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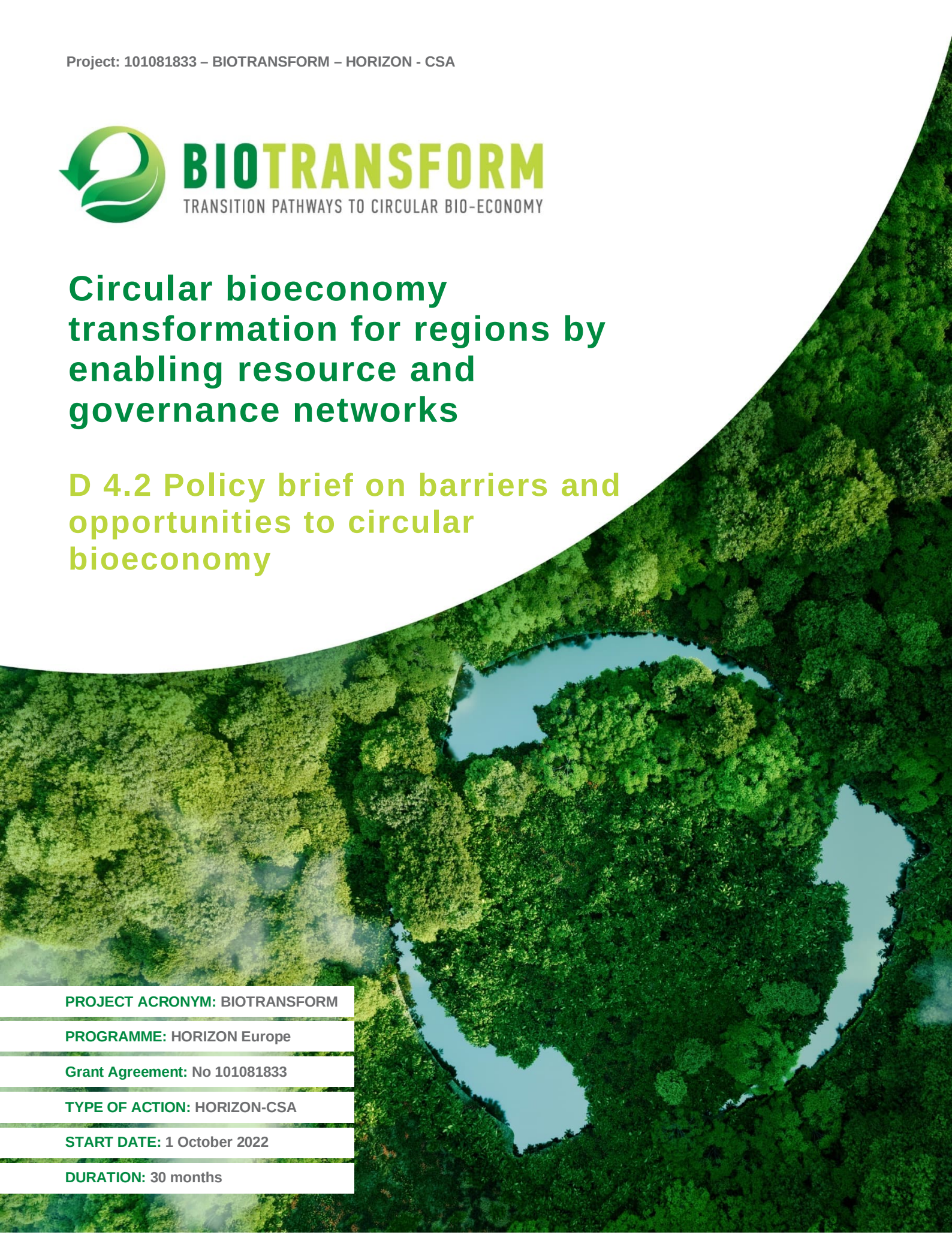
BIOTRANSFORM
TRANSITION PATHWAYS TO CIRCULAR BIO-ECONOMY

Circular bioeconomy transformation for regions by enabling resource and governance networks

D 4.2 Policy brief on barriers and opportunities to circular bioeconomy



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Executive Summary

Circular bioeconomy lies at the intersection of circular economy and bioeconomy, both of which have been identified as key contributors to the delivery of the European Commission's Green Deal objectives and related strategies.

