short lifespans, and limited inclusiveness. Several contributing factors have been identified: a lack of shared understanding of bioeconomy goals[14]; unwillingness to contribute financially; conflicting interests[15]; and the absence of facilitation mechanisms to manage co-creation and negotiation processes[16]. Top-down initiatives that fail to integrate regional and local perspectives often result in low stakeholder engagement, weak ownership, and uneven benefit distribution—particularly disadvantaging smallholders and grassroots organisations.

As a result of the above, several collaborative schemes currently rely on temporary project-based funding and ad hoc coordination efforts[17], leading to their discontinuation after a few years. Without stable financial and governance frameworks, they struggle to remain operational and meaningful. Over time, this erodes stakeholder trust, reduces continuity, and limits the capacity of such networks to influence broader policy or market transitions.

The European Rural Bioeconomy Network (ERBN), developed through BioRural, aims to address this fragmentation by offering a coordinated platform for rural actors across Europe. ERBN is built to encourage durable cooperation, grassroots involvement, and cross-sectoral integration. To succeed, however, initiatives like ERBN require a supportive policy environment that enables bottom-up collaboration, facilitates participation, and aligns with national and EU bioeconomy goals.

Policy Recommendations

- Develop EU guidance for collaborative rural bioeconomy schemes by creating official handbooks and best practice toolkits on how to establish, govern, and sustain networks and platforms.

[14] Szarka, Klaudia, et al. "Co-Design of Regional Bioeconomy Strategies." *Sustainability* 15, no. 8 (2023): 6967. https://doi.org/10.3390/su15086967.
[15] D'Amato, A, et al. "Knowledge Co-Production in Finland." *Forest Policy and Economics* (2022): 102820. https://doi.org/10.1016/j.forpol.2022.102820.
[16] Torre, A., et al. "PSDR Program in France." *Journal of Rural Studies* (2023). https://doi.org/10.1016/j.jrurstud.2022.12.034.
[17] Donner, M and Vries, H. "How to Innovate Business Models for a Circular Bio-Economy?" *Business Strategy & the Environment* (2021). https://doi.org/10.1002/bse.2725.

Guidance should cover scheme typologies, actor mapping, management structures, impact KPIs, and cross-sector cooperation methods.

- Integrate active networks into national and EU bioeconomy strategies as formal stakeholders in both design and implementation phases. Assign advisory or operational roles to existing clusters and promote cross-regional partnerships between similar networks.
- Introduce support measures at national and regional levels to ensure networks are resilient and effective, including:
    - Blended financing options combining grants, equity, and revolving funds
    - Provision of physical and digital infrastructure for coordination hubs
    - Dedicated technical assistance units to help navigate regulatory and bureaucratic complexity
- Establish action plans for inclusive engagement using participatory tools such as local focus groups and citizen panels, cross-regional events and exchange programs, community-led development strategies (e.g., LEADER), third-party mediators and mentoring schemes to build capacity and resolve conflicts

Expected Impacts

- Strengthen the establishment of resilient, long-lasting, and participatory networks that consolidate knowledge and actively accelerate the adoption of circular rural bioeconomy solutions.
- Foster trust and community among stakeholders, catalysing new partnerships and co-designed innovations adapted to local conditions.
- Ensure balanced participation across different types of stakeholders, geographic areas, and sectors, mitigating power asymmetries and supporting social equity in the bioeconomy transition.

Future Research to Support the Recommendations and Impact

- Comparative governance analysis across different collaborative models (e.g., cooperatives, clusters, digital platforms) to identify what makes some networks more sustainable and impactful than others. Contextual variables such as institutional frameworks and cultural factors should be considered.
- Development of robust monitoring and evaluation tools to track the added value, longevity, and systemic impact of bioeconomy networks and partnerships—especially in rural settings.
- Research on conflict mediation and power asymmetries in co-creation environments. Understanding how conflicting interests are managed in practice can inform better design of facilitation, decision-making, and benefit-sharing mechanisms within collaborative schemes.

Policy Brief 8: Enhance Education, Knowledge Transfer and Training Policies for Advancing Circular Rural Bioeconomy

Challenge

A successful transition to a circular rural bioeconomy (CB) hinges on a workforce that is not only technically competent but also capable of holistic systems thinking, entrepreneurial action, and innovation. The BioRural project, notably through its stakeholder mapping and thematic analyses (e.g., D1.2), has reinforced that education, training, and knowledge transfer are critical enablers for widespread uptake of bio-based solutions in rural contexts. Modern participative approaches to knowledge sharing rely on integrating traditional ecological knowledge with emerging science and technology, requiring tailored learning systems that are both inclusive and adaptive[18].

However, several structural and content-related limitations persist across EU education and training frameworks, as outlined by relevant studies and reports[19]. Firstly, there is no consistent or standardised system for CB education. Curricula are often fragmented, outdated, or insufficiently tailored to real-world challenges. In many cases, courses remain discipline-specific or multidisciplinary at best, rarely embracing the transdisciplinary approaches needed to tackle circularity across value chains. Teaching methods often rely on passive learning through lectures, neglecting hands-on, experiential, or co-creative learning techniques critical for translating knowledge into practice[20].

Equally, current programs tend to overlook soft and transversal skills such as entrepreneurship, digital literacy, and stakeholder communication—skills increasingly demanded in dynamic bioeconomy markets[21]. Stakeholder collaboration is often weak, with minimal involvement of bioeconomy actors in curriculum development or delivery. As a result, gaps persist between skills supply and demand, particularly in new and hybrid job profiles relevant to CB value chains[22].

Rural areas face additional disadvantages. Training opportunities are often geographically inaccessible, poorly promoted, or unaffordable for small-scale operators. Local initiatives often lack support to offer flexible, context-specific learning experiences or informal training formats such as peer-to-peer exchange and community-led learning[23]. The consequence is a widening skills and participation gap between urban and rural stakeholders, which ultimately hampers inclusive and competitive bioeconomy development.

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[18] Jack, C., A. H. Adenuga, A. Ashfield, and M. Wallace. "Investigating the Drivers of Farmers' Engagement in a Participatory Extension Programme: The Case of Northern Ireland Business Development Groups." *Sustainability* 12, no. 11 (2020): 4510. https://doi.org/10.3390/su12114510.

[19] Global Bioeconomy Summit. *How to Shape Education for a Sustainable Circular Bioeconomy?* 2020. https://gbs2020.net/wp-content/uploads/2021/03/Report_Workshop_education_GBS2020.pdf.

[20] Organisation for Economic Co-operation and Development (OECD). *Fostering Green Growth in Agriculture: The Role of Training, Advisory Services and Extension Initiatives.* 2015. https://doi.org/10.1787/9789264232198-en.

[21] Fasolino, M., G. Zavalloni, and D. Viaggi. "The Role of Collaboration and Entrepreneurship in Strengthening the Participation of Primary Producers in the Bioeconomy." *[Book/Proceeding Title]* (2023). https://doi.org/10.1016/B978-0-323-90569-5.00013-5.

[22] Paris, B. et al. "Current Practices of Bioeconomy Education and Training in the EU." *Sustainability* 15 (2023). https://doi.org/10.3390/su15020954.

[23] European Court of Auditors. The EU Priority of Promoting a Knowledge-Based Rural Economy Has Been Affected by Poor Management of Knowledge-Transfer and Advisory Measures. Special Report No. 12/2015. Luxembourg: Publications Office of the European Union, 2015.

Policy Recommendations

- Mainstream Circular Bioeconomy (CB) across all levels of education, from primary schools to tertiary institutions, embedding practical, systems-based learning alongside theoretical knowledge. Promote creativity, experimentation, and project-based learning.
- Develop harmonised standards for accredited CB higher education programmes, ensuring they incorporate:
    - Interdisciplinary and transdisciplinary curricula rooted in circularity, sustainability, and innovation.
    - Dual and work-based learning pathways linked to emerging bioeconomy sectors.
    - Modules to develop transversal skills, digital competencies, and entrepreneurial mindsets.
    - Agile course structures that can rapidly adapt to technological and market changes.
- Modernise Vocational Education and Training (VET) and continuous VET (CVET) by co-designing curricula with CB industry, R&D actors, and rural stakeholders. Promote modular formats and issue micro-credentials to support flexible, stackable learning for adults and professionals.
- Establish regional bioeconomy learning strategies, tailored to local sectoral strengths and needs. These strategies should:
    - Facilitate peer-learning, informal training networks, and co-creation hubs at local level.
    - Engage local authorities, SMEs, civil society, and education providers in joint curriculum planning.
    - Offer incentives—such as training vouchers, subsidies, or tax breaks—for participation in rural training schemes, especially by smallholders or marginalised groups.
- Integrate education and training into national and regional bioeconomy strategies, setting clear targets and indicators for workforce development, lifelong learning access, and knowledge diffusion.

Expected Impacts

- A better-prepared workforce, equipped with a combination of technical, entrepreneurial, and systems-thinking skills to respond to evolving bioeconomy challenges.
- Faster innovation and stronger knowledge transfer, facilitated by deeper integration between academia, industry, and local communities, translating research into market-ready and socially acceptable bio-based solutions.
- More inclusive rural development, through expanded access to training and education for underserved areas, women, youth, and other underrepresented groups.
- Stronger economic resilience and regional competitiveness, enabled by a workforce that can create, scale, and sustain locally adapted circular bioeconomy value chains.

Future Research to Support the Recommendations and Impact

- Mapping of existing education and training initiatives in CB across the EU to identify strengths, gaps, and replicable models, particularly in rural contexts.
- Foresight studies on bioeconomy skills demand, aligned with sectoral innovation roadmaps and labor market data, to inform future curriculum development and workforce planning.
- Impact assessments of different pedagogical models, especially those using co-creation, peer-learning, or informal training in rural and low-tech settings.
- Evaluation of micro-credentialing and modular certification systems for their effectiveness in reaching diverse learner groups and supporting lifelong learning pathways in CB sectors.

Policy Brief 9: Advancing the Bioeconomy: Strengthening Competences, Applied Research, and Innovation through an Integrated AKIS Framework

Challenge:

Despite sharing sustainability objectives, key EU strategies such as the Bioeconomy Strategy, the European Green Deal, and the Farm to Fork Strategy often diverge in priorities. While the Bioeconomy Strategy supports advanced biotechnologies and valorisation of residues, the European Green Deal emphasizes input reduction and regulatory caution, particularly in areas like advanced biotechnologies. These misalignments cause policy and regulatory uncertainty, which delays innovation uptake and discourages stakeholder engagement.

A further layer of complexity arises in the alignment between the Bioeconomy Strategy and the emerging EU Vision for Agriculture and Food. While both aim to foster resilient food systems, the Vision often prioritizes productivity and food security, while the Bioeconomy Strategy puts stronger accent on increasing efficiency and reducing pressure on resources. This results in contradictions in resource allocation, and innovation priorities, especially at the regional level.

Fragmented policy implementation across sectors (e.g., agriculture, energy, waste) and governance levels further inhibits the integration of sustainable bio-based innovations. Funding schemes are often misaligned, favouring conventional approaches over circular, cross-sectoral solutions. Moreover, administrative burdens and siloed institutional frameworks prevent efficient collaboration and discourage participation, particularly from SMEs and local actors[24].

