TREASoURcE Circular Bioeconomy Practices: Barriers and Opportunities for Transferability

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2026

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1. INTRODUCTION

TREASoURcE aims to initiate systemic change by developing circular economy solutions in cities and regions for currently underutilized plastic waste, end-of-life electric vehicle batteries and bio-based waste and side streams. The project also explored how its solutions could be replicated and transferred to its replication target areas. The replication process of any practice or tool involves several phases, with dissemination and knowledge sharing playing critical roles in ensuring its success and sustainability. This report focuses on two circular bioeconomy solutions created during the lifetime of the project – **Rural-Urban Symbiosis Model & Tool and Local Bioeconomy Model.** To disseminate information about these practices as well as to understand their transferability and replication potential in TREASoURcE target areas, we conducted several workshops (see ANNEX 1).

During workshops we presented the content of the models and shared best practice on engagement with municipalities as well as their encouragement to establish a biogas plant. Subsequently, to understand the local specifics, we discussed following questions in each target area:

- Which stakeholders would be the most appropriate starting partners for developing local bioeconomy models in your region?
- What challenges or barriers (technology, regulations, society) might prevent the development of local bioeconomy models in your region?

Participants represented key professional organisations in the bioeconomy sector (including farmers' unions, the federation of food producers), industry bodies such as biogas associations and companies, research institutions, chambers of agriculture and commerce, circular-economy NGOs, national institutions such as environmental agencies, the chambers of waste management, the inspectorates for environmental protection, and local governments.

In-depth workshop activities focusing on circular bioeconomy practices were conducted in Estonia, Poland and Germany. Primary data collection through introductory stakeholder workshops was conducted for Lithuania and Latvia at the initial stage of the project providing valuable preliminary insights into the local bioeconomy context. Therefore, the analysis for Latvia and Lithuania was supplemented with desk research, drawing on existing literature, policy documents, and relevant reports. This combined approach ensured that the findings remain grounded in both stakeholder input and evidence-based secondary sources, enabling a more comprehensive and balanced assessment.

This report provides a concise overview of both practices and then examines the potential for their transfer to the TREASOURCE target areas. The final section presents a cross-country synthesis, outlining key similarities and differences between the countries and highlighting the criteria for transferability.

2. Circular Bioeconomy Practices

2.1. Rural-Urban Symbiosis Model & Tool

The Rural–Urban Symbiosis Model provides a structured and practical approach for identifying and developing circular value chains between rural and urban regions, with a focus on biobased side and waste streams, biogas production, and nutrient recycling. It supports public authorities, planners, farmers, waste management companies, and private-sector actors in mapping local bioresources, understanding stakeholder roles, and designing sustainable cooperation models. To make the model accessible, the project created an Online Tool hosted on the Moodle platform, transforming the framework into a user-friendly learning and decision-making resource. Through five modules, users can explore the concepts of rural–urban symbiosis, map resources and stakeholders, assess technological options, understand governance and funding conditions, and analyse real-world case studies.

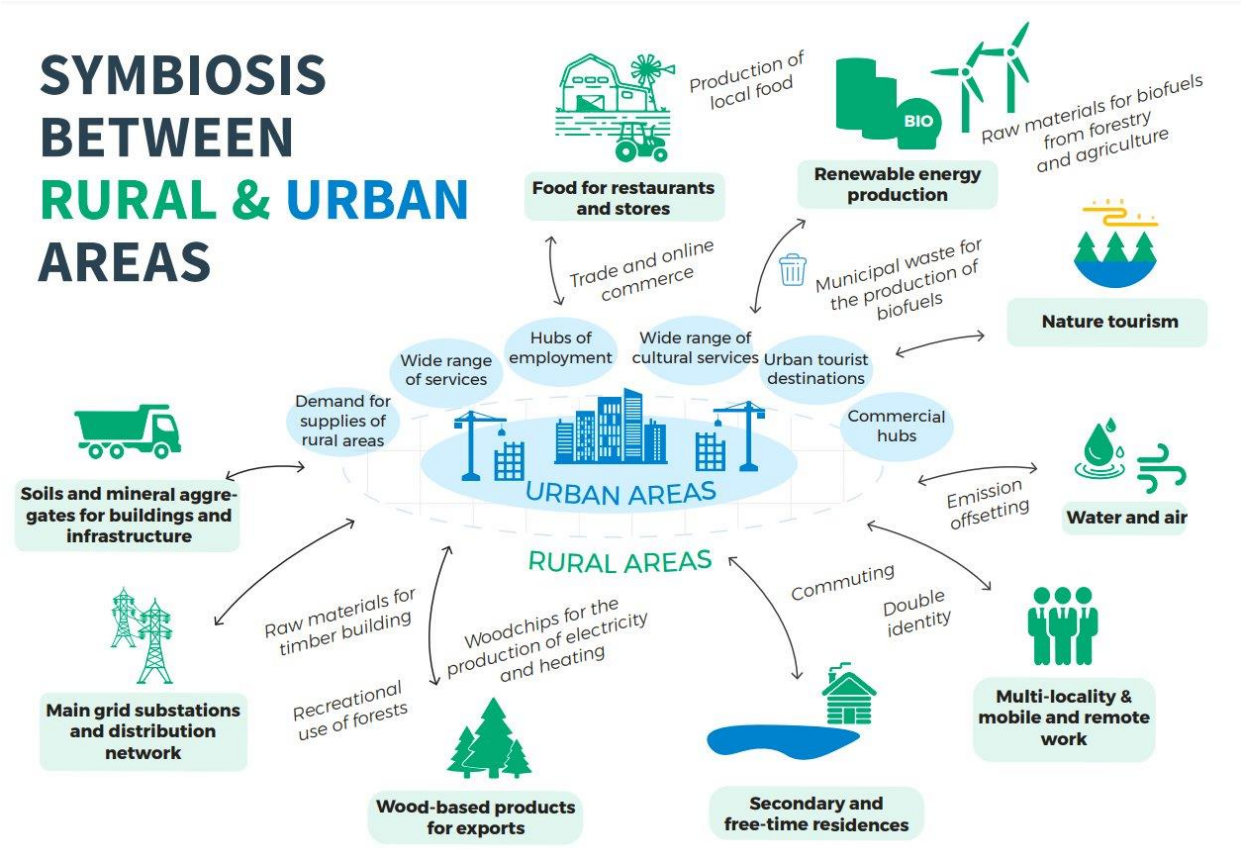
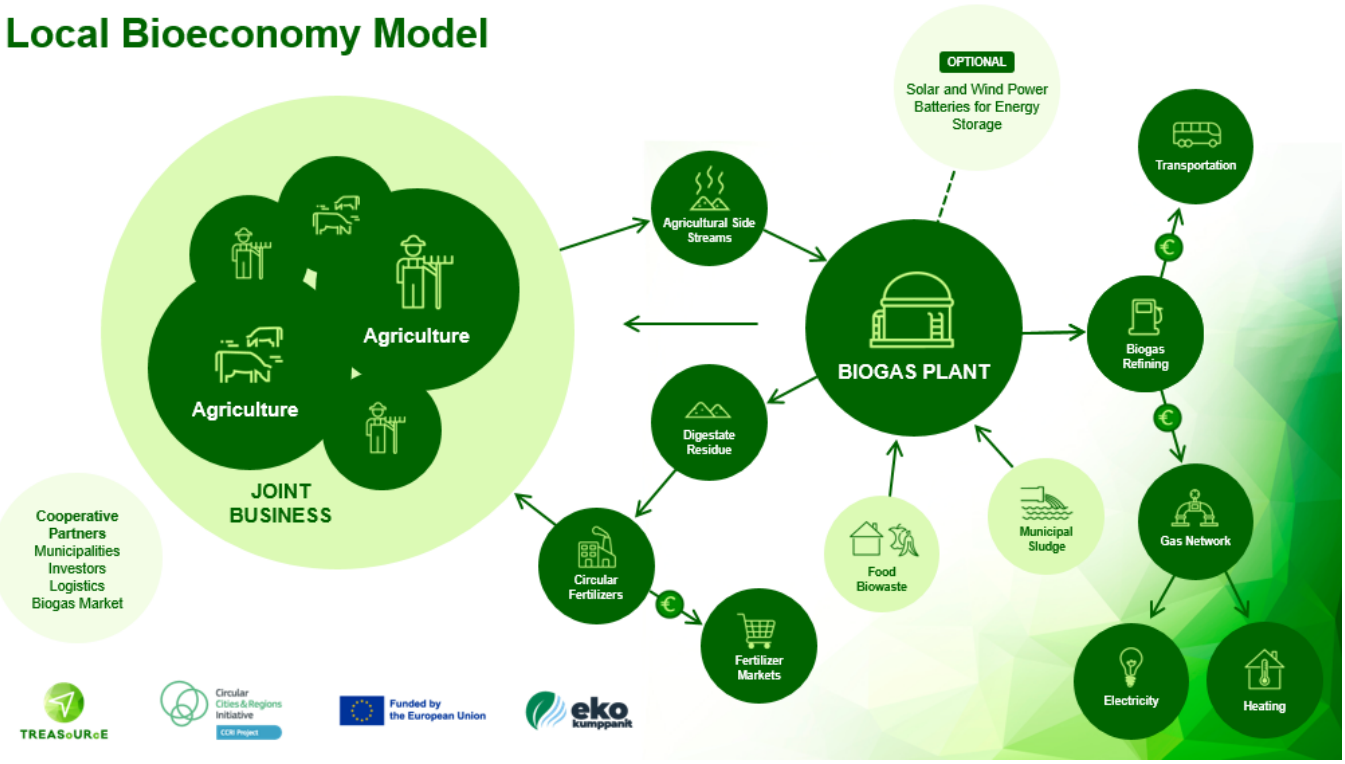