This background paper aims at providing an overview of the opportunities created by a shift to a circular biobased system, and of the key barriers hampering this transition at regional level, using illustrations from the BIOTRANSFORM pilot cases. This document also briefly outlines how the assessment framework addresses these regional challenges using a holistic approach based on life cycle thinking. The methodology tested through these exemplified use cases can be replicated to many more European regions. Adopting such a framework equips regional policymakers with the tools to render well-informed decisions tailored to their regional limitations. This white paper is a first step into the creation of technical guidelines for regional authorities to address governance and financing barriers to the transition within their strategy, and the definition of final policy recommendations to lift the identified barriers.

1. Introduction

Based on the European Commission's definition, bioeconomy comprises those parts of the economy that use renewable biological resources from land and sea – such as crops, forests, fish, animals and micro-organisms – as well as their residual streams to produce food, materials and energy. On the other hand, circular economy is an economic system in which the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste is minimized (EU, 2015). Circular bioeconomy is thus the application of the concept of circular economy to biological resources. Circular bio-based systems can rely on various feedstocks, both virgin and secondary bio-based materials, but they must follow circular principles, i.e. the optimization of resource consumption, the prevention of losses and waste, or the optimal re-use and recycling generated waste, as well as the recovery and return of nutrients to the field. Circular bioeconomy has been defined by the European Commission as a catalyst for systemic change, with the potential to contribute to all dimensions of the Green Deal by producing fossil-free materials, enhancing the protection of the environment and ecosystems, while also delivering on Europe's economic prosperity and ensuring a Fair and Just transition (EC, 2020).

The 2018 EU bioeconomy directive prioritizes sustainability and circularity to achieve Sustainable Development Goals (SDGs) by replacing conventional products with a more sustainable biobased system, surpassing fossil-based benchmarks. Implementing this entails overcoming environmental, socio-economic limitations, and addressing policy, governance, and technical challenges. The key hurdles are varying biomass capacities and types, technology adaptation, infrastructure development, policy regulation, and socio-economic challenges. Furthermore, it also requires economic viability and market access through a collaborative approach.

While circular bioeconomy has the potential to deliver significant benefits, by substituting fossil-based resources by renewable ones and by applying the circularity principles aiming to optimize resource consumption, ongoing analyses within the BIOTRANSFORM project have highlighted that closing the loop of nutriments in specific biobased processes does not consistently yield significant environmental advantages. It is important to note that bioeconomy is not necessarily circular by essence, although it relies on renewable resources, and that the principles of the circular economy are not universally applicable to the bioeconomy; instead, a distinct set of considerations is necessary. For instance, the cultivation of primary feedstock for biobased products should not lead to the degradation or the depletion of natural resources (such as water and soil), nor should the hunger for biomass as feedstock yield to vast monocultures of maize or other quickly growing biomass plants. Very often, industrial applications ask for economies of scale, which is to be seen as critical, when it comes to biomass production, their associated land management, and their logistics. Also, biobased products should be designed and produced so that they follow circularity principles (extended lifetime, possibility to be re-used, repaired, and ultimately only if there is no other feasible option recycled or composted). It is also to be noted that all biobased materials are not always degradable and mixing biomaterial with fossil material makes the recycling difficult.

2. The BIOTRANSFORM project

Before transitioning to a circular biobased system, a thorough assessment is essential to determine whether the overall sustainability of the new bio-based system and product surpasses that of conventional alternatives. Additionally, evaluations should incorporate a local perspective to ascertain the acceptability of potential trade-offs.