AKIS (Agricultural Knowledge and Innovation Systems) offers a practical governance solution to align strategies, foster collaboration between research, practice, and policy, and guide innovation processes. A robust, integrated AKIS can connect policy frameworks with applied research and innovation actors, ensuring that sustainability, competitiveness, and local value creation are pursued in tandem[25].

Policy Recommendations + Expected Impacts

- Establish a unified framework linking bioeconomy policies with the Green Deal, Circular Economy, and Farm to Fork strategies. National AKIS coordination bodies should oversee alignment.

  Impact: Reduced policy fragmentation and conflicting signals, resulting in improved stakeholder confidence and accelerated innovation uptake.

- Support regional and EU-wide innovation hubs within AKIS that connect agriculture, biotechnology, waste, and energy sectors.

  Impact: Strengthened cross-sector collaboration fosters resource efficiency, shared R&D, and development of integrated, high-impact solutions.

[24] Toptsidou, A., and K. Böhme. "Futures of Cohesion Policy: With or without you?" 2025. https://doi.org/10.1080/02513625.2025.2518862.

[25] Kurtsal, I., et al. "Education and Training in Agriculture and the Bioeconomy: Learning from each other." 2023. https://doi.org/10.1016/B978-0-323-90569-5.00002-0.

- Harmonize funding criteria across CAP, Horizon Europe, and regional programs to prioritize systemic and applied bioeconomy innovation.

  Impact: Greater access to funding for SMEs and research alliances; improved coordination and impact of public investment.

- Support regionally adapted bioeconomy strategies co-developed through AKIS platforms, twinning programs, and stakeholder engagement.

  Impact: Strengthened local ownership, effective policy implementation, and inclusive growth across EU territories.

- Introduce digital platforms and standardised templates for application, monitoring, and reporting. Involve end users in co-design of administrative tools.

  Impact: Reduced bureaucratic barriers for smaller organisations and enhanced accessibility for diverse innovation actors.

Future Research to Support the Recommendations and Impact

- Evaluate successful AKIS structures that bridge technical, environmental, and social knowledge domains to support cross-sector bioeconomy projects.
- Develop methods to assess the long-term environmental, social, and economic outcomes of AKIS-driven innovation, including adoption rates and system resilience.
- Improve real-time, disaggregated data for agriculture, forestry, waste, and bioenergy to guide evidence-based policymaking and funding priorities.
- Investigate administrative and structural barriers in current funding instruments, especially for SMEs, cooperatives, and early-stage projects in rural areas.
- Map coordination practices between regional, national, and EU bioeconomy strategies to identify enablers of effective multilevel governance.
- Use user-centred design methods to pilot streamlined grant procedures and digital tools that lower entry barriers for innovation actors.

Policy Brief 10: Boosting Rural Bioeconomy: Supporting Emerging Bio-Based Industries, Greening Traditional Sectors & Developing Regional Circular Bio Clusters

Challenge: Underutilised Potential of Bio-Based Industries in Rural Areas

The bioeconomy holds vast potential for addressing societal challenges such as food and energy security, climate change, and rural decline. Yet, in rural areas, bio-based industries continue to face major barriers. Despite representing a sector valued at €2.4 trillion (2019)[26], bioeconomy initiatives receive only 3% of CAP funding, with many EU countries lacking national strategies to guide their development. Traditional sectors like agriculture and forestry are often locked into outdated, resource-intensive models, with limited incentives or support to adopt greener and circular practices.

Compounding this is a structural mismatch in support mechanisms: emerging rural bio-based businesses face fierce competition from fossil-based incumbents, backed by mature infrastructure and economies of scale[27]. Without targeted policy action, investment in biorefineries, cascading biomass systems, and circular value chains remains limited, creating bottlenecks across the value chain—from raw biomass availability to processing and market access.

Environmental sustainability adds another layer of complexity. Expanding biomass use without careful planning risks land use conflicts, deforestation, and biodiversity loss[28]. Current policy emphasis on bioenergy, rather than high-value material uses, undermines efficiency and diverts resources from innovative, less land-intensive solutions[29]. At the same time, rural bio-based SMEs lack access to technical expertise, risk-sharing instruments, and market incentives needed to become competitive players in the transition to a circular bioeconomy.

To unlock this potential, policy must take a value-chain-wide perspective—coordinating action across sectors, boosting investment, and creating the enabling environment for regional bio-clusters rooted in sustainability and local benefit.

Policy Recommendations

- Increased financial and investment support through blended financing schemes combining public and private funding (e.g., match EAFRD with regional co-financing for pilot projects) and Loan guarantees and insurance schemes to de-risk market entry for SMEs, backed by successful examples highlighted in the BioRural Toolkit.
- Establish regional bioeconomy hubs for technology transfer (e.g., small-scale modular biorefining units), building on platforms like the European Rural Bioeconomy Network (ERBN).

[26] Circular Bioeconomy Monitoring Consortium (BIC). *European Bioeconomy in Figures, 2008–2019.* https://biconsortium.eu/sites/biconsortium.eu/files/publications/European-Bioeconomy-in-Figures-2008-2019.pdf.

[27] Philp, J. "The Bioeconomy, the Challenge of the Century for Policy Makers." *New Biotechnology* 40 (2018): [pages if available]. https://doi.org/10.1016/j.nbt.2017.04.004.

[28] Field, C. B., and K. J. Mach. "Rightsizing Carbon Dioxide Removal." *Science* 356, no. 6339 (2017): 706–707. https://doi.org/10.1126/science.aam9726

[29] Mandley, G., et al. "EU Bioenergy Development to 2050." *Renewable and Sustainable Energy Reviews* (2020): [page details if available]. https://doi.org/10.1016/j.rser.2020.109858.

- Integrate bioeconomy modules into agricultural vocational training across EU curricula by 2030, focusing on circular models and value-added product design.
- Designate rural bio-industrial zones with tax incentives and shared infrastructure to attract clustered enterprises.
- Mandate public procurement quotas (e.g., 30% bio-based sourcing in municipal materials by 2030) to build early demand and improve visibility.
- Ensure CAP Strategic Plan alignment with bioeconomy goals, allocating at least 15% of CAP funds to initiatives that retain rural value.
- Implement EU-wide certification schemes for biomass traceability and regulatory simplification across sectors.
- Require participatory biomass mapping at regional level, involving local producers in resource planning.
- Channel LEADER funds into local bioeconomy projects through multi-stakeholder governance structures.

Expected Impacts

- Multiplicative effects for rural/regional economies (VA, employment, jobs)in regions with bio-cluster infrastructure.
- Strengthened rural entrepreneurship and reduced dependency on biomass imports.
- Reduced emissions and pollution through circular biomass use and residue valorization.
- Improved biodiversity and land stewardship through integrated forestry and agriculture practices.
- Enhanced inclusion and skill development, particularly for youth and underrepresented groups.
- Slowed rural depopulation and revitalized community networks through inclusive innovation models.

Future Research to Support the Recommendations and Impact

- Develop KPIs and economic multipliers to measure job creation, GDP growth, and rural resilience.
- Study how bio-based industries can promote equity in rural employment and leadership.
- Improve access to spatial data on biomass availability, water, and soil health to support sustainable cluster development.
- Advance tools for assessing ecological thresholds and ensuring sustainable biomass sourcing in line with EU directives.
- Examine successful regional models to identify transferable practices and design robust stakeholder engagement strategies.
- Establish systems to track progress and adjust policies dynamically based on real-world evidence.

Policy Brief 11: Accelerating Circular Business Models in the EU: A Pathway to Sustainable Economic Growth

Challenge: Scaling Circular Business Models Amid Fragmentation and Inequality

The EU has positioned circular business models (CBMs) at the heart of its green transition, with frameworks such as the Circular Economy Action Plan, European Green Deal, and directives on waste and ecodesign providing strategic direction. However, despite strong policy ambition, the uptake and implementation of CBMs remain uneven across sectors and regions.

Key obstacles persist. Infrastructure gaps between member states create disparities in waste treatment and material recovery. SMEs, which make up over 99% of EU enterprises, struggle with the high upfront costs of transitioning to circular systems and face difficulties accessing targeted funding[30]. Regulatory inconsistencies across borders hinder economies of scale and innovation transfer, while consumer behaviour remains largely shaped by price sensitivity and convenience over sustainability considerations.

The fragmentation of innovation ecosystems further compounds these barriers. Technological solutions in design, recycling, and digital resource tracking exist but often remain locked in pilot stages due to lack of cross-sector collaboration and coordinated investment. Without decisive measures to close these structural gaps and provide supportive market conditions, the EU risks falling short of its circularity and climate targets.

Policy Recommendations + Expected Impacts

- Invest in recycling, remanufacturing, and reverse logistics infrastructure across all member states using instruments such as the *Recovery and Resilience Facility*.

  Impact: Reduces regional disparities, increases circular material flows, and supports a just transition across the single market.

- Deploy blended finance tools (e.g., grants, loan guarantees, tax incentives) and streamline access to *Horizon Europe* and *LIFE* funding for circular innovation.

  Impact: Increases SME participation in circular value chains and unlocks job creation in resource-efficient industries.

- Accelerate full implementation and enforcement of a revised *Waste Framework Directive* with common recycling definitions, labelling standards, and extended producer responsibility schemes.

  Impact: Establishes a level playing field for businesses and improves investor confidence.

- Launch coordinated EU-wide awareness campaigns and labelling systems (e.g., Digital Product Passport) that promote circular consumption.

[30] Dace, Elina, Alessandro Cascavilla, Marco Bianchi, Elisa Chioatto, Emy Zecca, Luana Ladu, and Gülşah Yilan. "Barriers to Transitioning to a Circular Bio-Based Economy: Findings from an Industrial Perspective." *Sustainable Production and Consumption* 48 (2024): 407-418. https://doi.org/10.1016/j.spc.2024.05.029.

Impact: Drives demand for circular products, empowers informed choices, and accelerates market transformation.

- Increase public investment in circular technologies through *Horizon Europe* and expand the *Circular Cities and Regions Initiative* to rural and peri-urban contexts.

  Impact: Advances scalable circular solutions, fosters interdisciplinary R&D, and bridges urban-rural innovation gaps.

Expected Impacts

- **Environmental**: Significant reduction in resource use, emissions, and landfill waste; improved circularity in key value chains (e.g., plastics, textiles, construction).
- **Economic**: The circular economy could generate billions in benefits by 2030; enhanced competitiveness and resilience of EU industries.
- **Social**: Large number of jobs in circular sectors by 2030; increased public engagement and equity in the green transition.

Future Research to Support the Recommendations and Impact

- Assess long-term cost-efficiency of circular value chains versus linear models, especially for SMEs and public procurement systems.
- Explore behavioural nudges, incentives, and trust-building mechanisms to shift consumption patterns across demographics and regions.
- Research on advanced recycling (chemical, enzymatic), biodegradable alternatives, and digital tracking tools (e.g., blockchain for material flows).
- Comparative analysis of national and regional circular economy policies to identify successful implementation models and areas for harmonization.
- Document and analyse case studies of successful cross-sector circular partnerships and their impact on innovation scaling.

4.2 Specific Policy Briefs

Policy Brief 12: Accelerating the Decarbonization of Forestry Sector Activities in the EU

Challenge:

Forests are central to the EU's climate strategy—acting both as carbon sinks and sources of renewable materials. Yet, paradoxically, forestry operations themselves remain largely dependent on fossil energy[31]. Mechanized harvesting, off-road transport, residue handling, and biomass processing are all significant contributors to the land-use sector's emissions footprint. Without targeted intervention, this undermines the sector's overall climate mitigation potential.