Figure 1. Symbiosis between Rural & Urban Areas

2.2 Local Bioeconomy Model

The project examines opportunities to develop local bioeconomy ecosystems, with biogas plants at their core. Municipalities play a key role in advancing these ecosystems as they are striving for carbon-neutral energy production, and local biogas generation offers a practical solution. The use of biogas in transport offers municipalities a way to reduce transport emissions and oil dependence. At the same time, municipalities' recycling nutrient production is increased. This increases security of supply both in terms of energy and nutrients. The project conducted surveys to assess local bioeconomy models in small municipalities in the Tampere region (Pirkanmaa), Finland. Based on these findings, a framework outlining the fundamental principles for developing and implementing a local bioeconomy model was created. *The local bioeconomy model* was presented as an example of the objectives promoted by the Rural–Urban Symbiosis Tool and as a practical illustration of how such a model can be implemented.

In the model example, farmers are at the center, and production focuses on biogas and recycled fertilizers. However, the model is suitable for many types of bioeconomy, with local activity and cooperation at its core. The aim is to increase the self-sufficiency of the regions.



3. Barriers, Needs and Opportunities for Transferability

This section brings together the insights gathered during the workshops in the target areas (see Annex 1 for details). Because the Rural-Urban Symbiosis Model and the Local Bioeconomy Model are closely interconnected, the barriers, needs, and opportunities for transferability largely overlap.

The information presented in the following section reflects the diversity of our target areas (Estonia, Latvia, Lithuania, Northern Germany and Poland) and naturally varies in its level of detail. This is because the depth of insight we were able to capture depended heavily on the knowledge and experience shared by workshop participants, as well as the availability of supporting materials in each region. In some areas, rich local input and accessible documentation allowed for more comprehensive analysis, while in others, limited data resulted in more concise descriptions. Together, these variations provide an honest and context-sensitive picture of the current landscape across all target regions.

As mentioned above, workshop activities exploring circular bioeconomy practices were carried out in Estonia, Poland, and Germany, hence, the description for these countries is based on these events. For Lithuania and Latvia, primary data was gathered through initial stakeholder workshops, which offered early insights into each country's bioeconomy landscape, but had to be supplemented with additional desk research, drawing on existing literature, policy frameworks, and relevant reports.

3.1 Poland

3.1.1 Key Barriers

Regulatory and Systemic Issues
Poland's waste and biogas sector faces significant regulatory challenges that hinder its development. Current legislation is highly restrictive, particularly due to the strict division between agricultural and waste-based biogas plants. This separation limits the flow of substrates and reduces opportunities for cooperation between facilities, ultimately weakening the efficiency of the system. Moreover, regulations are inconsistent across rural and urban areas, unclear requirements for new waste categories, such as textile segregation create uncertainty for operators, municipalities and citizens. Although the waste registration system (BDO) is mandatory, its implementation is often flawed. Misuse and lack of compliance undermine its effectiveness, reducing trust in the system.