The BIOTRANSFORM project aims to address the key hurdles through a holistic, comprehensive framework in six European regions involving collaboration between governments, industries, research institutions, and local communities. The project aims to implement an integrated assessment framework, tailoring a methodology for the decision-makers. The BIOTRANSFORM assessment package will employ three established evaluation tools (the Impact Assessment Tool, IAT; the Resource Flow Analysis (RFA) Tool, and the Logistics MOOV Tool) and a variety of indicators. The evaluation of circular bio-based transition pathways, considering regional challenges, policy, governance, and intervention methodologies will foster robust and effective EU-wide transition toward a sustainable bioeconomy. Emphasis is placed on meticulous consideration of environmental and socio-economic dimensions, local interlinkages, and feedback effects within regional policy governance and financial opportunity. The schematic of the Bioeconomy framework with various steps and the feedback loop is shown below:

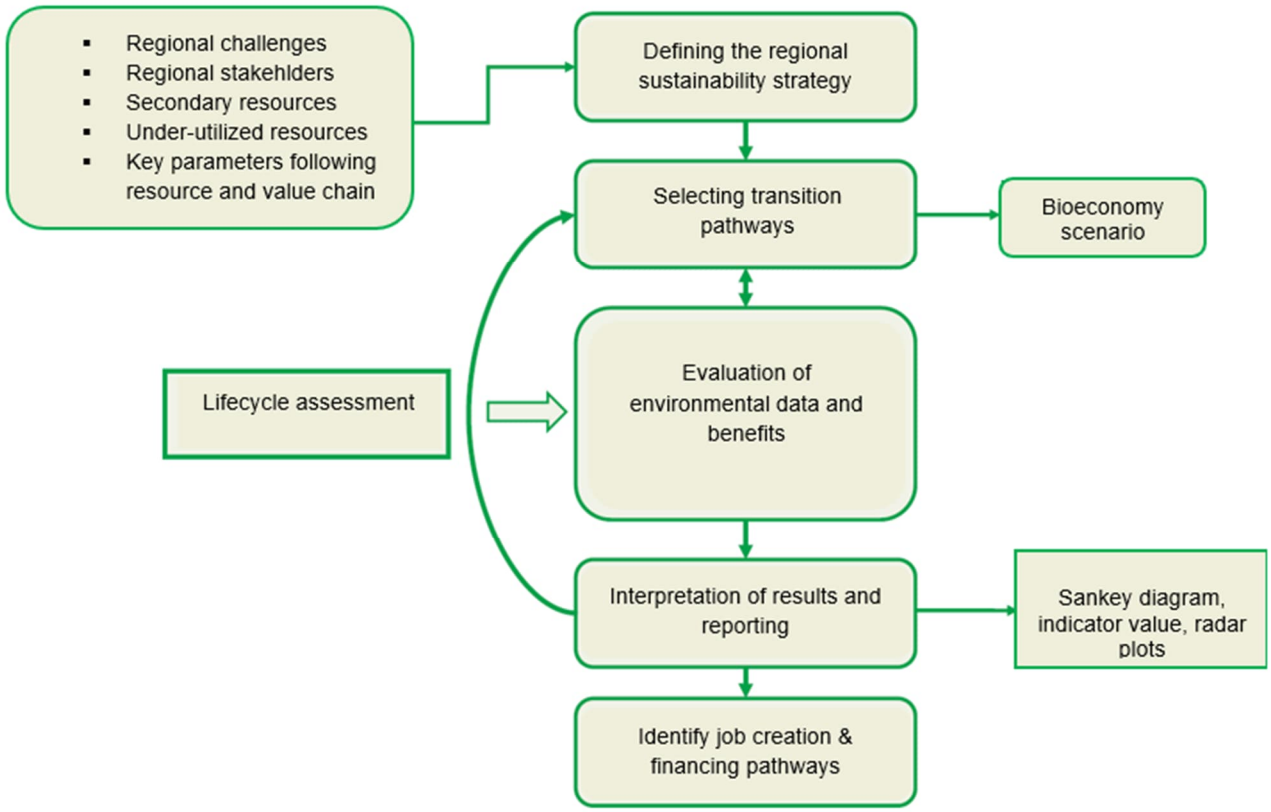

Figure 1: Flowchart showing comprehensive approach to assess the regional transition by using the BIOTRANSFORM tools

In addition to the tools and methodology, BIOTRANSFORM will produce technical guidelines for policy makers to provide guidance on how to lift some of the listed financial and governance barriers to implement the shift, as well as on how to integrate the project tools and methodology in their circular bioeconomy strategies.

Despite the determinant role played by local and regional policies in tackling the challenges and harnessing the opportunities offered by the transition, complementary actions at the European level might be needed, especially through the implementation of a European legal and economic framework that favours the establishment of ambitious regional circular bioeconomy strategies.