Despite the ambitions of the EU Green Deal and national forestry plans, most decarbonization policies overlook operational emissions from forest management. Logging and biomass transport machinery rely heavily on diesel, while slash burning and inefficient residue use release particulate matter and reduce soil carbon retention. Unlike other industrial sectors, forestry lacks targeted incentives or mandates for fuel switching or electrification.

Evidence from countries such as Finland and Austria shows that emission reductions of over 50% are possible through the adoption of alternative fuels (e.g., HVO, biomethane), electric and hybrid machinery, and digital optimization tools for precision forestry. These approaches not only reduce emissions but also improve soil protection, biodiversity outcomes, and long-term operational efficiency. However, the widespread deployment of such technologies is limited by a lack of aligned EU and national funding, infrastructure, and market signals.

Policy Recommendations + Expected Impacts

At the EU Level

- Integrate machinery electrification into *CAP Strategic Plans*, particularly for thinning, pruning, and forest logistics operations.
  Impact: Accelerates transition for small-scale operators and boosts emissions reductions at source.
- Create a dedicated instrument supporting pilots and scaling of renewable fuels, energy-efficient equipment, and precision forestry technologies.
  Impact: Encourages early adoption, de-risks innovation, and fosters supplier ecosystems.
- Introduce conditional sustainability benchmarks tied to actual GHG savings, fuel origin, and residue use efficiency.
  Impact: Aligns biomass use with net-zero targets, protecting carbon sinks and biodiversity.
- Lower excise taxes for verified renewable fuels used in forestry, while gradually increasing costs for fossil-based fuels.
  Impact: Creates a market incentive for clean fuel adoption and levels the playing field for sustainable operators.

[31] Samaras, C., and K. Zierock. "Off-Road Vehicles: A Comparison of Emissions with Those from Road Transport." *Science of the Total Environment* 169 (1995): [page numbers if available]. https://doi.org/10.1016/0048-9697(95)98123-Z.

- Align certification standards with the *Carbon Removal Certification Framework* (CRCF), covering all emissions sources across the forestry chain.
  Impact: Enhances traceability and market recognition for low-carbon wood and biomass products.

At the Member State Level

- Offer subsidies or climate bonuses for replacing diesel-powered machinery with electric or hybrid alternatives (e.g., forwarders, skidders, chippers).
  Impact: Stimulates equipment turnover and lowers emissions across terrain classes.
- Establish guaranteed purchase schemes or feed-in premiums for fuels derived from forest waste streams.
  Impact: Closes biomass loops and strengthens rural fuel autonomy.
- Provide tools and advisory services enabling operators to track, benchmark, and report operational emissions.
  Impact: Enhances transparency and empowers data-driven decarbonization planning.
- Support forestry schools, cooperatives, and extension services to cover fuel alternatives, electric machinery maintenance, and residue valorization.
  Impact: Builds workforce capacity and supports behavioural change across the sector.

Expected Impacts

- 30–60% GHG emissions reduction from forestry[32] operations by 2030 in early-adopting regions.
- Improved energy sovereignty in rural areas via local production and use of renewable fuels.
- Increased sustainability and market readiness of forest biomass[33] chains under climate certification regimes.
- Public health benefits from lower diesel particulate emissions and reduced slash burning.
- New green jobs in forest machinery maintenance, fuel logistics, and digital services.

Future Research to Support the Recommendations and Impact

- Comparative LCAs of fossil vs. renewable fuel use in forestry operations across different forest types and machinery classes.
- Assess the practical limits and cost-benefit of electrifying forestry equipment in diverse terrains and climatic conditions.
- Study adoption barriers and drivers among forest owners, contractors, and cooperatives—e.g., risk aversion, peer networks, financing access.

[32] Nebasifu, A. A., N. Pietarinen, A. Fridén, H. Ekström, T. T. Harrinkari, D. D'Amato, and N. Droste. "Forest Policy in Nordic Countries: Expert Opinions on Future Needs, Uncertainties, and Recommendations." *Trees, Forests and People* 16 (2024): 100582. https://doi.org/10.1016/j.tfp.2024.100582

[33] Routa, J., A. Asikainen, R. Björheden, L. Röser, and L. Prinz. "Forest Energy Procurement: State of the Art in Finland and Sweden." Wiley Interdisciplinary Reviews: Energy and Environment 4, no. 1 (2015): 26–40. https://doi.org/10.1002/wene.24.

- Examine how integrating operational decarbonization into biomass sustainability certification affects EU carbon accounting, forest health[34], and biodiversity.

[34] Nebasifu, A. A., N. Pietarinen, A. Fridén, H. Ekström, T. T. Harrinkari, D. D'Amato, and N. Droste. "Forest Policy in Nordic Countries: Expert Opinions on Future Needs, Uncertainties, and Recommendations." *Trees, Forests and People* 16 (2024): 100582. https://doi.org/10.1016/j.tfp.2024.100582

Policy Brief 13: Advancing Sustainable Fertilizer Use in Europe: Toward Policy Coherence and Organic Alternatives

Challenge

Fertilizers play a critical role in ensuring agricultural productivity across Europe; however, their widespread use is directly associated with a range of environmental challenges, including soil degradation[35], water pollution, and greenhouse gas emissions. Primarily, the excessive use of mineral (synthetic) fertilizers negatively impacts soil, leading to acidification, alkalinisation, and salinisation, all of which disrupt nutrient balance, harm beneficial microorganisms, and degrade soil structure and fertility. These chemical changes can reduce crop productivity and make soils increasingly dependent on synthetic inputs. At the same time, fertilizers can be washed into nearby water bodies, causing eutrophication—a process where excess nutrients lead to harmful algal blooms that deplete oxygen and damage aquatic ecosystems. Runoff can also contaminate groundwater with nitrate[36].

On the other hand, organic fertilizers are natural mineral-based products that supply essential nutrients to plants while helping reduce reliance on synthetic fertilizers. Waste biomass materials used as organic fertilizers include animal manure, crop residues, food waste, agro-industrial waste, green waste, sawdust and wood chips, slaughterhouse waste, and aquatic biomass such as seaweed and fish waste. They release nutrients slowly, supporting balanced plant growth and healthier soil over time. By feeding soil microbes, they improve soil structure and fertility. Rich in trace elements and considered eco-friendly, they offer a safer, more sustainable option than chemical fertilizers[37].

Regulation (EC) No 2003/2003, known as the Fertilisers Regulation, is a voluntary European directive that establishes rules for the marketing, labelling, and packaging of specific inorganic (mineral) fertilizers. It aims to ensure that only fertilizers meeting defined standards for composition, safety, and environmental impact can be freely traded across the European market, thereby reducing trade barriers and potential risks to public health and safety. However, the regulation applies only to a specific category of mineral fertilizers that comply with these criteria, excluding all other types of fertilising materials. Notably, organic fertilizers do not fall within the scope of this legislation and are therefore not regulated under this directive, highlighting a significant gap in the harmonised EU framework for fertilizer products.

National fertilizers are fertilizing products that are regulated individually by each EU Member State rather than under a unified EU framework. Each country sets its own rules for approving and marketing these products, resulting in significant variation across the EU. Some Member States have developed strict and detailed regulatory systems, similar to those used for plant protection products, while others operate more open markets with minimal oversight. The governance structures also vary, with some countries relying on a small number of policy officers, while others involve industry committees or standardisation bodies, which in some cases develop legally binding national standards.

[35] Food and Agriculture Organization (FAO). *Soil Pollution: A Hidden Reality.* Rome: FAO, 2020. https://www.fao.org/documents/card/en/c/I9183EN/

[36] World Health Organization (WHO). *Nitrate and Nitrite in Drinking-Water: Background Document for Development of WHO Guidelines for Drinking-Water Quality.* Geneva: WHO, 2016. https://cdn.who.int/media/docs/default-source/wash-documents/wash-chemicals/nitrate-nitrite-background-jan17.pdf?sfvrsn=1c1e1502_4

[37] Shaji, H., S. Chandran, and T. Mathew. "Organic Fertilizers as a Route to Controlled Release of Nutrients." In *Controlled Release Fertilizers for Sustainable Agriculture*, 2021. https://doi.org/10.1016/B978-0-12-819555-0.00013-3

Current fertilizer-related policies remain fragmented across EU Member States, lacking coherence and alignment with the EU's sustainability goals. At the same time, the uptake of organic and bio-based alternatives remains limited due to regulatory, economic, and technical barriers. Advancing sustainable fertilizer use in Europe requires harmonized policy frameworks and stronger support for the development, accessibility, and adoption of organic alternatives[38].

Policy Recommendations

- Expand the EU Fertilizer Regulation to include organic and waste-based fertilizers under harmonized standards, ensuring consistent safety, environmental and market guidelines across Member States.
- Introduce stricter nutrient application limits and farm-level nutrient management plans to prevent overuse of synthetic fertilizers and ensure inputs are matched to crop needs.
- Review the regulatory framework that hinders collective approaches to the cascading use of by-products and residues from primary agricultural production
- Promote sustainable fertilization by funding the use of organic fertilizers and enhancing farmer knowledge through targeted training and advisory support services.
- Increasing the support for research and innovation in the development and improvement of efficient, low-impact organic fertilizers.

Expected Impacts

- Expanding the regulation to include organic and waste-based fertilizers will ensure product safety, support environmental protection, and improve market access across the EU.
- Stricter nutrient application limits and farm-level planning will reduce fertilizer overuse, leading to healthier soils and less pollution of water bodies.
- Promoting sustainable fertilization through funding and farmer training will encourage widespread adoption of eco-friendly practices and improve long-term agricultural productivity.
- Increasing support for research and innovation in organic fertilizers will drive the development of more efficient, low-impact products that benefit both farmers and the environment.
- These actions will help reduce nitrate contamination in water sources, contributing to better public health and ecosystem balance.
- A stronger circular economy will emerge as demand for waste-based fertilizers grows, creating economic opportunities in recycling and bio-based industries.
- Harmonized policies will ease trade and compliance burdens for producers, supporting a more integrated and competitive EU fertilizer market.
- The overall approach supports the EU Green Deal by aligning agricultural practices with sustainability, climate, and biodiversity goals.

Future research to support the recommendations and impact

- More data is needed on the long-term impacts of organic and waste-based fertilizers on different soil types, crop yields, and ecosystem health across varied agro-climatic regions.
- There is limited comparative research on the nutrient release efficiency and environmental footprint of different types of organic fertilizers versus synthetic ones.

[38] European Parliament and Council of the European Union. *Regulation (EC) No 2003/2003 of 13 October 2003 Relating to Fertilisers.* Official Journal of the European Union, 2003. https://eurlex.europa.eu/eli/reg/2003/2003/oj/eng

- Further studies are required to evaluate the economic viability and scalability of organic fertilizer production from diverse waste biomass sources.
- Research is needed to assess how harmonised EU regulations would impact smaller producers and national markets, especially in countries with less developed regulatory systems.
- Better understanding is required of farmers' perceptions, barriers to adoption, and training needs related to sustainable fertilization practices.
- Long-term monitoring frameworks should be developed to track environmental outcomes, such as reductions in nutrient runoff, greenhouse gas emissions, and improvements in soil health.