Social Perception and Awareness
Public awareness of waste management, biogas, and circular economy systems remains very low. Many myths persist, such as the widespread belief that "all waste goes into one bin," which discourages proper separation and recycling efforts. Resistance from local communities is also common, often driven by concerns about unpleasant odors or misinformation about biogas facilities. In addition, opposition from certain groups (sometimes presenting themselves as environmental advocates but lacking scientific grounding) has blocked investments and slowed the expansion of sustainable infrastructure. These social barriers highlight the need for better education, transparent communication, and community engagement to build trust and acceptance.

Operational and Technical Barriers
Beyond regulatory and social issues, the sector struggles with practical and technical obstacles. Transporting waste streams between rural and urban areas is logistically difficult and costly, limiting the efficiency of collection and processing systems. Biowaste contamination is another serious

problem, with materials such as glass jars frequently mixed into organic waste. This contamination makes mechanical sorting impossible and reduces the quality of feedstock for biogas production. Finally, challenges in managing nutrient cycles (particularly the issue of excess nitrogen) pose risks to environmental sustainability and complicate the integration of biogas into broader agricultural systems. Addressing these operational barriers will require investment in infrastructure, improved waste segregation practices, and innovative solutions for nutrient management.

3.1.2 Underutilized Waste Streams

Food and Kitchen Waste
A significant portion of food waste generated by the HORECA sector (hotels, restaurants, and catering) continues to end up in mixed waste streams rather than being separately collected. This practice undermines opportunities for recycling and biogas production, while also increasing landfill volumes. Household food waste faces similar challenges, as segregation practices remain poor and inconsistent. Without effective separation at the source, valuable organic material is lost, and the potential for energy recovery or composting is greatly diminished.

Industrial Waste
Despite the considerable potential of industrial waste for biogas production, Poland has very few industrial biogas plants in operation. Several waste streams remain underutilized, including straw and other agricultural residues, which could serve as valuable feedstock. The cellulose and paper industry also generates large amounts of residues that are currently burned rather than recycled into energy. Coffee waste represents another overlooked resource, with its organic content suitable for biogas conversion. Unlocking these streams would require investment in infrastructure and supportive policies to encourage industrial-scale biogas development.

Packaging, Plastics and Biomaterials
Packaging waste management suffers from a lack of coordination and clarity. Segregation practices are insufficient, and disposal instructions are often unclear, leaving consumers uncertain about how to properly handle different types of packaging. Biodegradable packaging, in particular, frequently ends up in mixed waste due to unclear labelling and the absence of strong regulatory frameworks. This not only reduces recycling efficiency but also undermines the environmental benefits of biodegradable materials. Innovation is urgently needed in packaging design, chemical composition, and processing technologies to create materials that are easier to recycle and better integrated into circular systems.

Animal and Organic Waste
The processing of dead animals, such as the operations carried out by companies like the SARIA Group, already recovers water, fat, and meals. However, there is significant potential to expand such approaches and increase the recovery of valuable resources. Similarly, surplus bread and near-expiry products represent an untapped opportunity. Instead of becoming waste, these items could be redirected into food recovery programs or used as feedstock for biogas production. Developing systems to capture and repurpose these organic materials would strengthen circular economy practices and reduce unnecessary waste.

3.1.3 Needs and Opportunities

Information, Education, and Awareness
A strong need exists for improved information systems and public education in the field of waste management and biogas. Mapping waste streams across both rural and urban areas would provide a clearer picture of resource flows and highlight opportunities for more efficient use. Awareness-raising campaigns are equally important, as they can help citizens understand the benefits of proper segregation, the role of biogas in sustainable energy, and the broader concepts of the bioeconomy. Clear and unified labelling systems for packaging would further support these efforts, making it easier for consumers to dispose of materials correctly and reducing contamination in recycling streams.

Better Legislation and Policy Support
Policy reform is essential to unlock the potential of biogas and circular systems. The current biogas plant classification system should be restructured to allow more flexible use of substrates, enabling plants to adapt to local waste availability. In addition, stable regulations and targeted support mechanisms—such as subsidies for agricultural innovation and small-scale biogas plants—would encourage investment and foster growth in the sector. By creating a predictable and supportive legislative environment, policymakers can help build confidence among stakeholders and accelerate the transition toward sustainable waste management.

Tools for Cooperation
Collaboration between institutions, municipalities, and communities is crucial for effective waste management. Stakeholder maps that identify organizations willing to cooperate would provide a foundation for building partnerships and aligning efforts. The development of regional cooperation models could further enhance efficiency by pooling resources and managing waste streams collectively. Educational platforms dedicated to waste management, the bioeconomy, and local value chains would also play a vital role, offering knowledge-sharing opportunities and fostering innovation at the community level. Together, these tools would strengthen cooperation and create a more integrated approach to sustainability.

Key Stakeholders in Local Bioeconomy Development
During the workshop, municipalities and local governments were identified as the most important stakeholders in developing a local bioeconomy model. They are seen as having the greatest capacity and authority to initiate, coordinate, and promote bioeconomy-related development activities at the local level. Other key stakeholders include non-governmental organizations and local foundations, farmers and agricultural cooperatives, as well as educational institutions. These actors play an essential role in knowledge dissemination, community engagement, and practical implementation. Industry representatives and food processors were also recognized as crucial stakeholders, particularly as potential leaders in collaborative initiatives and value chain development.

Stakeholder Engagement and Communication Channels
Effective stakeholder engagement requires the use of trusted and accessible communication channels. Agricultural advisors, municipal communication platforms, and social media were identified as the most effective tools for reaching and mobilizing local actors. In addition, local events and women's rural organizations (KGW) should be actively involved, as they provide strong community networks and grassroots outreach. Combining the sale of local products with educational and informational activities was highlighted as a particularly promising approach, as it enhances product attractiveness while simultaneously raising awareness about bioeconomy principles.

Good Practices and Practical Measures

Promising models for local bioeconomy development include biorefineries that utilize multiple raw materials and agricultural cooperatives that share resources to create value within a circular economy framework. A concrete and actionable measure would be the establishment of cooperation platforms and networking forums. These could serve as spaces for initiating partnerships and building trust among stakeholders. Once initial connections are formed, cooperation could continue independently, fostering long-term collaboration and innovation.

3.1.4 Recommendations

1. Harmonize Biogas and Waste Legislation

Create a flexible, unified regulatory framework that removes the strict separation between agricultural and waste-based biogas plants.

- Allow mixed-substrate use based on local availability
- Standardize rules across rural and urban areas
- Clarify requirements for new waste streams (e.g., textiles, bio-packaging)

2. Launch a Nationwide Education Campaign

Develop a coordinated communication strategy to address misinformation and low awareness.