Within the stepwise BIOTRANSFORM transformation methodology, we aimed to select specific transformation pathways, which are replicable to more European regions.

3. Specific challenges to the transition

While the circular economy presents significant socioeconomic and environmental advantages, numerous barriers hamper the requisite transition. Only by being aware of these barriers, their interlinkages, and feedback effects within the socioeconomic and environmental systems can policy makers deliver well-integrated and tailor-made proposals to address them.

The BIOTRANSFORM project has collected and analysed the challenges encountered in its study regions through interviews and workshops, revealing standard limits and barriers indicative of the broader situation of linear economies at the European Union level. In initial stakeholder discussions, it was acknowledged that overcoming barriers requires more comprehensive implementation rather than solely relying on changes in regional policy. Considering regional limitations and stakeholder interests, the project's assessment framework aims to pinpoint the optimum bioeconomy transition pathways.

a. Environmental

While transitioning to circular bioeconomy several environmental challenges are to be considered, such as addressing climate change and managing natural resources in a sustainable way, including by preserving biodiversity. From an environmental impact perspective, the shift from a fossil to a bio-based economy can present trade-offs. This is well illustrated in the case of Finland, where biodiversity loss is observed in areas where forestry activities are carried out, and phosphorus and nitrogen discharged by the pulp and paper industry cause water eutrophication. The effects of climate change, such as soil degradation, also threaten the establishment of new biobased supply chains.

Another environmental challenge consists in managing competition between different uses of land and biomass feedstocks, while guaranteeing that bioeconomy development benefits everybody. Indeed, there is not enough land available to ensure a transition for the production of all consumer products from fossil-based to bio-based. There is also a need to shift the recovery of biomass side streams, that are now mostly used for low-value applications like energy or feed, to a cascading utilisation. This shift requires to challenge the current pathways and convince the users.

A hierarchy of use and objectives must therefore come from political vision and guidance by public authorities, to ensure that bioeconomy is set in a sustainable way and in line with economic, social,

and environmental priorities for the region. Moreover, the regional bioeconomy strategy must coordinate potential competition of land use induced by the global shift toward more bio-based value chains, despite the potential benefits of individual initiatives.

b. Socio-economic and financial

A transition to circular bioeconomy requires both public and private financial support for setting up and bringing biobased projects to market scale. However, the analysis of the six pilot regions has highlighted that one recurrent challenge is the **lack of funding to support circular bioeconomy**.

This is largely due to the difficulty of **finding a sustainable business model** for many biobased industries, caused among others, to possible fluctuations in the availability of input biomass (*i.e. the case of Charles SPA, where the input is biowaste, the volume of waste is subject to fluctuations due to seasonality of tourism*), and the low demand of biobased products compared to mainstream products (*i.e. in the case of the Rhenish region, new biobased flows for chemical industry compete with long established and well-functioning and optimised systems*). In addition to the challenges above, the novelty of circular biobased business models generates a higher risk perception than conventional businesses, thus discouraging private investors from providing financial support.

Additionally, public investments are often lacking in crucial areas for the transition, and especially in research and development. An example of this is the Charles SPA region, where R&D support from both public and private sources is the lowest compared to other Czech regions (OECD, 2020), and the index of R&D employees per 1000 inhabitants is the lowest one in the Czech Republic.

From a socio-economic perspective, it could be stated that the elements listed above as opportunities for the transition could also become barriers to the shift. In some regional contexts, the **low education and high rate of commuting/emigration of skilled labour outside the area** do not facilitate the development of transition expertise, the creation of a favourable environment for innovation and the establishment of new biobased businesses. For instance, the region of Western Macedonia faces the social challenge of having an elderly population, with a lower level of education than the national average, and a general lack of advanced and up-to-date skills. Well-planned upskilling activities are needed especially in economically underdeveloped areas. These programmes can be guided by national experts and financed for example by structural funds (e.g., ESIF, ERDF, etc.).