Policy Brief 14: Smart Farming for optimised biomass production

Challenge

Biomass production and processing may affect the nature and environment of the surrounding area in an undesirable way. The activities imply Greenhouse Gas Emissions (GHG) in both direct and indirect ways. Direct implications derived from fossil fuel consumption for operation of machinery for the production and indirectly due to input of e.g. fertilizer, plant protection and the production of machines used.

Applying smart farming strategy can save cost, increase biomass production and quality. Moreover, there will be a potential for reduced GHG. Smart farming requires applying Precision Agriculture (PA) i.e. guidance technic, rote planning, data recording, decision making support etc. for optimal field operations ensuring less fuel consumption and overall reduction of inputs through site-specific application.

Smart farming and PA require knowledge to use high-tech equipment, both in terms of hardware and software. This may be challenging for the farmers. The necessary equipment used for smart farming and PA can be expensive and thus challenging for the biomass production economy. However, in some countries there exist support framework for such technologies and alternative to ownership by single farmer could be considered.

Below is a comprehensive set of policy recommendations and frameworks that government bodies, agricultural agencies, and stakeholders can consider to promote the adoption of smart farming practices specifically aimed at optimized biomass production. These policies focus on enabling technological innovation, enhancing farmers' capacity, and ensuring long-term environmental and economic sustainability.

Policy Recommendations

- Subsidies for supporting farmers to acquire technologies and machines needed for implementing smart farming and PA.
- Supporting schemes for farmers investment in precisions technique, e.g. fertilize spreaders and sprayers for graduated application of fertilizer and plant protection products according site specific need.
- Support the development and use of remote sensing technologies within field operations, e.g. use of field robots and drones
- Promote and simplify the concept of joint ownership or purchase of machines and equipment by a group of farmers or agricultural associations
- Extension services should be expanded and trained to provide recommendations and technical support to farmers applying smart farming and PA
- Decision support systems dedicated directly to optimized biomass production
- Support interdisciplinary research on advanced breeding, high-yield cultivars, and field trials integrating precision agriculture for different biomass feedstocks (e.g., grasses, woody crops).
- Create regional innovation hubs or demonstration farms focused on biomass crops, showcasing cutting-edge precision farming methods to local growers.
- Fund university–industry collaborations that develop practical, scalable tools (e.g., soil sensors, drone platforms) for real-world field conditions.

- Strengthen agricultural extension programs to incorporate precision agriculture modules and hands-on training for biomass crop management.

Expected Impacts

- Farmers using precision tools can lower input costs by applying fertilizers, pesticides, and water only where and when needed
- Reduce the negative environmental impact by reduced fertilizer losses and unnecessary use of plant protection products
- Decreased fuel consumption of agricultural machinery when field operations are following optimal routes.
- Improved productivity and biomass quality by optimized input of fertilizer, water and plant protection products.
- Remote sensing allows detailed field mapping to isolate areas of need
- Higher biomass yields and better crop quality often translate to improved market prices or contract terms for growers.
- Real-time monitoring of plant health and soil conditions enables timely interventions that reduce yield losses from pests, diseases, or nutrient deficiencies.
- Efficient biomass production can serve as a renewable energy source or feedstock, decreasing reliance on fossil fuels and lowering greenhouse gas emissions.

Future research to support the recommendations and impact

- Digital logistics management platforms integrating IoT, AI, and blockchain for real-time tracking, traceability, and efficiency
- Development projects that can improve the overall economy of local bio-based solutions through a focus on optimized logistics for all inputs and outputs, utilization of data/data management, quality assurance, etc.
- Utilization of side streams by setting up structure and platforms for information sharing, precise product specification, quality standards and documentation.
- Trials to explore how different precision inputs (fertilizers, irrigation levels) and harvest timings affect both yield and biomass quality metrics
- Development of open-source data standards, APIs, and protocols facilitating seamless data sharing among sensor networks, software platforms, and government databases.
- Interdisciplinary investigations into how precision biomass production can feed into local circular economies, reducing waste while generating secondary income streams.

Policy Brief 15: Unlocking the Potential of Promising Crop Types for Bioproducts in a Sustainable Bioeconomy

Challenge

Europe's transition to a sustainable, circular bioeconomy depends on scaling up new crop types for biobased products. This requires not only innovation in agriculture, but also market creation, long-term contracting, and active policy support to compete with cheap fossil alternatives.

In the transition to a circular bioeconomy, agriculture can provide renewable resources to replace fossil-based raw materials. However, current cropping systems remain focused on food, feed, and energy, limiting the supply of biomass for alternative bioproducts. Extending biomass production to areas with restricted potential for food production, such as degraded agricultural land, can serve as feedstock for biochemicals, fibres, and materials and is key to unlocking this potential.

Over the past decade, more than 100 crop species have been trialed in the Biobased Innovations Garden in Colijnsplaat (Zeeland, NL), coordinated by Delphy and Rusthoeve. These trials show that many crops are suitable for biobased production chains. Some crops are interesting due to specific molecules they contain—like sugar beet (glucose for ethanol), chicory (inulin/FOS), or castor bean and dandelion (for bio-nylon and rubber). These compounds can serve as building blocks for food, chemicals, or biofuels.

Beyond molecule extraction, the agricultural sector is also exploring whole-plant valorisation. After refining a crop for a specific compound, the remaining biomass often still has value—as animal bedding, bioenergy source, or even fertilizer to return nutrients to the soil, closing the loop. Miscanthus, for instance, is used in the paper industry where nearly the entire plant is processed.

A major opportunity lies in fibre crops. Depending on their properties, plant fibres can be used for applications such as paper, textiles, composites (e.g. in automotive), and building materials. The economic viability for farmers is a key consideration—known fibre crops like miscanthus, hemp, flax, and jute all require clear market pathways and profitability. The concept of the "value pyramid" helps clarify this: applications like textiles rank highest in value, followed by paper, with building materials at the lower end. Without sufficient value capture at farm level, adoption will stagnate.

A persistent barrier is the lack of local processing infrastructure. Fibre crops require specialized harvesting, retting, or refining steps. These facilities are often absent or too small-scale, making logistics inefficient. Additionally, the relatively high fixed costs of farming in the Netherlands may make low-margin crops better suited for production elsewhere in Europe.

Crucially, the success of new cropping systems depends on reliability across the entire value chain. Starting new crops requires investments in knowledge, machinery, and risk-bearing capacity. Without fair pricing, long-term agreements, and trust among stakeholders, farmers are unlikely to adopt new crops. This "learning cost" must be matched with strong incentives and stable market demand. Organising logistics and coordination is just as important as technical feasibility: both farmers and buyers need to be reliable partners in a value chain that is built for the long term.

Even when technical and agronomic feasibility is proven, biobased products often struggle to compete with fossil-based alternatives on price. Fossil raw materials remain widely available and artificially cheap, due in part to externalised environmental costs. This creates a distorted playing field, discouraging investment in bio-based alternatives. As a result, the key barrier is not agricultural production—but

market creation. Policy must address this imbalance by incentivizing the use of biobased alternatives and ensuring a stable market outlook.

Policy Recommendations

• Promote pilot supply chains: Support regional pilots that demonstrate end-to-end value chains—from crop production to product development.

• Encourage full-plant valorisation: Incentivize processing models that use both the primary and residual biomass fractions.

• Fund fibre crop development: Stimulate the cultivation and industrial use of fibre crops like hemp, flax, and miscanthus for paper, construction, and composites.

• Invest in biorefinery and fibre-processing infrastructure: Support scalable, regional facilities that enable processing of diverse biomass streams.

• Ensure farmer profitability: Embed economic models (e.g. value pyramid) into policy tools to promote high-value applications and fair grower returns.

• Support international coordination: Promote EU-level crop zoning and logistics strategies for crops with better cost-efficiency in specific regions.

• Provide transition subsidies: Offer financial support to farmers who introduce crops for biobased uses in rotation systems.

• Enable long-term contracting: Create policy conditions (e.g. guarantees, subsidies, or tax incentives) that stimulate long-term contracts between farmers and processors.

• Strengthen cross-sector collaboration: Foster partnerships between agriculture, industry, and research to co-develop crop-specific value chains.

• Support value chain coordination: Invest in independent facilitators or platforms to align logistics, pricing, and quality agreements between stakeholders.

• Stimulate demand for biobased products: Introduce procurement policies that prioritize bio-based content in public tenders, especially in construction, packaging, and infrastructure.

• Incorporate biobased crops into CAP measures: Use the Common Agricultural Policy (CAP/GLB) to support farmers growing crops for non-food, non-feed purposes.

• Enable carbon credit systems: Allow carbon sequestration or emission reduction from biobased production to be monetized through carbon markets.

• Level the playing field: Consider taxation or levies on fossil-based materials to make biobased alternatives more competitive.

Expected Impacts

• Increased crop diversity in agricultural systems, improving resilience and reducing monoculture risks.

• New income streams for farmers through access to emerging biobased markets.

• Greater biomass efficiency, using more of each plant and reducing waste.

• Lower GHG emissions through substitution of fossil-based materials and improved carbon sequestration.

• Boosted circularity by closing nutrient loops and using residual biomass as fertilizer or soil improver.

• Growth in regional biobased economies, especially in rural and underutilized areas.

• Improved competitiveness of EU agriculture by aligning crop production with high-value biobased markets.

Future research to support the recommendations and impact

• Agronomic studies on yield, soil impact, and pest resistance of fibre and molecule-producing crops.

• Techno-economic assessments of full-plant processing chains and multi-output biorefineries.

• Market analysis and consumer acceptance of bioproducts made from alternative crops.

• LCA studies comparing biobased and fossil-based value chains in terms of environmental impact.

• Crop breeding for improved fibre quality, yield stability, and molecule content under varying climates.

• Feasibility studies for processing infrastructure and regional logistic models across Europe.

Policy Brief 16:Empowering Rural Bioeconomy through Support for Small-Scale Modular Biorefineries

Challenge

Despite abundant biomass resources, rural regions across Europe remain underutilized in the bioeconomy transition. Large-scale biorefineries typically require centralized infrastructure and high feedstock volumes, making them unsuitable for decentralized rural settings. As a result, biomass residues from agriculture, forestry, and livestock often go unexploited—missing opportunities for local value creation and climate mitigation.

Small-scale modular biorefineries offer a promising, flexible alternative tailored to rural conditions. However, they face barriers such as limited financing, complex permitting, inconsistent policy support, and high technological risk. The EU Bioeconomy Strategy Progress Report (2022) highlights a lack of investment in decentralized systems, while real-world pilots—like those documented in BioRural—demonstrate that local innovation can deliver tangible benefits, including added value products, rural jobs, and GHG reductions. Yet, deployment remains limited due to gaps in market readiness, policy coherence, and cross-sector alignment.

Scaling modular biorefineries is not only a technical priority but a strategic opportunity to revitalize rural economies, retain youth, and decarbonize hard-to-electrify sectors through local energy and material systems.

Policy Recommendations

- Fund R&D for modular biorefinery processes that improve conversion efficiency and enable multiproduct outputs (e.g., biofuels, biochemicals, biochar).
- Support technology validation through pilots co-developed with local actors, as in BioRural's success cases.
- Deploy blended financing, loan guarantees, and green procurement targets to attract early-stage capital.
- Create stable demand through sustainability certifications and regional public procurement quotas.
- Streamline permitting for modular systems and clarify compliance pathways.
- Promote uniform biomass traceability and environmental accounting across EU regions.
- Support regional bioeconomy hubs (e.g., ERBN) offering technical assistance, training, and knowledge-sharing.
- Mandate stakeholder involvement from project design stages to ensure transparency and build trust.
- Prioritize facilities that valorize all process outputs (e.g., digestate, heat, biochar) and close loops locally.
- Encourage case-by-case evaluation using LCA to guide funding toward systems with optimal environmental returns.