- Public campaigns explaining waste segregation and biogas benefits
- Transparent communication about odor, safety, and environmental impacts
- Clear, standardized labeling for packaging

3. Build Integrated Waste Stream Mapping

Establish digital and institutional platforms that map waste streams and connect stakeholders.

- Real-time or regional waste flow mapping (urban + rural)
- Stakeholder databases (municipalities, farmers, industry, NGOs)
- Regional cooperation models

4. Invest in Infrastructure for High-Quality Biowaste Collection

Prioritize systems that reduce contamination and improve feedstock quality.

- Better segregation systems (households + HORECA sector)
- Dedicated collection for food waste and industrial organic streams
- Pre-treatment and sorting technologies

5. Activate Underutilized Waste Streams

Introduce targeted financial and policy incentives to unlock key waste streams.

- Support industrial biogas plants (e.g., for straw, paper sludge, coffee waste)
- Incentivize food waste recovery (HORECA, surplus food, bread)
- Promote circular use of animal by-products

3.2 Germany

3.2.1 Key Barriers

Policy and Regional Context
The development of the bioeconomy in Germany takes place within a specific policy and regional framework. Workshop demonstrated that bioeconomy policies are often perceived as complex or unclear, making it difficult for stakeholders to translate strategic objectives into concrete actions. In addition, transferring research results into practical applications remains a challenge, as innovations developed in academic settings do not always align easily with real-world conditions.

Berlin is a major metropolitan area, but it is geographically embedded within a predominantly rural region. In Germany, land availability is generally not a major constraint, and competition between urban and rural areas is relatively limited. On the contrary, Berlin actively promotes locally and regionally produced food, demonstrating the potential for stronger and mutually beneficial urban–rural linkages.

Biowaste, Biogas, and Resource Utilization
Biogas production and waste management form central pillars of Germany's bioeconomy. In Berlin, the collection of biowaste is mandatory and managed by the municipality. However, practical challenges persist, particularly regarding effective sorting and collection. Approaches vary between cities, reflecting differences in infrastructure and implementation practices.

Private companies also contribute to the system by collecting biowaste from restaurants. Public acceptance is generally not a major barrier, as concerns such as odors are relatively limited. Despite these efforts, several biological resources remain underutilized. For example, crayfish (an invasive species that has spread widely in Berlin's rivers) are not harvested for biomass due to low profitability. Coffee grounds are reused, but only on a small scale, indicating untapped potential for expanding circular solutions.

Rural–Urban Symbiosis and its implementation
The broader perspective of rural–urban symbiosis reveals both challenges and opportunities. While rural depopulation remains a concern in some areas, there is also a growing trend of people moving to the countryside, even without intending to engage in farming. This shift opens up possibilities for new types of rural economic activity.

Straw, for example, can serve as a sustainable construction material. As the carbon footprint of buildings becomes an increasingly important issue, sustainable building materials must become more cost-competitive with conventional alternatives. Public procurement can play a decisive role in accelerating this transition by prioritizing sustainable solutions and creating stable market demand. Without viable markets, even the most sustainable products cannot succeed.

Several innovative approaches illustrate the diversity of biobased solutions (e.g. moss is already used in water purification systems). The existing examples highlight both the complexity and the considerable potential of developing integrated, market-driven bioeconomy systems that strengthen rural–urban connections.

Structural Barriers to Local Bioeconomy Models

Despite progress, significant obstacles hinder the development of local bioeconomy models in Germany. One major challenge lies in inadequate collection and sorting infrastructure, particularly for biowaste. Logistical inefficiencies, long emptying intervals, and odor problems reduce system effectiveness. Low household sorting rates often result in biowaste being incinerated, leading to rapid loss of value when side streams are not separated in time. Furthermore, there are limited market incentives for recycling, and traceability is weak. Consumers often do not perceive tangible benefits from sorting waste and may question whether separated waste is actually recycled.

Cooperation also presents challenges, especially with farmers' organizations. Many actors do not see clear and direct benefits from participating in new initiatives. Language differences, lack of trust, and the multi-layered structure of agricultural organizations can complicate collaboration. The political environment is at times contradictory: traditional solutions, such as using waste for energy in district heating systems, may compete with or replace separate biowaste collection. In some contexts, the circular economy is framed as an ideological debate, slowing decision-making processes.

Urban farming is viewed as promising but faces structural limitations in Berlin. Much of the existing building stock does not support green roofs or productive surfaces. Future construction would need to integrate design principles that enable urban farming.

Germany already has a substantial number of biogas plants; however, feedstock availability is limited. Therefore, local bioeconomy models should increasingly focus on higher-value products and nutrient cycles rather than additional energy production.

3.2.2 Needs and Opportunities

Strengthening Urban-Rural Linkages
As noted above, Germany's bioeconomy operates within a favorable regional context. Land availability is generally not a major constraint, and competition between urban and rural areas is relatively limited. Berlin, although a major metropolitan area, is embedded in a predominantly rural region, offering strong potential for mutually beneficial urban–rural cooperation. Berlin's promotion of locally and regionally produced food demonstrates how urban demand can strengthen rural economies. Rural–urban symbiosis can create new economic opportunities, particularly as some rural areas experience demographic shifts, including new residents who may engage in alternative forms of rural economic activity.

Improving Collection Systems and Circular Infrastructure
Enhancing biowaste collection and sorting infrastructure is essential to unlock value from organic side streams. More efficient logistics and stronger incentives for households and businesses could significantly improve resource recovery rates.

Expanding High-Value Biobased Applications
Future local bioeconomy models should increasingly focus on higher-value products and nutrient cycles rather than additional energy production. Examples of innovative biobased solutions include:

- Moss-based water purification systems
- Technologies that treat urine and convert it into drinking water (with further work needed to address heavy metal contamination)
- Sustainable construction materials such as straw

These approaches highlight the diversity of potential biobased applications and the importance of moving beyond energy-focused pathways.

Leveraging Public Procurement and Market Creation
Public procurement can play a decisive role in accelerating the transition toward sustainable materials and biobased solutions. By prioritizing sustainable products, public authorities can create stable demand and enable market scaling. Without such market formation mechanisms, innovative and sustainable solutions are unlikely to reach commercial maturity.

Mobilizing Key Stakeholders
Key stakeholders in Berlin and across Germany include national and local decision-makers, ministries, cities, and federal states. Companies, particularly start-ups in food processing, chemicals, and material technologies, should play an active role in innovation and commercialization.