Another economic aspect to consider within the transition is that regional economies are characterized by a **high level of dependency on imports and exports** within and outside the country's borders. Therefore, the strong interlinkage between material uses and national GDPs does not facilitate the introduction of new regional biobased supply chains. In this regard, we propose the prioritisation of different indicators other than GDP including the regional resource use and available skills but also important socio-economic factors like the Gini coefficient or the Human Development Index.

c. Policy and governance

The regional transition to circular bioeconomy demands the support of a dedicated regional strategy. Four out of six BIOTRANSFORM demo regions do not have a circular bioeconomy strategy. In some of them, the drafting of a strategy is underway, or the support is embedded in one or several other strategic documents or funding programmes, whereas in others a transition plan is completely absent.

The lack of regional priorities and an agenda on bioeconomy can be associated with **several internal and external governance challenges**. The transversal nature of circular bioeconomy entails that several policy departments in local and regional administrations may be interested in participating in the design and implementation of a circular bioeconomy strategy. This requires the alignment of their priorities and already existing sectoral regulations, resulting in a time and resource-consuming process that not all public administrations are willing to undertake. Inclusive internal governance and interservice cooperation are thus the key to bring around the table the relevant public administrations and departments at local or regional level, and particularly those in charge of economic development, agriculture and rural affairs, environment and waste, as well as research and innovation.

While regional governments play an essential role in steering the transition**, a diverse and wide set of additional actors shape the regional bioeconomy ecosystem** and should therefore be involved in the design of a regional strategy for bioeconomy. These stakeholders involve primary producers, businesses, representatives of sectoral associations, business intermediaries, as well as academic, scientific, and technological institutions. They represent various and often conflicting interests and perspectives, which if not mediated, can slow down or even halt the advancement of a regional strategy for the transition. Here public authorities have a key role to play, by acknowledging and channelling this diversity of views into a constructive and long-lasting dialogue and taking leadership to steer and facilitate the development of circular bioeconomy in the region. Mobilizing all these actors during the preparation of the strategy will not only help garner support around the strategy, but also bring additional expertise and ensure realistic and achievable objectives by involving those that operationalize the biobased value chains on the field.

This dialogue can be further facilitated by intermediary organisations specialised in the topic, such as **bioeconomy clusters**, or LEADER region managers.~~,~~ The size of a NUTS3 region could be foreseen for this transition management. In circular economy terminology, this position is also called “transition broker”, who need to be aware of available resources, skills, organisations, challenges, possibilities, and funding programmes in their specific regions. They can mediate relations between the wide set of stakeholders and help foster long term cooperation between sectors. However, these “brokers” are not present and operating in all regions. Many regions, such as Northern Burgenland and Charles SPA report the lack of specific bioeconomy bodies or networks, which in turn hampers the organised deployment of specific bioeconomy areas.

Besides the need for a dedicated strategy and set of policies, there are often regulations already in place that create a barrier for further valorisation of by-products and biobased materials, such as standards on end of waste. For instance, municipal solid waste is under strict end-of-waste principles and limitations regarding transport of waste, like logistics and legal handling restrictions, also exist.

d. Technological and technical

A key challenge to operationalise a circular biobased system is the l**imited knowledge of the available feedstock in the region**. The lack of skills and knowledge to transform these resources into high-value products also add to this challenge, as well as the potential fluctuations in the supply of these biobased inputs to the production process. For instance due to seasonality, such as olive biomass in Andalucia, or any other crop that is harvested at a specific point of time in the year. To be

able to define where waste can be minimised and where resource efficiency can be improved, policy makers need full visibility on the intricate inflows and outflows of resources, energy, costs, and other data in the area.

The Resource Flow Analysis tool

In the attempt to fill this knowledge gap, the BIOTRANSFORM project has developed a Resource Flow Analysis (RFA) Tool to assess the flow of resources within the circular bio-based economy using a Sankey diagram. This graphical tool proves valuable in making complex data flows more understandable and revealing patterns and inefficiencies, enabling a comprehensive understanding of the circularity of the system. This information can be used to integrate biobased resources into the existing value chains. Continuously updating and analysing Sankey diagrams will also allow for the monitoring of progress in terms of resource and energy efficiency during the transition.