Expected Impacts

- Reduced GHG emissions and avoided landfill through valorization of agricultural, forestry, and organic residues.
- Nutrient recycling (e.g., via digestate or biochar) to replace synthetic fertilizers.

- Decreased air and water pollution from better waste and emissions management.
- Adaptability to local feedstocks; energy versatility (biofuel, CHP, electricity).
- Lower logistics costs and emissions due to modular, localised design.
- Rural income diversification via energy sales, carbon credits, and product by-products.
- Job creation in installation, maintenance, and operations of small-scale systems.
- Improved rural energy resilience and autonomy.

Future Research Needs

- Flexible, cost-efficient technologies; simulate biomass flows and energy integration for modular systems.
- Explore innovative uses for fractions like lignin and wet organic residues.
- Include rural economic and social indicators in life cycle assessments.
- Investigate mechanisms to derisk investment and align incentives across EU/national frameworks.
- Use field data from real-world pilots to validate assumptions, guide scaling, and refine policy frameworks.

Policy Brief 17: Urban green residues: Wood, you waste it?

Challenge + Evidence Supporting the Challenge

The management of urban green residues—such as prunings and maintenance waste from parks and gardens—represents a largely untapped opportunity within the EU circular bioeconomy. Yet the current legal interpretation of *Directive 2008/98/EC* (the Waste Framework Directive), particularly Article 5, creates significant ambiguity regarding whether these residues can be considered by-products.

According to the Directive, by-products must originate as part of a *production process*. As a result, residues generated through *services* (e.g., landscaping and public maintenance) are excluded in some Member States, thereby defaulting to "waste" classification—even when they are harmless and highly reusable. This contradicts the waste hierarchy set out in Article 4, which prioritises *prevention* and *reuse* over disposal.

This legal ambiguity imposes disproportionate costs on municipalities, particularly in rural areas, which are required to pay for the disposal of biomass that could otherwise be transformed into valuable bioenergy or biomaterials. As confirmed by Eurostat, EU households produced 4.75 Mt of green and wood waste in 2022—much of it from municipal services. In Italy alone, approximately 1 Mt of such residues are generated annually, with an estimated disposal cost of €40–70 per ton. Unlocking the potential of these streams could save millions of euros, foster local value chains, and support rural employment.

Policy Recommendations

EU Level

- Amend Article 5(1)(c) of Directive 2008/98/EC to read:
  "the substance or object is produced as an integral part of a production process or a service"
  This small yet powerful amendment would explicitly allow harmless residues from public or private services—such as landscape maintenance—to qualify as by-products, enabling local circularity and preventing misclassification as waste.
- Clarify existing EU guidance to reinforce that service-derived biomass residues can meet by-product criteria when local reuse pathways are available. This interpretation already exists in the *Guidance on the interpretation of key provisions of Directive 2008/98/EC on waste* and should be standardised across Member States.

Member State Level

- Implement simplified permitting procedures for local SMEs and cooperatives handling non-hazardous green residues in accordance with by-product status.
- Support decentralised biomass valorisation through local or regional reuse schemes—especially in rural areas—linked to bioenergy and biomaterial markets.
- Promote knowledge exchange and capacity building for municipalities and local service providers to better understand legal pathways and reuse potential of urban green waste.

Expected Impacts

- Potential savings of over €5 million annually in Italy alone if just 10% of such waste is reused locally.
- Municipalities can redirect savings into improved landscape management, while enabling local SMEs to generate value from bio-based products (e.g. wood chips, compost, biofuels).
- Reduced emissions from transport and incineration, and increased prevention of fires and floods through more frequent and affordable green maintenance.
- Local job creation, particularly in rural areas, and greater participation of small enterprises in the bioeconomy through simplified regulatory access.

Future Research to Support the Recommendations and Impact

- Comparative studies are needed to examine how Member States interpret and apply Article 5(1)(c) of Directive 2008/98/EC, particularly regarding service-derived biomass. This would help identify inconsistencies, inform EU-level guidance updates, and propose best practices for integrating circular bioeconomy principles into waste legislation.
- Further research should assess the total volume and quality of urban green residues across the EU that could be valorised as by-products. Such data would support evidence-based policymaking, scenario modelling, and investment planning.
- Studies should evaluate how reclassifying green residues as by-products affects municipal budgets, SME participation, rural employment, and carbon emissions over time.
- Pilot projects could explore the technical and economic feasibility of mobile or small-scale treatment units for urban green residues (e.g., for chipping, pelletising, composting), including integration into local district heating or bio-based value chains.

Policy Brief 18: Encourage Investments in (Biomass-based) Bioenergy Villages

Challenge

The EU's clean energy transition—articulated through the Clean Energy for All Europeans package, the Renewable Energy Directives (RED II & RED III), and the European Green Deal—recognizes the critical role of energy communities in promoting decarbonization, resilience, and citizen participation.

Bioenergy Villages [39](BEVs) represent a well-established model of bioenergy communities (BECs). These are locally governed systems that produce and distribute heat—and in some cases, electricity—using locally sourced biomass[40]. They are typically operated by citizen cooperatives, municipalities, or social enterprises.

By positioning BEVs within the broader framework of energy communities, they can benefit from EU-level funding mechanisms, legal protections, and governance models, making them more scalable and institutionally recognized.

Key Problems Addressed by Bioenergy Villages

- Underutilized Biomass Streams: Millions of tonnes of biomass—such as prunings, sawmill residues, and garden waste—are either wasted or openly burned. BEVs valorize these streams, reducing emissions and enhancing energy autonomy.
- Rural Energy Inequality: Many rural regions continue to rely on outdated and inefficient heating systems. BEVs modernize heating infrastructure using local renewable resources, reducing fossil fuel dependence.
- Lack of Citizen Ownership: Most European energy systems remain centralized and profit-driven. BEVs empower communities to own and manage their energy infrastructure, fostering local trust and reinvestment.
- Slow Progress Toward Climate Goals: BEVs contribute directly to heating decarbonization, air quality improvement, and the realization of climate-neutral rural communities, in line with EU objectives.
- Fragmented Support Structures: The lack of consistent legal and financial frameworks across Member States limits the replication and scale-up of BEVs.

Policy Recommendations

- Establish targeted national and regional funding lines for community-managed biomass heating systems, prioritizing locally sourced feedstocks.

[39] Jenssen, T., D. König, and L. Eltrop. "Bioenergy Villages in Germany: Bringing a Low Carbon Energy Supply for Rural Areas into Practice." *Renewable Energy* 61 (2014): 74–80. https://doi.org/10.1016/j.renene.2012.08.014.

[40] BioVill. *Successful Bioenergy Villages in Europe.* Deliverable D2.1, Horizon 2020 Project No. 691661. European Commission, 2016. https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5adf13840&appId=PPGMS.

- Encourage public–community ownership models through simplified administrative procedures.
- Provide fiscal incentives to municipalities that champion local energy transitions.
- Include biomass-based district heating in CAP Strategic Plans, the Just Transition Mechanism, and the Recovery and Resilience Facility.
- Provide capital grants for boilers, pipework, automated controls, and smart metering.
- Develop village-scale biomass logistics and storage hubs to ensure supply security and reduce transport costs[41].
- Support formalized supply contracts with local biomass providers (e.g., farmers, foresters, municipal services).
- Harmonize biomass legislation to distinguish between biomass and waste, simplifying permitting and encouraging circularity.

Expected Impacts

- Systems like that in Ghelința, Romania show up to 83% system efficiency and 871 tons CO_2 reduction per year.
- Contributes to EU targets under RED III for renewable heating and cooling.
- Reduces energy poverty in underserved and remote communities.
- BEVs promote community ownership through cooperatives or social enterprises, increasing transparency and public trust.
- Transforms organic residues into energy and heat, reducing illegal burning and associated
- Creates direct jobs (operation, maintenance, logistics) and indirect jobs (equipment suppliers, fuel processing).
- Offers centralized or modular systems that are less dependent on outdated, inefficient appliances.
- BEVs offer a scalable and reportable model—adaptable from small villages (~500 inhabitants) to larger rural clusters (~5,000+).

Future Research to Support Implementation

- Techno-Economic Feasibility by Region analyzing financial, logistical, and performance data across diverse EU rural contexts.
- Comparative Legal and Regulatory Studies on mapping Member State implementation of RED III energy community provisions and identifying legal bottlenecks (e.g., grid access, taxation, procurement) and propose harmonized governance models for cooperative energy systems.
- Assess long-term biomass availability and its potential conflicts with land use, biodiversity, and sustainability targets.

[41] Bozhikaliev, V., I. Sazdovski, J. Adler, and N. Markovska. "Techno-economic, Social and Environmental Assessment of Biomass Based District Heating in a Bioenergy Village." *Journal of Sustainable Development of Energy, Water and Environment Systems* 7, no. 4 (2019): 601-614. https://doi.org/10.13044/j.sdewes.d7.0257.

Policy Brief 19: Reclassifying Waste-Derived Algae in aquaculture

Challenge

Algae cultivated on waste substrates—such as municipal wastewater or anaerobic digestate—face significant regulatory uncertainty because current frameworks tend to classify such biomass as "waste" due to the discarded nature of the input materials. This classification not only restricts their use in producing high-value products but also limits their marketability. For example, the ESPP Legal Opinion on algae from waste animal by-products (ABPs) highlights that when manure or slurry is used as the substrate for algae growth, it falls under strict ABP regulations that maintain its "waste" status until it meets very specific criteria [42]

The lack of a clear End-of-Waste (EoW) status is a major barrier. A dedicated factsheet on wastewater-derived algae biomass demonstrates that despite over 20 EU projects focusing on nutrient recovery (closed SABANA, Saltgae, All-Gas, AlgaeBioGas, Alg-AD, Water2Return, LIFE AlgaeCan…; in progress: REALM, Cronus, FuelPhoria, Locality, NAMOR…), the estimated potential of recovered algae biomass of around 210 kt dry matter per year in the EU remains largely untapped because of regulatory ambiguity [43] This lack of EoW criteria directly impacts the ability of stakeholders to commercialize these materials.

A joint letter from industry and regulatory stakeholders calls for the European Commission to assess wastewater treatment streams—including those producing algae biomass—for EoW criteria [44] .This letter emphasizes that without regulatory reform, investments in technology and infrastructure remain stalled, and secondary resources are lost in classification uncertainty. In addition, EU4Algae, the flagship initiative of DG MARE in algae domain, clearly states in their Outcome report[45] that "The Waste Framework Directive (WFD) restricts the use for food and animal feed of algae grown on wastewater or manure. To enable safe reuse, there is a need for clear regulatory guidelines defining when algae biomass is no longer considered waste and can be legally recycled."