Farmers and agricultural cooperatives, including aquaculture producers, are essential actors, though the multi-layered nature of agricultural representation (e.g., European, national, and regional associations) must be taken into account. Researchers and educational institutions are vital for knowledge production, mapping of side streams, and piloting new solutions. Consumers and households also play an important role through sorting behavior, purchasing decisions, and participation in incentive schemes.

A successful bioeconomy transition requires coordinated engagement of:

- National and local decision-makers, ministries, cities, and federal states
- Companies, particularly start-ups in food processing, chemicals, and material technologies
- Farmers, agricultural cooperatives, and aquaculture producers
- Researchers and educational institutions (for knowledge production, side-stream mapping, and piloting)
- Consumers and households (through sorting behavior, purchasing decisions, and participation in incentive schemes)

Stronger cooperation across these groups is essential to develop integrated, market-driven bioeconomy systems that reinforce rural–urban connections.

3.2.3 Recommendations

Effective Stakeholder Engagement Strategies

Workshop participants identified several effective approaches for stakeholder engagement:

1. **Concrete Incentives**

Both financial incentives (e.g., discounts, deposit systems, “green pass” models) and social incentives (e.g., competitions, visible traceability) can drive participation. The German bottle deposit system (Pfand), with its high return rates, serves as a successful example.

2. **Test Platforms and Pilot Collection Systems**

Starting with small-scale pilots allows for the development of collection standards (e.g., fast pickup, cleanliness), demonstration of measurable benefits, and gradual scaling.

3. **Combining Sales and Education**

The sale of local products can be combined with practical workshops (e.g., upcycling, recipes using side streams) to promote behavioral change and awareness.

4. **Building Trust-Based Relationships with Farmers**

Engagement with farmers is most effective when clear channels for influence exist, such as access to decision-makers, visibility, and funding pathways.

5. **Networking and Visibility of Information**

Scattered expertise (start-ups, research institutions, and municipal departments) should be brought together on common platforms to reduce “blind spots” within the ecosystem.

Promising Models and Future Directions

The workshop identified several promising development pathways:

- **High-value side stream utilization**, such as mushroom-based materials and foods, and bio-composites.

- **Soil regeneration and nutrient cycling**, using solutions such as biochar, compost, and rock flour, as well as biological methods involving fungi, bacteria, and hemp. These approaches generate both environmental and economic benefits.

- **Urban farming and biodiversity solutions**, including green roofs, insect-friendly construction elements (“insect bricks”), and local gardens. These require updated design guidelines for new buildings.

- **Blue bioeconomy pilots**, particularly the utilization of Baltic Seaside streams (e.g., shellfish and fish processing residues) for feed or specialty products. Consumer-facing products (such as dog food made from shellfish) can increase visibility and stimulate demand.

- **Clear Value Hierarchy and Cascading Use**

  Side streams should first be directed toward higher value-added applications—such as nutrient recovery, food-grade uses, and materials—before being used for energy production.

3.3 Estonia

3.3.1 Key Barriers

Regulatory Barriers

Current regulations prohibiting the mixing of wastewater sludge with manure, regardless of sludge quality, limit nutrient recycling opportunities. The practice of using horse manure for biogas production was actively discussed during the workshops. Current regulations in Estonia as well as in the EU don't allow mixing wastewater sludge with manure for fertilization, regardless of sludge quality. Yet sludge from small, non-industrial towns may be clean and safe. A policy recommendation is to allow case-by-case analysis: if sludge is free of heavy metals, its digestate could be used as fertilizer, supporting nutrient recovery and circular practices. Until now, mixing wastewater sludge with manure means the resulting digestate can't be used as fertilizer as it falls under sludge regulations and is limited to landscaping use, losing valuable nutrients. Without differentiated, risk-based assessment frameworks, valuable nutrients are lost from agricultural cycles.

Furthermore, complex and sequential planning procedures create significant barriers to bioeconomy investment. Long administrative timelines reduce investment attractiveness and slow down circular innovation. Where environmental assessments and public participation processes are not coordinated efficiently, innovation cycles are extended, affecting competitiveness and resource utilization. It has been discussed that foreign investors are discouraged from entering the market due to the almost three-year detailed planning process, including mandatory public involvement procedures. This suggests a need for policy reform, which would help to streamline planning timelines, introduce flexibility in stakeholder engagement, and as a result to create fast-track pathways for strategic investments.

Ambiguity in Terminology

Unclear distinctions between "waste" and "by-products" create legal uncertainty and hinder market development. For example, digestate from biogas production may be regarded as a residue under national regulations while being considered an inherent production by-product by operators. Inconsistent waste codes and sector-specific ambiguities complicate transactions, increase administrative burdens, and limit participation in digital marketplaces designed to facilitate industrial symbiosis.

Circular Economy Education in the Agricultural Sector

As discussed during the workshops, young farmers demonstrate strong interest in circular and responsible farming practices, yet they face uncertainty in implementation. This reflects a broader European challenge of translating sustainability ambitions into farm-level practice (European Commission, 2018). The absence of structured guidance and applied circular economy support systems creates a gap between education and operational reality.

3.3.2 Needs and Opportunities

Expanding Farm-Based Circular Tourism

Estonia has significant potential to scale up farm-based tourism models that integrate sustainability education, rural development, and circular economy principles. Strengthening such initiatives would enhance rural–urban linkages, deepen public understanding of food systems, and create diversified income streams for small farms. Although the concept of family-friendly rural experiences that combine leisure, education, and sustainability has strong potential in Estonia, it remains insufficiently developed

and institutionalized. Farm-based tourism, where families actively participate in seasonal agricultural activities, represents an approach consistent with short supply chains and sustainable food system transitions promoted at EU level (European Commission, 2018; 2020a). However, it is not yet systematically integrated into tourism strategies or rural development frameworks. As a result, opportunities to strengthen consumer awareness, reconnect people with food production, and diversify farm income remain underutilized.

Regulations and Administrative Efficiency
Regulatory reform allowing case-by-case assessment of wastewater sludge quality represents a significant opportunity. Where sludge meets strict contaminant thresholds, digestate could be approved for agricultural use, enabling nutrient recycling and reducing dependence on synthetic fertilizers. Such an approach would support the goals of the EU Circular Economy Action Plan and contribute to closing phosphorus and nitrogen cycles in a scientifically sound manner.

Improving administrative efficiency would substantially enhance the investment climate in rural bioeconomy sectors. Conducting environmental assessments and public consultations in parallel rather than sequentially could shorten approval timelines without weakening environmental safeguards. Simplifying permit applications for low-risk, small-volume waste streams would increase operational flexibility for biogas facilities and other circular enterprises. Digitalized and standardized permitting systems could further improve transparency and predictability.