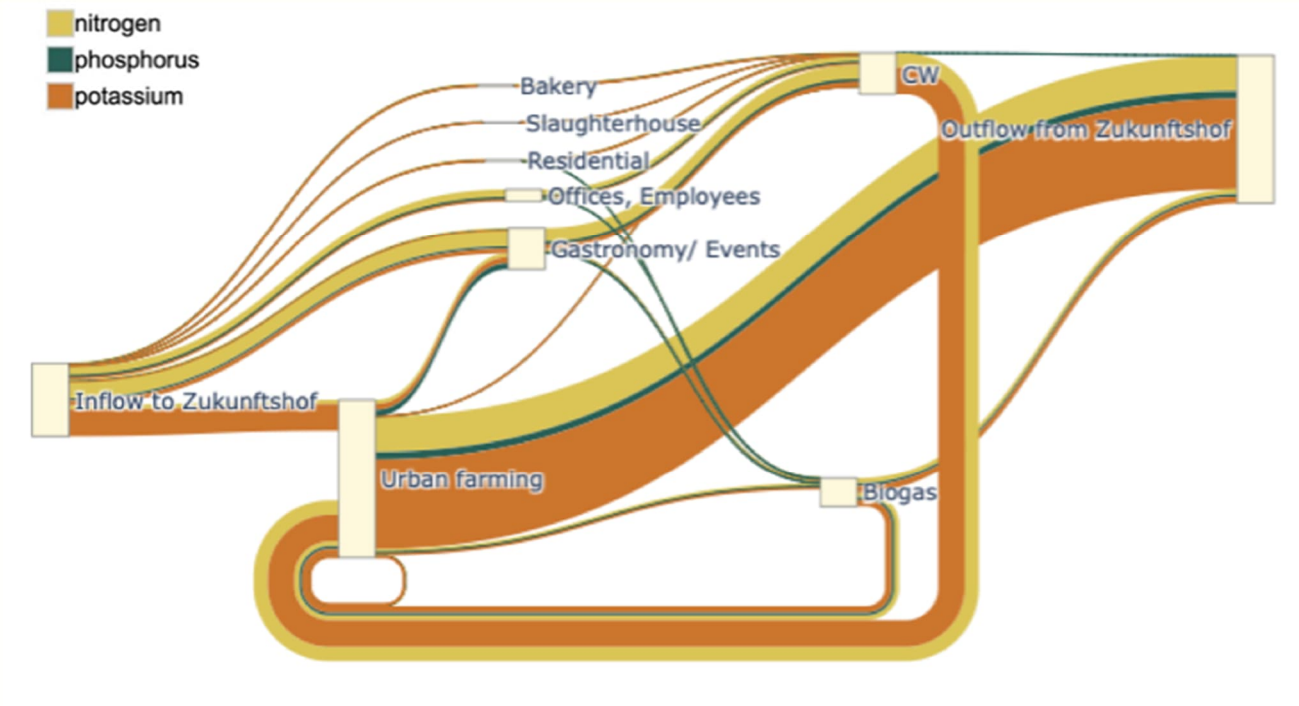

Figure 2: Example of a Sankey diagram, in this case shown as nutrients.

To properly exploit the available biomass, **an efficient collection and transportation system together with adequate (pre-) processing facilities, not too far in distance**, are necessary. Within the BIOTRANSFORM approach of connected biorefineries, pre-processing and the first step of value generation can already happen at decentralised scale close to the occurrence of resources. The residues of this first step can be transported further and combined with similar resources, which can in the end be converted to platform chemicals or similar. However, some regional contexts present logistics and infrastructure difficulties which can impair the process. The example of Andalusia regarding olive production shows that only 30% of the residual biomass is used as energy source. Furthermore, this conversion is hampered, as the region does not have enough electric power plants. The big potential and value of olive processing residues and their valuable polyphenols are not yet established. After a first valorisation, the residues from olive-pruning, olive stones, and olive pomaces

could then further be used to produce energy through pyrolysis, gasification, combustion, and the production of biofuels like bioethanol and biodiesel. Therefore, this valuable input is underutilised in the region due to technological limitations. In addition, the mountainous profile of some areas does not facilitate the transport of biomass, and in turn increases logistics costs.