Industry webinars and detailed discussions, as summarized in the ESPP SCOPE Newsletter on regulatory challenges, provide concrete examples from pilot projects (listed above) where algae grown from treated wastewater met stringent heavy metal and pathogen standards. In All-Gas project, biomethane produced from algae biomass digestion was successfully validated in three vehicles over more than 70,000 km. Moreover, the lipids extracted from the algae were found to meet quality standards sufficient for blending with conventional (bio)diesels. This example demonstrates that waste-derived algae can produce fuels that comply with stringent performance criteria, highlighting the feasibility of converting waste substrates into high-quality energy products. Additional evidence from pilot projects indicates that algae cultivated from treated wastewater also deliver consistent quality for various applications, such as in animal feed and agriculture (Alg-AD, SABANA, Saltgae, Water2Return, LIFE AlgaeCan). These pilot projects serve as proof of concept, showing that with appropriate processing and quality control, waste-derived algae can overcome regulatory challenges. This demonstrates that with the proper regulatory adjustments, waste-derived algae can reliably achieve the quality required for high-value applications [46].

Policy Recommendations

- Establish Clear EU End-of-Waste Criteria: Develop science-based, transparent criteria that specifically address algae biomass produced on waste substrates. As it is clear that wastewaters may contain a wide range of contaminants and pathogens, it is essential to ensure safety of recovered materials. It should be

[42] European Sustainable Phosphorus Platform. *Legal Opinion on the Waste/Animal By-Product (ABP) Status of Waste-Derived Algae, with Particular Reference to the Animal Feeds Regulation.* 2024.
[43] EurEau (European Federation of National Associations of Water Services). "Products from Waste Water–Algae Biomass." Factsheet, 2019. https://www.eureau.org/documents/diverse/6078-factsheet-on-products-from-waste-water-algae-biomass/file.
[44] Pellegrini, A., N. Baucells, and European Biogas Association (EBA). *Letter to the European Commission, DG Environment: EU End-of-Waste Status for the Value Chain Food, Water & Nutrients.* 2021. https://www.europeanbiogas.eu/wp-content/uploads/2021/07/Jointletter_2021_05_DGENVI-EoW-v3_7_21.pdf.
[45] European Commission. *Overview of European Initiatives for a Safe and Sustainable Algae Industry.* Brussels, 2025.
[46] Cai, T., S. Y. Park, and Y. Li. "Nutrient Recovery from Wastewater Streams by Microalgae: Status and Prospects." *SCOPE Newsletter* no. 100 (2013). https://www.phosphorusplatform.eu/images/scope/ScopeNewsletter140.pdf

indicated that waste substrates differ. In particular, municipal and industrial wastewater treatment sludges should retain waste status, to ensure traceability and monitoring, unless they have undergone processing to a product with consistent quality and safety characteristics and a market for use. On the other hand, many substrates, currently considered as waste, should be reconsidered, for example side-streams from food processing. The criteria should consider successful pilot projects e as benchmarks for quality and safety.

- Harmonize Quality and Safety Standards: Create and implement uniform quality control protocols, including explicit contaminant and pathogen limits. Utilize documented cases—such as the consistent performance of algae from treated wastewater in achieving heavy metal and pathogen standards—to define these benchmarks.
- Promote Regulatory Dialogue and Stakeholder Collaboration: Facilitate regular consultations between industry stakeholders, technology developers, and EU regulatory bodies. This should include sharing best practices from the listed pilot projects that have validated safe use of algal biomass for specific products.
- Provide Targeted R&D and Pilot Project Funding: Allocate dedicated funds for research and pilot projects that not only refine processing techniques but also test scalability. Funding should support demonstrations and developing protocols for ensuring quality standards and stable production.
- Integrate with Broader EU Initiatives: Align the regulatory reform for waste-derived algae with the objectives of the EU Blue Bioeconomy Initiative, the EU Green Deal[47], and recommendations from the Europarl Bioeconomy Study.

Expected Impacts

- Clear regulatory status will unlock the commercial potential of algae-based products, leading to wider market adoption across various industries. This will lead to higher production of algae on waste streams, supporting EoW, self-sustainability and circular economy efforts.
- Reclassifying waste-derived algae as valuable resources will promote nutrient recycling, reduce disposal costs, and lower dependency on primary raw materials.
- Improved wastewater treatment and nutrient recovery will lead to reduced environmental pollution and lower greenhouse gas emissions through effective CO_2 capture.
- Regulatory clarity and established safety standards will encourage private investment and stimulate innovation in bio-based technologies.
- Targeted R&D funding and pilot projects will enable rapid scale-up of proven technologies, as seen in pilot installations that meet rigorous heavy metal and pathogen standards. This will stimulate further investments and technological improvements.

Future research to support the recommendations and impact

- Establish longitudinal studies to track contaminant uptake and persistence in waste-derived algae across various production cycles. These studies should help develop and standardize risk assessment protocols tailored to different waste substrates.
- Assess different processing methods to determine the most effective techniques for achieving EoW status while maintaining product quality.
- different production systems to determine the most efficient for processing waste streams to quality biomass.
- Examine the economic feasibility, market barriers, and social impacts of transitioning waste-derived algae from a regulatory perspective to full-scale commercialization.

Relevant projects and networks:

[47] European Commission. *The European Green Deal.* Brussels: European Commission, 2019. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

ALG-AD - Creating value from waste nutrients by integrating algal and anaerobic digestion technology: https://vb.nweurope.eu/projects/project-search/alg-ad-creating-value-from-waste-nutrients-by-integrating-algal-and-anaerobic-digestion-technology/

AlgaeBioGas - Algal bacterial treatment of biogas digestate, recycling CO2 and mineral nutrients, using excess heat, producing algal products and biogas feedstock: https://www.algaebiogas.eu

CRONUS - Capture and Reuse of Biogenic Gases for Negative-Emission – Sustainable biofuels: https://cronushorizon.eu

EABA Working group Algae4wastewater: https://www.eaba-association.org/en/working-groups

EU4Algae – A collaborative European stakeholder platform: https://submariner-network.eu/eu4algae/

FuelPhoria - Accelerating the sustainable production of advanced biofuels and RFNBOs - from feedstock to end-use: https://fuelphoria.eu

LIFE AlgaeCan - Adding sustainability to the fruit and vegetable processing industry through solar-powered algal wastewater treatment: https://www.lifealgaecan.eu

Locality - Nature-positive aLgae-based fOod, agriCulture, AquacuLture and textIle producTs made in North and Baltic Sea ecosYstems: https://www.locality-algae.eu

REALM - Reusing Effluents from Agriculture to unLock the potential of Microalgae: https://realmalgae.eu/the-research/

SABANA - Sustainable Algae Biorefinery for Agriculture and Aquaculture: https://www2.ual.es/sabana/project/

Saltgae - Demonstration project to prove the techno-economic feasibility of using algae to treat saline wastewater from the food industry: https://www.saltgae.eu

Water2Return - Recovery and recycling of nutrients turning wastewater into added-value products for a circular economy in agriculture: https://www.water2return.eu

Policy Brief 20: Support the implementation of innovative aquaponics systems

Challenge

Aquaponics — the integrated cultivation of fish and plants in a symbiotic, closed-loop system — holds significant promise for Europe's rural bioeconomy. It offers localized food production with high resource efficiency, minimal waste, and low environmental footprint. Yet, despite these advantages, the implementation of such systems remains marginal and faces several systemic barriers. The experience of a pioneering aquaponics enterprise in Portugal, actively engaged in the BioRural project, offers concrete insights into the barriers and challenges that this sector is facing nowadays.

At present, aquaponic producers encounter regulatory, financial, and infrastructural obstacles that inhibit scaling, innovation, and mainstream adoption. The lack of a coherent regulatory framework tailored to hybrid systems like aquaponics, which blur the lines between agriculture and aquaculture, means that these systems often fall into a legislative void, with unintended consequences. In countries like Portugal, for example, aquaponic facilities are classified as industrial operations, even though they serve agricultural purposes. This forces producers to operate in industrial zones, dramatically increasing land costs and distancing them from rural development efforts.

Moreover, aquaponic products cannot currently be marketed as organic under EU legislation, despite being produced under more sustainable, resource-efficient conditions than many conventionally certified systems. This puts aquaponic producers at a significant market disadvantage, unable to compete fairly in a growing consumer segment that prioritizes sustainability and health. Simultaneously, the lack of targeted funding mechanisms and the absence of professional recognition or dedicated training programs for aquaponics limit access to investment, innovation capacity, and skilled labour — all of which are essential for the sector's growth.

Without addressing these issues, aquaponics will remain a niche solution, rather than a mainstream driver of rural development, food system resilience, and ecological transition.

Policy Recommendations

1. Develop an EU-Wide Organic Certification for Aquaponics

- Create a specific certification scheme tailored to the unique features of aquaponic production (perhaps via Life Cycle Assessment or ISO environmental performance).
- Ensure that certification criteria uphold EU organic principles while recognizing the closed-loop nature of aquaponic systems.
- Engage with aquaponic producers, researchers, and certification bodies to co-design standards that are practical, credible, and science-based, while also learning from existing U.S. models where aquaponics can be certified organic.

2. Revise Zoning and Land Use Policies

- Update national and EU-level guidance to classify aquaponics as a form of primary production, making it eligible for establishment in rural zones.
- Encourage integration of aquaponics into rural spatial planning tools, including LEADER strategies and Local Action Group agendas.
- Support land-use flexibility for circular and integrated systems that combine elements of aquaculture, agriculture, and biowaste management.
- Urban and Peri-Urban Integration - policy support for urban aquaponics (zoning flexibility, building integration incentives, rooftop/indoor farming frameworks, alignment with Smart City agendas).

3. Create Integrated and Inclusive Funding Mechanisms

- Design funding programs that explicitly target hybrid systems like aquaponics, bridging the agriculture-aquaculture divide.
- Promote innovation grants, green finance instruments, and business incubators tailored to circular and regenerative food systems.
- Prioritize funding mechanisms that reward resource efficiency, carbon reduction, and local value creation over conventional yield metrics.

4. Mainstream Aquaponics in Education and Professional Pathways

- Introduce aquaponics modules into agricultural, aquaculture, and environmental science curricula at vocational and university levels.
- Develop capacity-building programs for new entrants, including young farmers, urban growers, and rural entrepreneurs.
- Establish professional certification pathways that recognize the technical complexity and interdisciplinary nature of aquaponics.
- Promote educational aquaponics systems in schools and universities not just for training technicians, but for building sustainability literacy, entrepreneurship, and community engagement.

5. Support the Digitalization and Circular Optimization of Systems

- Promote IoT and AI monitoring systems to optimize the performance of aquaponic systems, ensuring productive efficiency and food safety.
- Development of predictive models for water and nutrient management to improve recirculation efficiency and reduce environmental impacts.
- Foster collaborations between technology providers, system designers, and producers to develop smart, low-energy, modular aquaponics models.

6. Support Innovative Business Models & Go-to-Market Strategies

- Enable preferential public procurement for local/sustainable aquaponic produce.
- Support short food supply chains (SFSCs) and local logistics integration.
- Encourage public-private partnerships to facilitate market uptake.
- Recommend policy and tech development for transparent aquaponics supply chains, especially relevant in public health, school meals, and urban food strategies.

Expected Impacts

- Enhanced Competitiveness and Market Access: Organic certification would allow aquaponic producers to access high-value markets, level the playing field, and communicate their sustainability credentials to consumers.
- Territorial Cohesion and Rural Innovation: Legal recognition of aquaponics as a primary activity would facilitate its inclusion in rural development plans and allow units to be established in cost-effective locations, benefiting underused rural infrastructures.
- Business Model Resilience and Innovation: By supporting integrated funding and promoting circular finance mechanisms, aquaponics enterprises could grow with greater autonomy and long-term viability.