Clarifying Waste and By-Product Definitions
Providing clearer national guidance on waste classification and aligning interpretations with EU waste framework principles would strengthen legal certainty. Establishing transparent end-of-waste criteria for digestate and similar residues would facilitate their integration into agricultural and industrial markets. Clear definitions would also enhance the functioning of digital marketplaces and industrial symbiosis initiatives by reducing administrative ambiguity.

Opportunities for Food Waste Utilization
Beyond biogas production, Estonia could expand into food waste prevention systems, composting, safe animal feed recovery, and biobased material innovation. Prioritizing material recovery pathways would better reflect the EU waste hierarchy, which emphasizes prevention and reuse before energy recovery. Diversifying utilization routes would maximize the value retained within the system.

Developing Industrial Symbiosis Parks
The establishment of industrial symbiosis parks near existing biogas facilities offers strong potential for integrated regional development. Such parks could combine pyrolysis units for woody biomass, nutrient recovery installations, and enterprises capable of sharing locally generated energy, water, and materials. This systemic approach would reinforce rural–urban symbiosis, strengthen regional circular value chains, and increase overall resource efficiency.

The discussion topics presented above were provided as the input to Waste Reform taking place in Estonia (as of October 2025). The conclusions are also very relevant for the Estonian Circular Bioeconomy Roadmap, which is in the process of renewal.

3.3.3 Recommendations

1. Introduce Risk-Based Nutrient Recovery Regulation

A shift toward a risk-based, science-driven regulatory framework for nutrient recovery would allow safer and more efficient use of wastewater sludge and digestate in agriculture.

- Introduce case-by-case assessments based on contaminant thresholds.
- Allow agricultural use of sludge-based digestate from small, non-industrial municipalities when strict quality criteria are met (e.g., heavy metals, pathogens, organic pollutants).
- Establish clear standards, monitoring protocols, and traceability systems to safeguard environmental and public health.

2. Streamline Planning and Environmental Permitting Procedures

Improving planning and environmental permitting system would make bioeconomy investments more attractive and significantly shorten project approval timelines.

- Conduct public consultation, environmental impact assessment, and detailed planning procedures in parallel rather than sequentially. This could significantly reduce project approval timelines from multiple years to a more competitive timeframe.
- Introduce simplified and fast-track permitting for low-risk circular economy projects and small-volume, short-notice waste streams. These measures would reduce barriers for domestic and foreign investors.

3. Clarify Waste and By-Product Definitions

Raising awareness about the distinction between “waste” and “by-product” and reducing sector-specific ambiguities would improve legal certainty and strengthen industrial symbiosis initiatives. Clear classification frameworks are essential for unlocking secondary material markets and reducing administrative burdens.

4. Strengthen Circular Economy Education

Strengthening circular economy education in Estonia is essential for closing the gap between sustainability ambitions and farm-level implementation. Providing accessible guidance would enable young producers to confidently implement nutrient recycling, side-stream valorization, and sustainable farming practices.

- Establish structured knowledge-transfer systems dedicated to circular agriculture. This could include practical toolkits, dedicated circular economy extension services, mentorship networks, and targeted training programs for young farmers.
- Embed applied circular economy competencies into agricultural and vocational education curricula.

5. Promote Diversified Food Waste Valorization Pathways

Estonia could expand food waste management strategies beyond biogas production toward higher-value and prevention-oriented approaches. Priority should be given to food waste prevention systems, composting, and safe animal feed recovery where appropriate. Diversifying valorization pathways would maximize resource efficiency within the national bioeconomy.

6. Develop Industrial Symbiosis Parks Linked to Biogas Facilities

Developing industrial symbiosis parks around existing biogas facilities would strengthen Estonia’s circular value chains and create integrated hubs for resource-efficient regional development. These

integrated hubs could enhance rural–urban linkages and demonstrate systemic circular bioeconomy models.

- Support the creation of industrial symbiosis parks through targeted policy tools and regional development funding.
- Co-locate complementary technologies such as pyrolysis units, nutrient recovery systems, and resource-sharing enterprises.
- Enable shared energy, water, and material flows to improve overall resource efficiency.

7. Integrate Farm-Based Circular Tourism into Rural Development Policy
Integrating farm-based tourism that combines sustainability education, leisure, and participation in agricultural activities into national rural development and tourism policy would help diversify farm incomes while strengthening public engagement with sustainable food systems.

- Embed farm-based tourism models into national tourism and rural development strategies
- Provide financial incentives, promotional support.
- Encourage sustainability-focused visitor experiences that combine education, leisure, and hands-on agricultural activities.
- Raise public awareness of sustainable food systems.

3.4 Latvia

3.4.1 Key Barriers

Latvia has taken concrete steps toward circular bioeconomy implementation, but several systemic barriers persist. The circular material use rate remains lower than the EU average, reflecting challenges in transforming waste streams into secondary raw materials and in scaling circular industrial processes. According to the *Latvia 2024 Circular Economy Country Profile* by the European Environment Agency, material consumption efficiency and use of recycled inputs lag relative to EU benchmarks, highlighting structural and infrastructure gaps that constrain circular resource flows (EEA 2024).

Household recycling and biowaste collection systems also face challenges. Separate collection mandates introduced recently have underlined the need for tailored evaluation frameworks and municipal capacity to sustainably manage food and organic waste, as detailed in research on biowaste management practices in Latvia (Cudecka-Purina 2025). Likewise, workshops participants mentioned that overall public knowledge about circular opportunities remains limited, especially among citizens. Participants highlighted the need for better material design, improved supportive digital tools, and stronger cooperation between research institutions, public administration, and the circular economy sector to accelerate advances in waste management and recycling. They also emphasized the importance of a supporting legal framework and noted that economic incentives can significantly influence household willingness to recycle or compost biowaste.

The *Latvian Bioeconomy Strategy 2030* underscores the country's potential in agriculture and forestry but also notes that natural capital remains inefficiently used. Achieving the strategy's ambitious objectives (such as raising bioeconomy value-added, exports, and employment) requires improved policy coherence and stronger stakeholder engagement. Additionally, national studies and projects such as the *Waste To Resources* initiative highlight ongoing challenges with packaging waste recycling,

biowaste systems, and the development of secondary raw materials markets, indicating that structural barriers remain in household and industrial waste systems (*Waste to Resources Latvia* 2023).