The MooV tool

Within the BIOTRANSFORM project, the **MooV tool** (by VITO) focuses on the logistics and transportation aspects of the transition to a circular bio-based economy, with the aim to identify areas where resources are underutilised or where inefficiencies exist. The tool aims to find the optimal supply chain network solution matching the set objective (e.g., cost minimisation or maximum fleet emission reduction) and considering regional-specific constraints (e.g. production hotspots, low emission zones, loading capacities). MooV will analyse the current supply chain configurations in the region and by simulating the effects of changes in product demand on the supply chain, the tool will help to plan for and foresee fluctuations in demand and adjust the supply chain accordingly.

e. Transversal barriers

The analysis of the case study regions has highlighted the existence of several transversal barriers to the transition. Circular bioeconomy can appear very complex due to its transversality across multiple themes and sectors. Therefore, in many regional **areas there is still low awareness and understanding of this concept, and of the interconnected benefits** this system can bring to the local ecosystems, communities, and economy. This can apply to public administrations, for instance resulting in low political interest in the topic, but also to consumers, leading to distrust towards biobased products and unwillingness to pay a premium price.

Even when the concept is understood, one additional obstacle to the implementation of this system is the **fear of change** and hesitation in adopting new technologies or products, which can be found in entrepreneurs, investors, and consumers alike. To debunk traditional beliefs and garner trust around circular bioeconomy, all players have to be informed about the advantages of biobased products and systems, with tailored communication approaches focusing on specific aspects relevant to the target audience and their specific interests (such as safety, costs, sustainability).

However, the analysis carried out within the project has shown that circular biobased systems and the positive impacts they deliver cannot be replicated to all regional contexts and territorial scales. As different regions may have distinct environmental, economic, and social characteristics, no size that fits all systems exists. Therefore, the effectiveness of biobased approaches depends on tailoring them to the specific usage context and regional challenges. **Customization is critical to maximizing the benefits of biobased and biodegradable products**. Therefore, the effectiveness of biobased approaches depends on tailoring them to the specific usage context and regional challenges. The BIOTRANSFORM project has created a clear stepwise methodology for enabling the regional transformation. The resources identified have been detailed enough that any European region wanting to explore those same value chains can directly apply the methodology, without having to undertake the baseline research for the possible metabolization pathways. The selected resources and planned metabolization routes are listed in the following table.

Region	Feedstocks	Use type	Potential environmental impacts
Northern Burgenland (AT)	Straw	Building and packaging	▪ GHG emission ▪ Water consumption ▪ Freshwater eutrophication ▪ Resource circularity
Charles SPA (CZ)	▪ Bio-waste from restaurants, catering and hotel industry ▪ Municipal waste ▪ Beverage productio n residuals as an alternative (beer)	▪ Waste --> biogas, compost, lubricants ▪ Beverage residuals --> extraction of various biomaterials for cosmetic, food, and pharma applications	▪ GHG emissions ▪ Recovery of food waste
Western Macedonia (EL)	Sewage sludge (Alternative feedstock: Wood biomass)	▪ Green hydrogen ▪ Alternative products in case of wood as feedstock: Medium Density Fiber boards, Electricity from wood chips, fertilizer from wood ashes.	During hydrogen production and use as fuel: ▪ Sulfur Oxide and Nitrogen Oxide emissions ▪ GHG emissions
Finland	Lignin	▪ Battery material ▪ Adhesive or coating ▪ Polymer production	▪ GHG emissions ▪ Water consumption
Andalusia (ES)	Olive biomass	▪ Biomaterials ▪ Bioenergy	▪ GHG emissions ▪ Water scarcity
Northern Westphalia (DE)	Sugar, cellulose, hemicellulose from range of biomass/side streams	▪ Biofuels ▪ Bio-based chemicals	▪ GHG emissions ▪ Biodiversity ▪ Water consumption, ▪ Freshwater quality ▪ Land use ▪ Soil health

Table 1: Use case regions, their feedstocks, planned indicators.

4. Opportunities for the transition

a. Environmental

The transition from linear fossil-based systems involves shifting from a model that relies heavily on finite fossil fuels and generates environmental degradation, to one that is more sustainable, regenerative, and aligned with ecological boundaries.