- Knowledge and Workforce Development: Dedicated training and certification, as well as access to new technologies, would build a qualified workforce capable of scaling aquaponics and integrating it with local food, energy, and waste systems.
- Environmental and Climate Benefits: Circular design and digital optimization would maximize resource-use efficiency, reduce emissions, and contribute to the EU's climate neutrality goals.

Future research to support the recommendations and impact

To sustain and scale the transition towards integrated aquaponic systems, research and innovation efforts should focus on:

- Designing robust, climate-adaptive aquaponics models tailored to different rural contexts across Europe.
- Quantifying the environmental performance of aquaponic systems in terms of water savings, nutrient use efficiency, and carbon balance.
- Evaluating the nutritional quality and health benefits of aquaponic products to support consumer trust and public procurement.
- Developing predictive tools using IoT and AI for real-time management of water quality, nutrient dynamics, and plant-animal interactions, in order to enhance resource-use efficiency.
- Assessing the feasibility of modular and cooperative production systems, especially for replication in low-density rural areas.
- Exploring the integration of circular feed solutions, including the use of insects, microalgae, and agri-food by-products/surpluses as dietary supplements for fish, promoting a reduction in the dependency on fishmeal and fish oil.
- Research on new aquaculture species with high feed efficiency and resilience to environmental variations (e.g., Scortum barcoo, a highly sustainable species rich in omega-3, which is under development in Europe) and support for marketing initiatives to overcome market resistance and conservatism towards new aquaculture species.
- Studying the potential for carbon sequestration and ecosystem services in aquaponic systems, contributing to climate policy goals.

These research priorities will provide the scientific, technical, and socio-economic foundation needed to back evidence-based policymaking, derisk investments, and strengthen the bioeconomy potential of aquaponics in Europe.

Policy Brief 21: Recycled and biobased plastics: Promoting a complementary approach

Challenge

European and French regulations encourage the incorporation of recycled plastics to reduce waste and the carbon footprint, making recycling a key part of the circular economy. However, this approach tends to relegate biobased plastics, which are derived from renewable resources, to a secondary role, when they could play a strategic complementary role.

A more balanced approach is needed to support recycling and biobased plastics simultaneously, by structuring appropriate industrial sectors, developing technical standards and ensuring their compatibility with end-of-life requirements (recyclability, compostability, biodegradability).

Current and future regulations must recognise biobased plastics as solutions in their own right, contributing to a reduction in environmental impact, raw material sovereignty and local industrial innovation.

Policy Recommendations

EU Level

- Establish regulatory parity between recycled and biobased plastics by formally recognising the latter as a valid and strategic alternative to fossil-based plastics. This would align with broader EU goals under the Green Deal, Circular Economy Action Plan, and Bioeconomy Strategy.
    - Introduce targeted EU-level support mechanisms for biobased plastics, including:dedicated funding for R&D and scale-up. Tax incentives for production and use. Innovation grants and pilot procurement programs for biobased materials.
- Integrate biobased plastics into circularity frameworks, ensuring compatibility with current and future recycling systems. Where integration proves challenging, support the development of dedicated value chains, including material standardisation, infrastructure, and stakeholder coordination.

Member States Level

- Promote aligned national frameworks that support both recycled and biobased plastics under a common European vision. National incentives, standards, and roadmaps should reflect EU policy coherence to avoid market distortions and ensure cross-border scalability.
- Allow flexibility for local conditions in implementation—considering factors such as biomass availability, industrial ecosystems, and waste infrastructure—while maintaining alignment with EU-wide circularity and sustainability objectives.
- Support rural and regional production ecosystems through tailored measures that integrate biomass producers, processing facilities, and end-users, thereby promoting local supply chains and rural development.

Expected Impacts

- Enhanced use of biobased plastics supports the reduction of lifecycle greenhouse gas emissions and fossil fuel dependence. Proximity between biomass production and plastics manufacturing can further lower emissions through shorter supply chains and improved traceability.

- Establishing biobased plastics production in rural areas creates new market opportunities for biomass producers, fosters high-value applications of agricultural and forestry residues, and contributes to job creation in bio-based industries.
- Currently, only 25% of biobased plastics used in Europe are manufactured domestically. Scaling up local production will strengthen the EU's industrial autonomy and reduce exposure to global market fluctuations and supply chain risks.
- Local and regional biobased plastics ecosystems would allow for improved material circularity, particularly when tied to sustainable farming practices, waste valorisation, and integrated end-of-life options such as composting or recycling.
- A better-defined and supportive regulatory environment would boost confidence and participation from market actors, accelerating the development of new applications and facilitating the entry of SMEs and cooperatives into the bioplastics value chain.

Future Research to Support the Recommendations and Impact

- Research is needed to deepen our understanding of how biobased plastics interact with recycling infrastructure, particularly concerning mechanical and chemical recyclability, compostability, and biodegradability. These insights are key to formulating clear, workable end-of-life standards.
- Comparative LCAs of different biobased plastics and feedstocks should be expanded to fully assess their environmental performance and inform policy and certification schemes.
- Investigations into the cost structures, market potential, and logistical needs of rural-based bioplastics production are critical to inform investment strategies and policy incentives.
- Behavioural studies on consumer trust, willingness to pay, and understanding of biobased labels can help shape outreach, labelling frameworks, and policy instruments that drive adoption.
- Comparative legal research across Member States can identify inconsistencies, assess the impact of current regulatory incentives, and guide the development of a harmonised EU framework that fully integrates biobased plastics into the circular economy.
- Interdisciplinary research should explore the integration of biobased plastics within broader rural bioeconomy systems—including links to modular biorefineries, agricultural cooperatives, and biomass valorisation clusters.

Policy Brief 22: Bio-Based Textiles in the EU: Growth Barriers and Policy Solutions

Challenge

The European Union`s sectors of biomass production and conversion generated 728 billion EUR of added value in 2021, while employing 17.2 million people. This equals to 5% of the gross domestic product of the EU and 8.2% of the total labour force. There is an evident growth of the value added by the bio-economy between 2012 and 2021 of 39% mainly driven by the bio-based manufacturing sectors[48].

Bio-based textiles contribute with only 3.5% in the bio-economy`s added value or 26 billion EUR and 4.1% of the total workforce. There is a minor growth of the added value from this sector of the bio-economy of 2.8% between 2008 and 2021 and a significant decrement of the employment in this sector of 38.1% for the same period. The sector is divided between bio-based textiles participating with 37%, bio-based wearing apparel with 30.3% and leather with 32.7%. Among the leading producers of bio-based textiles in Europe are Italy, Germany and France whit the rest of the member states being far behind[49].

Bio-based textiles, while offering a sustainable alternative to conventional materials, face a range of challenges that hinder their broader adoption[50]. One major issue is the sourcing of raw materials, as many bio-based fibers rely on agricultural feedstocks that may compete with food production or place pressure on land and water resources. This is particularly relevant for crops like cotton or corn, which can be environmentally intensive. In terms of production, many bio-based fibers require specialized technologies that are not yet widely available, resulting in higher production costs and inconsistent quality. These limitations make it difficult for bio-based materials to compete economically with synthetic textiles, especially in the fast fashion sector. Moreover, end-of-life management remains problematic: not all bio-based textiles are biodegradable or recyclable, and infrastructure to process them is often lacking. The issue is compounded by limited consumer awareness and widespread misconceptions—many equate bio-based with fully sustainable, which is not always accurate. Certification systems and industry standards are also still developing, leading to gaps in accountability and transparency across supply chains. Lastly, the performance of some bio-based materials remains inferior to that of synthetic alternatives in terms of durability, flexibility, and color retention, limiting their suitability for certain products[51].

Policy Recommendations

- Provide targeted incentives and support for the development and use of non-food biomass sources to reduce competition with food production and environmental pressure and integrate sustainable fiber crops into the EU's Common Agricultural Policy through subsidies and technical assistance for low-impact cultivation.
- Support the creation of regional innovation hubs in underperforming member states to enhance competitiveness and reduce regional disparities.
- Promote co-investment schemes for investors supporting the bio-based textile sector and implement temporary price support mechanisms to enhance market competitiveness of EU-based bio-based textile producers.
- Invest in infrastructure and research to develop recycling and composting systems tailored to bio-based and blended textiles.

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[48] Lasarte López, J., F. Mainar-Causapé, G. Borzacchiello, and A. Rodríguez Fernández. *Jobs and Wealth in the EU Bioeconomy / JRC-Bioeconomics* [Dataset]. European Commission, Joint Research Centre, 2022. http://data.europa.eu/89h/7d7d5481-2d02-4b36-8e79-697b04fa4278

[49] European Commission, Joint Research Centre. *2023 EU Industrial R&D Investment Scoreboard.* Luxembourg: Publications Office of the European Union, 2024. https://publications.jrc.ec.europa.eu/repository/handle/JRC140676

[50] Harmsen, P., et al. *Bio-based Textiles in a Sustainable and Circular Bioeconomy.* European Commission, Joint Research Centre, 2025. https://publications.jrc.ec.europa.eu/repository/handle/JRC140676

[51] Manshoven, S., K. Dubois, J. W. Hanssens, and A. Gillabel. *The Role of Bio-based Textile Fibres in a Circular and Sustainable Textiles System.* European Environment Agency / ETC CE, 2023. https://www.researchgate.net/publication/368880906_The_role_of_biobased_textile_fibres_in_a_circular_and_sustainable_textiles_system

- Create and enforce harmonized standards for defining and certifying bio-based textiles, including sustainability and bio-content criteria.

Expected Impacts

- Increase investment in sustainable textile production, boosting industrial competitiveness and innovation.
- Enhance the economic viability of bio-based textiles, allowing EU producers to better compete with synthetic alternatives.
- Create new employment opportunities in agriculture, manufacturing, recycling, and research sectors.
- Support rural development and income diversification for farmers through the cultivation of sustainable fibre crops.
- Reduce environmental pressure by shifting from food-based to non-food biomass and promoting low-impact cultivation practices.
- Strengthen regional economies and reduce disparities by fostering innovation hubs in underperforming member states.
- Improve circularity in the textile sector through the development of recycling and composting infrastructure tailored to bio-based materials.
- Decrease landfill waste and pollution by supporting biodegradable and recyclable textile solutions.
- Build consumer trust through clear standards, certifications, and labelling for bio-based textile products.
- Minimize greenwashing and ensure transparency across the textile value chain. Encourage responsible public and private purchasing decisions based on verified sustainability criteria.
- Advance EU environmental and climate goals by reducing dependence on fossil-based textiles and lowering emissions.

Future research to support the recommendations and impact

- Understanding environmental impacts of large-scale bio-based textile production, particularly in terms of land use, biodiversity, and water consumption.
- Comparative life-cycle assessments to evaluate the actual sustainability benefits of bio-based textiles versus conventional and recycled alternatives.
- Exploring the socio-economic implications of introducing bio-based crops into agricultural systems, including potential trade-offs with food production and rural livelihoods.
- Examining scalability and economic viability of emerging recycling and composting technologies tailored to bio-based and blended textiles.
- Developing standardized metrics for measuring bio-content and sustainability performance across the textile value chain, along with more robust evaluations of certification and labelling schemes to minimize greenwashing and improve supply chain transparency.
- Understanding consumer attitudes, behaviour, and willingness to pay for certified bio-based textiles is also critical for designing effective awareness and market engagement strategies.
- Identifying region-specific barriers to innovation and industrial development in underperforming areas will help tailor support measures more effectively.