3.4.2 Needs and Opportunities

Latvia has notable opportunities to strengthen its circular bioeconomy by accelerating strategic policy integration. The *Latvia 2024 Circular Economy Country Profile* demonstrates that national strategies such as the Action Plan for Transition towards Circular Economy 2020–2027 provide a policy foundation to improve material efficiency and resource productivity if fully implemented (EEA 2024).

Latvia's bioeconomy sectors, including agriculture and forestry, offer underutilized feedstocks suitable for higher-value applications if adequate processing and logistics infrastructure is developed (*Mapping Latvia's biobased potential* 2020). Tools to increase public awareness and participation in resource sorting (e.g., home composting incentives) can enhance biowaste capture rates and foster community engagement in circular practices, according to recent research on household biowaste management (Cudecka-Purina 2025).

Also, International collaboration platforms such as the *Agri-Biocircular Hub* project present opportunities to link Latvian agrifood and bioeconomy actors with wider European networks, promoting innovation and attracting investment into circular bioeconomy solutions[1].

3.4.3 Recommendations

1. Strengthen Implementation of the Bioeconomy Strategy 2030
Latvia has laid important groundwork through its Bioeconomy Strategy 2030, but the next step is to shift from high-level vision to concrete, coordinated implementation.

- Translate strategic objectives into measurable indicators and sector-specific action plans.
- Define clear institutional responsibilities to support accountability.
- Improve coordination among ministries responsible for agriculture, environment, innovation, and economic development.

2. Improve Biowaste Collection and Feedstock Quality
Although separate biowaste collection is now mandatory across Latvia, the quality and consistency of implementation differ significantly between municipalities.

- Address systemic barriers in household sorting behavior and collection efficiency.
- Strengthen public engagement to improve participation and reduce contamination.
- Develop clearer operational guidelines for municipalities and waste operators.

3. Strengthen SME Support
Small and medium-sized enterprises are central to Latvia's rural and bioeconomy sectors, yet many face financial and technical barriers that limit their ability to adopt circular and innovative practices.

- Expand advisory services to strengthen SME capabilities.

[1] The Investment and Development Agency of Latvia, together with partners from four countries, will implement the "AGRI-BIOCIRCULAR-HUB" project | Latvijas Investīciju un attīstības aģentūra

- Improve access to risk-sharing finance instruments to support circular business model uptake.
- Build on collaborative platforms like the *Sustainable Circular Bioeconomy HUB* to enhance knowledge transfer and multi-actor cooperation.

4. Promote Industrial Symbiosis and Regional Clustering

Industrial symbiosis initiatives in Latvia show strong potential for linking sectors and enabling circular value chains, but broader regional scaling is needed to fully realise these benefits.

- Build on cross-sector cooperation models such as the *Waste to Resources Latvia* project to enhance secondary material exchange.
- Develop regional cluster approaches that connect agriculture, forestry, food processing, waste management, and energy sectors.
- Strengthen cross-border collaboration through platforms like BIOEAST to support knowledge-intensive bioeconomy development.

3.5 Lithuania

3.5.1 Key Barriers

Lithuania has developed several strategic and analytical documents addressing bioeconomy potential; however, it lacks a fully integrated and formally adopted national bioeconomy strategy. Bioeconomy objectives are embedded across multiple policy domains, resulting in fragmented governance (BIO-EAST Initiative, 2023).

The country's circular material use rate remains relatively low compared to leading EU Member States, reflecting limited secondary raw material utilization and infrastructure gaps (European Environment Agency, 2024). National assessments of Lithuania's bioeconomy indicate structural dependence on lower value-added biomass sectors and insufficient technological upgrading for higher-value biobased production (European Commission, 2022).

Industrial collaboration across sectors remains uneven, and circular innovation ecosystems (in textiles, plastics, and advanced biobased materials) are still developing (ACR+, 2023). Administrative complexity and limited coordination across environmental, agricultural, and innovation policies can further slow commercialization of circular solutions.

At the consumer level, waste separation continues to pose challenges, with workshop participants noting that household biowaste collection is particularly difficult. Some even suggested looking to the South Korean model, where households are required to separate food waste or face fines, though they also acknowledged that such an approach works partly because South Korea has a highly disciplined societal culture.

3.5.2 Needs and Opportunities

Lithuania has strong biomass resources and growing biotechnology, positioning it well for expansion into higher-value biobased materials, bioenergy, and biochemical production (European Commission, 2022). Developing a comprehensive national bioeconomy strategy would improve policy coherence, clarify stakeholder roles, and align circular bioeconomy development with EU objectives (BIOEAST Initiative, 2023).

Strengthening recycling infrastructure, implementing circular public procurement policies, and expanding financial support mechanisms for small and medium-sized enterprises (SMEs) would further accelerate the uptake of circular business models (European Environment Agency, 2024). In addition, the establishment of pilot and demonstration facilities (such as biorefineries) would enable the transition from low-value biomass use to higher-value biobased production, improving competitiveness and innovation capacity (Aleinikovas et al, 2023).

Investment promotion initiatives such as national bioeconomy investment programs illustrate the country's potential to attract foreign direct investment into circular biobased industries (Invest Lithuania, 2023). Strengthening cross-sector collaboration and industrial symbiosis networks would further support value retention within regional supply chains.

3.5.3 Recommendations

1. Develop and Implement a National Circular Bioeconomy Strategy
Lithuania could benefit from introducing a comprehensive, cross-sectoral bioeconomy strategy that integrates agriculture, energy, waste management, and innovation policies. This will reduce policy fragmentation and improve coordination.

- Define clear governance structures and stakeholder roles.
- Align with EU Green Deal and Bioeconomy Strategy.
- Establish measurable targets (e.g., circular material use, biobased production).

2. Strengthen Circular Infrastructure
Invest in recycling systems and waste valorisation infrastructure to improve circular material use rates. This helps to address current infrastructure gaps and low circularity performance (EEA, 2024).

- Expand separate collection and sorting systems.
- Develop markets for secondary raw materials.
- Introduce circular public procurement.

3. Support Innovation Ecosystems and Demonstration Projects
Accelerate innovation by supporting pilot plants, living labs, and demonstration facilities. This helps to scale circular solutions and reduce commercialization risks.

- Focus on textiles, plastics, and biobased materials.
- Provide funding for SMEs and start-ups.
- Foster collaboration between academia and industry.

4. Enhance Cross-sector Collaboration and Industrial Symbiosis
Strengthening networks between agriculture, industry, and municipalities to optimize resource use will help to improve resource efficiency and enables circular value chains.