An important aspect of the shift to biobased systems is the **cascading use of biomass**, which aims at turning waste into resources by increasing efficiencies along the metabolization pathway and by ultimately ensuring the return of nutrients and residual carbon to the soil. By repurposing biological secondary resources (former waste) as a replacement for virgin feedstocks, these biomass residues offer a transformative opportunity for regional economies to reduce dependencies on finite fossil resources and mitigate their associated environmental impacts, such as pollution, habitat destruction, or climate change. Within the BIOTRANSFORM project, each demo region explores a pathway of repurposing residues, such as sludge, straw, wood, and olive biomass, as feedstock to produce new products or processes (see table 2). In the business-as-usual scenario, the manufacturing of these products requires fossil fuel derivatives and produces residual chemicals which are released in air, water and land.

Additionally, the environmental sustainability of circular bioeconomy lies in the **ability of this system to deliver a net reduction in carbon emissions**, wherein the carbon emitted during the production and utilisation of renewable resources must be offset by the amount sequestered or captured in the soil. This system has the potential to contribute significantly to the European Union's 2030 target to reduce greenhouse gas emissions.

The Impact Assessment Tool

In order to account for greenhouse gas emissions savings and compare them to conventional production pathways, BIOTRANSFORM will rely upon the IAT. The impact assessment tool consists in a list of sustainability assessment indicators framed within the "Doughnut Economics" model of planetary and social boundaries (Raworth 2017). The indicators represent environmental, economic and social hotspots (e.g., renewable energy adoption targets, social equity measures) which must be assessed and monitored while imposing the objective of reducing the environmental burden in the six pilot regions.

b. Socio- economic

An important difference from current fossil-based, globalised supply chains is that, to have ready access to biological resources, **the implementation of many aspects of the bioeconomy will occur at regional and local levels**. The shift to circular biobased systems has thus the potential to

stimulate economic growth by generating new avenues for bio-based industries in the region, ultimately contributing to a more resilient and environmentally responsible regional economy.

The establishment of new businesses working on the valorisation of underutilised resources can **generate new job opportunities in the bioeconomy sector**, increasing employment in the area. This constitutes an opportunity particularly for deindustrialising regions where the phase down of heavy industry creates the need for retraining and re-skilling of large workforce. An instance of this is North Rhine Westphalia, a former fossil-based industrial region where open lignite mining will be phased out by 2030, leading to an estimated cut of around 14,000 jobs.

The establishment of biobased businesses in the region could bring further awareness on bioeconomy and **foster creativity, openness to change, and innovation capacity in the region, all while creating a favourable environment for startups and SMEs to settle in the area**. Bioeconomy can thus also be a driving force in depopulating rural areas to secure attractive jobs that are not necessarily associated with farming.

In addition, as one of the key principles of circular bioeconomy is maximising resource effectiveness by using biomass in products that create the most economic value over multiple lifetimes, if optimised over time, these systems have the potential to generate economic profit. To unlock these economic benefits, biomass use should be given to higher-value applications and continuous reuse, with energy recovery as the last option. One of the aims of the BIOTRANSFORM project is precisely to explore pathways that would enable extraction of further value from resources compared to the current ones.

5. Conclusion

Circular biobased systems have the potential to unlock several environmental and socio-economic benefits. However, barriers lie in the way of the transition and trade-offs are to be considered in the context of the shift. **BIOTRANSFORM offers a holistic assessment framework and guidelines** to steer policy makers in the design and implementation of circular bioeconomy in the regional contexts. Among its contributions, the BIOTRANSFORM assessment package will also allow understanding of the type of data needed to conduct the analysis and implementation of circular bioeconomy in different regions.

While acknowledging that this package will not be able to address all the above-mentioned challenges, the BIOTRANSFORM methodology and tools can help advance the transition of some European regional contexts, with replication potential to other similar ones within the European Union (through transfer of good practices, financial and governance guidelines for the transition, pathways applicable to regions with similar bio characteristics). In addition, **it seems also important to improve the European legal and economic framework so that circular bioeconomy can become the norm**. Circular biobased systems are usually local and operating at smaller scale. This makes it difficult for them to achieve economies of scale and to compete with globalised, fossil-based ones, that also take advantage of externalisation of labour costs. The upcoming implementation of several pieces of European legislation, such as the Corporate Sustainability Reporting, the Green Claims, the EU Taxonomy, and the Ecodesign for Sustainable Products Regulation, should improve the situation and make environmentally and socially sustainable systems more competitive. BIOTRANSFORM shall also formulate final policy recommendations to overcome these different challenges.

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