5. Conclusions

The European Union's transition toward climate neutrality, circularity, and rural revitalization hinges on the systemic deployment of sustainable bioeconomy models that are inclusive, innovation-driven, and territorially anchored. The diverse policy insights outlined above converge on a central message: unlocking the bioeconomy's full potential requires a shift from fragmented support to coordinated, multi-level governance that prioritizes local value creation, cross-sectoral alignment, and equitable access to innovation.

Rural areas—despite being rich in biomass resources, local knowledge, and entrepreneurial capacity—remain underleveraged in the bioeconomy. This is due not to a lack of potential, but to policy and investment misalignments, outdated regulatory barriers (such as in waste classification), and insufficient support for decentralised and small-scale solutions such as modular biorefineries, bioenergy villages, or smart precision farming technologies.

Emerging models like bio-based innovation hubs, energy cooperatives, circular clusters, and digitalised biomass logistics systems demonstrate that it is possible to combine environmental performance with rural economic regeneration. Yet these solutions will only scale if embedded in coherent policy frameworks that connect the dots between the Green Deal, CAP Strategic Plans, RED III, and the EU Bioeconomy Strategy. Tools like AKIS (Agricultural Knowledge and Innovation Systems), simplified funding access, and harmonised sustainability certification are essential enablers.

Moreover, targeted investments in skills, infrastructure, and regional capacity-building—supported by applied research and life-cycle thinking—can bridge the gap between high-level ambitions and on-the-ground adoption. Whether through better classification of green residues, decarbonisation of forestry operations, or empowering smallholders via smart farming tools, the transition must be pragmatic, participatory, and tailored to local realities.

The success of the EU bioeconomy depends on its ability to go beyond pilot projects and produce scalable, replicable, and just solutions. Doing so requires a policy approach that sees bioeconomy not just as a sectoral opportunity but as a strategic lens for sustainable development, economic democracy, and climate resilience across all of Europe's territories.

Annex I: BioRural Contribution to the public consultation on the upcoming EU Bioeconomy strategy

BioRural Contribution to the public consultation on the upcoming EU Bioeconomy strategy

Summary

Prioritising coherence, innovation, and targeted investment will be essential for the renewed EU Bioeconomy Strategy to effectively support the transition to a sustainable and circular bioeconomy. The BioRural Horizon Europe project, active over the past three years, has contributed a rich evidence base from grassroots stakeholders and technical experts across Europe to support the transition to a circular bioeconomy.

Key activities included:

- Survey results from over 400 key bioeconomy stakeholders on the drivers and barriers to a circular bioeconomy.
- 43 national multi-innovation workshops across 14 countries that captured grassroots stakeholders' opinions on redesigning linear to circular value chains
- The development of a European Rural Bioeconomy Network with over 550 key stakeholders and associated toolkit for a circular bioeconomy
- Range of other activities that engaged 1000's of stakeholders including in: knowledge exchange workshops, regional and European challenges, identification of success stories and innovation processes.

These activities informed **23 evidence-based policy briefs**:

- **12 Horizontal briefs** that are applicable to the Bioeconomy Strategy and includes recommendations that apply across the entire bioeconomy, cutting across multiple sectors.
- **11 Specific briefs** offering targeted recommendations for key bioeconomy sectors and value chain stages.

The following table outlines how the BioRural project's findings and recommendations directly support the four main objectives of the upcoming EU Bioeconomy Strategy update, demonstrating their strategic relevance and policy alignment.

Strategy Pillar	How BioRural Policy Briefs Contribute
1. Ensuring long-term competitiveness and investment security	Support for innovation systems, new crop types, modular biorefineries, and rural clustering mechanisms.
2. Increasing resource-efficient and circular use of biological resources	EoW streamlining, valorisation of residues, bio-based alternatives, circular business models.
3. Securing competitive and sustainable biomass supply	Smart farming, logistics centres, forestry decarbonisation, sustainable fertiliser uptake.
4. Positioning the EU in the expanding global bioeconomy	Harmonised standards, certification, and support for novel value chains (e.g. algae, textiles, aquaponics).

Horizontal Policy Briefs

The horizontal policy briefs address cross-cutting challenges and enablers relevant to the entire bioeconomy landscape. These recommendations are designed to improve coherence across EU sustainability frameworks, streamline regulation, foster innovation, and build structural support for the transition to a circular bioeconomy. They target system-level levers such as classification standards, carbon certification, rural networks, and education

systems—ensuring that the broader policy environment supports sustainability, competitiveness, and inclusivity across all sectors.

Policy Brief Title	Key Recommendation	Why It Matters (Context)
Strengthen Coherence Between the EU Bioeconomy Strategy and Key Sustainability Agendas	Ensure policy alignment between the Bioeconomy Strategy and other EU green frameworks (e.g. Green Deal, CEAP).	Fragmented policies risk inefficiency and conflicting goals. Coherent strategies amplify impact and sustainability.
Streamline End-of-Waste Criteria	Develop sector-specific, material-specific EoW criteria.	Current approval processes for reused bio-based materials are slow and inconsistent, hampering circular practices.
Harmonise Classification and Certification Protocols for Biobased Products	Introduce EU-wide harmonised standards and certifications.	Fragmented classification systems lower consumer confidence and create trade barriers.
Develop (Public) Market Information Systems	Improve access to data on biomass supply, by-products, and market conditions.	Lack of reliable data restricts efficient resource use and discourages SME participation.
Integrating Rural Circular Bioeconomy Models into the EU Carbon Removal Certification Framework (CRCF)	Include rural circular practices in CRCF methodologies.	Many valid rural carbon removal methods (e.g. composting) are not currently recognised, limiting their impact and funding eligibility.
Systematically Embed Innovation in the Circular Bioeconomy	Establish structured innovation pipelines and platforms across the bioeconomy.	Innovation remains fragmented; structured embedding would support scaling and systemic impact.
Support Local and Micro-Regional Biomass Storage and Logistics Centres	Promote intermediate depots in decentralized biomass chains.	Local biomass is underutilised due to inconsistent availability and high logistics costs.
Develop a Supportive Framework for Rural Circular Bioeconomy Networks	Institutionalise support for regional networks and collaborative schemes.	Effective collaboration drives innovation and sustainability but is currently ad hoc and under-supported.
Enhance Education, Knowledge Transfer and Training Policies	Create a standardised, accessible education and training system for CB.	Disjointed curricula and low outreach weaken workforce readiness for the circular bioeconomy.
Strengthen Competences and Innovation via Integrated AKIS Framework	Leverage Agricultural Knowledge and Innovation Systems (AKIS) to support applied research.	Connecting stakeholders through AKIS enhances innovation uptake and rural development.
Boosting Rural Bioeconomy: Support Emerging Industries and Clusters	Promote green innovation in both new and traditional rural industries.	Rural industries face barriers to green transition and lack support for biobased clustering.
Accelerating Circular Business Models in the EU	Scale up circular business models via funding, guidance, and partnerships.	Circular models are underutilised despite their potential for sustainability and growth.

Specific Policy Briefs

The specific policy briefs focus on targeted themes, sectors, or value chain stages within the circular bioeconomy. They include concrete actions for decarbonising forestry, promoting sustainable fertilisers, enhancing smart farming, valorising green residues, and unlocking innovation in aquaponics, algae, textiles, and bioplastics. These briefs respond to real-world bottlenecks identified through stakeholder engagement and provide focused, actionable recommendations to scale up promising practices and technologies across Europe's diverse bioeconomy.

Policy Brief Title	Key Recommendation	Why It Matters (Context)
Accelerating the Decarbonization of Forestry Sector Activities in the EU	Incentivise clean fuels and sustainable practices in forestry operations.	Logging and residue management contribute significantly to emissions; policy gaps limit cleaner alternatives.
Advancing Sustainable Fertilizer Use in Europe	Harmonise regulations and support organic/bio-based alternatives.	Fragmented policies hinder uptake of sustainable fertilizers, conflicting with EU green objectives.
Unlocking the Potential of Promising Crop Types	Support market creation and long-term contracting for new bio-crops.	Innovative crops lack incentives and are uncompetitive versus fossil-based alternatives.
Smart Farming for Optimised Biomass Production	Offer shared-access and subsidies for smart farming technologies.	Tech costs and knowledge gaps prevent farmers from adopting precision agriculture.
Empowering Rural Bioeconomy through Small-Scale Modular Biorefineries	Fund R&D and implementation of scalable modular biorefineries.	Small biorefineries can enhance rural development but need long-term investment plans.
Urban Green Residues: Wood, You Waste It?	Clarify EoW criteria for urban green residues to enable valorisation.	Unclear regulation results in usable biomass being discarded, increasing municipal costs.
Encourage Investments in (Biomass-Based) Bioenergy Villages	Classify BEVs within EU Bioenergy Communities for access to finance.	BEVs promote local energy sovereignty but lack institutional and regulatory support.
Reclassifying Waste-Derived Algae in Aquaculture	Update classification to allow algae grown on waste to lose "waste" status.	Current waste classification hinders use of algae in high-value products.
Support the Implementation of Innovative Aquaponics Systems	Create a tailored regulatory and funding framework for aquaponics.	Aquaponics is efficient and sustainable but faces legislative and funding gaps.
Recycled and Biobased Plastics: Promoting a Complementary Approach	Integrate biobased plastics in EU recycling and circularity policies.	Biobased plastics are underutilised despite environmental benefits and innovation potential.

Bio-Based Textiles in the EU: Growth Barriers and Policy Solutions	Support sourcing, production innovation, and EoL solutions for biotextiles.	Bio-based textiles face sourcing, cost, and scalability issues, limiting market penetration.

Cross-Cutting Insights and Strategic Recommendations

The BioRural policy briefs collectively highlight several overarching themes essential for advancing a circular rural bioeconomy in Europe.

1. Policy Coherence Across EU Frameworks - Strong alignment between the Bioeconomy Strategy and Green Deal, CEAP, and CRCF is essential to streamline goals, maximise synergies, and reduce inefficiencies.
2. Clear and Harmonised Regulatory Frameworks - Particularly on EoW criteria and biobased product standards—ensuring consistency will accelerate investment and material reuse.
3. Investment in Infrastructure and Innovation Capacity -Funding for logistics, modular biorefineries, and rural innovation platforms is critical to unlock local circular bioeconomy potential.
4. Education, Training, and Knowledge Networks - Tailored programs, AKIS integration, and regional networks enable workforce readiness, knowledge transfer, and scalable innovation

All policy briefs are accessible via the BioRural Toolkit (https://biorural-toolkit.eu/) and the BioRural Website (https://biorural.eu/)

Annex II: Template for the development of the Policy Briefs

Title

(Provide a clear and concise title that summarizes the key issue and policy focus)\

Challenge + Evidence supporting the challenge

(Describe the key problem or challenge that needs to be addressed. Support your explanation with relevant data, research findings, or real-world examples. No more than 3-4 paragraphs)

Policy Recommendations

(Outline specific, actionable policy measures that can help address the challenge. Ensure recommendations are practical and evidence-based. Write in bullet point format(

Expected Impacts

(Explain the potential outcomes of implementing the policy recommendations, including benefits for stakeholders, society, or the environment. Write in bullet point format)

Future research to support the recommendations and impact

(Identify gaps in knowledge or areas where further research is needed to strengthen the recommendations or evaluate their long-term effects.)