- Encourage clustering and regional cooperation.
- Facilitate knowledge-sharing and partnerships.

4. CONCLUSIONS & CRITERIA OF TRANSFERABILITY

Poland, Germany, and Estonia are at different stages of development in the field of biogas production, which was reflected in the varying focus of the workshops. In Poland and Estonia, discussions primarily concentrated on existing local biogas models, with particular emphasis on biogas production and the use of digestate as recycled fertilizer. In contrast, stakeholders in Germany demonstrated a stronger interest in advancing toward higher value-added applications, such as the production of pharmaceuticals and other advanced products derived from biobased side streams. A similar distinction can be observed in Lithuania and Latvia, where the bioeconomy is still largely based on primary biomass production, with ongoing efforts to shift toward higher value-added biobased products and integrated circular systems. Despite these differences in focus and maturity, many of the identified challenges and barriers were notably similar across all countries.

One of the most significant barriers is **the lack of effective cooperation between stakeholders**, which largely stems from structural limitations. There are no established or natural mechanisms to facilitate collaboration, meaning that cooperation must be actively initiated and supported. This requires dedicated actors, as well as organized platforms such as events, networks, and coordination bodies that can bring together stakeholders from different sectors. Similar challenges have been identified in Lithuania, where fragmented governance and weak cross-sectoral coordination limit the development of integrated bioeconomy value chains, as well as in Latvia, where stronger institutional leadership is needed to foster cooperation and local bioeconomy initiatives.

Regulatory constraints also represent a major obstacle to the development of local bioeconomy models. In many cases, strict, complex, or fragmented regulations limit opportunities for innovation and resource use. For example, the use of digestate as a recycled fertilizer can be restricted if it contains certain regulated inputs, even when it is otherwise suitable for agricultural use. Similarly, the utilization of biobased side streams for higher value-added products is often hindered by complex administrative requirements. Farmers and other primary producers frequently face a significant bureaucratic burden before these materials can be transferred to industrial applications. Comparable issues are evident in Poland, where strict separation between waste-based and agricultural biogas systems limits efficiency, and in Lithuania, where the absence of a unified bioeconomy strategy contributes to policy fragmentation and regulatory uncertainty.

In addition, **a widespread lack of information and awareness** poses a critical barrier. This challenge manifests at multiple levels: consumers may lack the knowledge needed to properly sort waste, leading to inefficiencies in recycling systems, while producers of biobased side streams—such as farmers—may not fully recognize the potential value of their by-products. In Latvia, for instance, low public awareness and unclear labeling systems contribute to poor waste segregation, while in Lithuania similar gaps exist in understanding circular bioeconomy opportunities among stakeholders. Overall, insufficient knowledge sharing and limited access to reliable information constrain the development of circular and local bioeconomy systems. Addressing this gap will require targeted education, improved communication strategies, and stronger knowledge exchange between stakeholders.

Finally, across all countries a structural challenge remains **the limited transition from low value-added biomass use toward higher value-added biobased production**. While significant biomass resources exist, their potential is not fully utilized due to technological, financial, and organizational barriers. Strengthening innovation systems, investing in biorefineries and pilot projects, and supporting industrial symbiosis are therefore essential to enable a more advanced and competitive circular bioeconomy.

Across the analysed countries, **several common barriers** consistently hinder the development of a circular bioeconomy. These challenges are interrelated and reflect both governance limitations and practical implementation gaps:

- Fragmented policies and unclear regulatory frameworks
- Low public awareness and social acceptance
- Insufficient waste separation and infrastructure for that
- Limited cross-sector collaboration
- Dependence on low value-added biomass use

Criteria of Transferability

The successful transfer and replication of circular bioeconomy practices depend on a set of enabling conditions that support both innovation and system integration. These factors influence not only the effectiveness of implementation but also the scalability and long-term sustainability of bioeconomy solutions across different regional contexts. Ensuring that these conditions are in place increases the likelihood that good practices can be adapted, adopted, and sustained beyond their original setting.

1. **Coherent and stable policy framework**
   A clear, consistent, and long-term policy environment is essential to reduce uncertainty and encourage investment. Integrated policies that align agriculture, waste management, energy, and innovation sectors enable coordinated action and support the development of circular value chains.

2. **Strong stakeholder cooperation (public – private – local)**
   Effective collaboration between municipalities, industry, farmers, research institutions, and civil society is crucial. Multi-level governance and cross-sector partnerships facilitate knowledge exchange, resource sharing, and the co-creation of locally adapted solutions.

3. **High-quality waste collection and data systems**
   Reliable waste segregation systems and accurate data on material flows are fundamental for efficient resource management. High-quality inputs (e.g., uncontaminated biowaste) and transparent data enable better planning, optimization, and monitoring of circular processes.

4. **Access to technology, innovation, and pilot facilities**
   The availability of technological solutions, research capacity, and demonstration projects supports experimentation and reduces risks associated with new business models. Pilot and demonstration facilities are particularly important for scaling up innovative biobased processes.

5. **Public awareness and community engagement**
   Social acceptance and active participation of citizens are key to the success of circular systems. Awareness-raising, education, and transparent communication improve waste sorting behavior, build trust in biobased solutions, and strengthen local ownership of initiative.

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ANNEX 1

Table 1. Replication workshops on bioeconomy topics.

Date	Location (if applicable)	Participants
24.03.2023	Estonia, Tallinn - onsite	18 (city and state level authorities, recycling organisations, private companies, associations)
19.5.2023	Latvia, Riga - onsite	16 (students, municipality/policy makers, researchers, companies)
23.5.2023	Lithuania, online	16 (students)
20.06. 2023	Poland	58 (companies, municipalities, academia, consultancy)
4.02.2025	Estonia, online	59 participants from Estonian local governments
24.04.2025	Warsaw, Poland - onsite	29 participants representing the following organisations: research institutions, professional associations such as National Bioeconomy Hub and Association Bioeconomy Cluster, local authorities, Polish Federation of Food Producers, Polish Chamber of Waste Management, Inspectorate for Environmental Protection, private companies both in retail of petrol as well as (food) waste management.
23.09.2025	Berlin, Germany - onsite	22 participants representing bioeconomy clusters, circular economy NGOs, research organization and industry representatives.
11.11.2025	Tallinn, Estonia - onsite	20 participants representing local governments in Estonia, research institutions, the representatives of the Ministry of Agriculture, biogas industry, farmers union, association of Estonian local governments and rural areas.