STRATEGIC CONCEPT PAPER FOR BIOECONOMY: SLOVENIA

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BIOEAST SUP

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EXECUTIVE SUMMARY

PURPOSE OF THIS DOCUMENT

This concept paper is an output of the BIOEASTsUP project, whose overall objective is to support Slovenia (and other countries participating in the BIOEAST initiative) in the unlocking of its bioeconomy potentials. It makes a good use of the previous research and strategic planning effort with a similar focus. In this context, we highlight the nationally funded project BRIDGE2BIO (Juvančič et al., 2021b), BBI JU CSA project CELEBio (Virant et al., 2020) and some strategic documents, most notably the Comprehensive Strategic Project of Decarbonisation (Karba, 2022). These documents provide a solid foundation to creating the bioeconomy strategy by defining sector-specific transformation pathways towards unlocking the potentials for a more sustainable, integrated and better performing bioeconomy in Slovenia.

The Concept Paper aims to **intensify the exchange between the policymakers and stakeholders** about the model of the future bioeconomy development in Slovenia. This exchange should **align our views about relevant pathways of bioeconomy sectors** in Slovenia: from primary production (agriculture, forestry, aquatic production systems) and conventional bioeconomy manufacturing sectors (food products and beverages, wood processing, pulp and paper), to the expanding 'hybrid' bioeconomy sectors, such as pharmaceutical preparations, textiles, manufacture of chemical products, construction, as well as energy supply, and service sectors engaged in ecosystem services valorization. We hope that this exchange will prove beneficial for enterprises and other economic entities operating in various bioeconomy sectors in Slovenia, to **recognise their synergies and accelerate cooperation** in integrated value chains. This would lead not just to the improved economic performance of participating companies, but also to a better exploitation of the potential for value added of the bioeconomy sectors, as well as **improved sustainability of the economic system** by closing (material, energy) loops of biomass utilisation.

The aim of this exchange is also **to review and critically assess the supporting environment** for the development of the bioeconomy in Slovenia. Dedicated strategic framework and coordinated policy support can direct and accelerate the processes of the restructuring of bioeconomy in the direction of improved economic performance, resilience and sustainability of the economic system. The Concept Paper is developing some proposals in this regard. Rather than suggesting a developed set of solutions, they are meant to intensify the exchange about the appropriate placement of the bioeconomy of the current institutional setup and system of development planning in Slovenia. These proposals are meant also as a step towards a more systematic and intensified coordination among policy makers in planning future actions to support the development of the bioeconomy and the favourable state of ecosystems.

Context and objectives[1]

A SUSTAINABLE BIOECONOMY ADDRESSES CURRENT ENVIRONMENTAL AND SOCIETAL CHALLENGES

The societal context in which the importance of the bioeconomy is growing coincides with the experience of the **global economic and climate crisis** in the first two decades of the new millennium, which revealed, among other things, the vulnerability of a growth-oriented economy based on non-renewable resources and the unsustainable use of renewables. The prevailing production and consumption patterns lead to **long-term and irreversible environmental changes**, which are reflected in the degradation of the environment and ecosystems and the loss of biodiversity. Profound changes are also taking place in the global trading system and organising business processes, in which a number of **short-term disruptions**, regional restructuring of distribution chains and a long-

[1] Apart from this Concept Paper, this section largely draws largely from the findings of the nationally funded strategic research (Juvančič et al., 2021b).

term reduction in international trade have happened in the last decade. If we add to this growing **geopolitical tensions** and unexpected events (COVID-19 pandemic, Russian agression), we can conclude that we are entering a period of **growing uncertainty in all key aspects** - the state of the natural environment, access to sources of raw materials and energy, business environment and, last but not least, in the wider social context.

Understanding **sustainable bioeconomy** as an economic paradigm that addresses various aspects of production and conversion of biomass, as well as sustainable ecosystem management and a different, circular organisation of business processes, can be seen as one of the answers to the listed societal challenges. Sustainable bioeconomy enables **synergies between the economic** (added value, innovation, knowledge, competitiveness, industrial development, advanced technologies), **social** (jobs, balanced development, rural development, responsible consumption, health) and **ecological** (climate change management, conservation of natural resources, waste reduction) components of development. At the same time, it also **suits the changing geostrategic context**, with the increasing importance of short and integrated supply chains.

Developed societies recognize the strategic importance of the bioeconomy in designing their long-term strategies

Considering the fact that the organization of technological and business processes in accordance with the principles of the bioeconomy contains elements of **technological and social innovation**, it is probably not surprising that the beginnings of integrating the bioeconomy into the strategic activities in Europe coincide with research, development and innovation (RDI) policy in early 2000s. Over the last two decades, various activities took place also at the multilateral level, **integrating of the bioeconomy into strategic development priorities**. In this context, we highlight in particular the achieved consensus of countries on the untapped potential of the bioeconomy in achieving the **UN's Sustainable Development Goals (SDGs)**, the role of the bioeconomy in achieving the goals of the **Paris Climate Agreement (2015)** and the **OECD guidelines for the strategic placing of the bioeconomy** in its member countries' development policies (2009).

The **EU published its Bioeconomy Strategy with an Action Plan in 2012**, which coincided with the publication of similar documents other leading world economies (eg. USA, China, Brasil). Year 2018 saw the publication of a **renewed EU bioeconomy development strategy**, which includes internationally accepted commitments (sustainable development goals, Paris Climate Agreement) and EU-level goals (European Green Deal, energy union, renewed industrial policy), as well as emphasises (eco)system aspects more strongly than before.

With the adoption of joint strategic guidelines in 2012 and its amendment in 2018, the **bioeconomy is the strategic development priority of the European Union**, which combines the goals of the reduction the society's dependence of fossil fuels, and the development of sectors that produce and add value to the biomass, based on knowledge and taking into account the environment and nature conservation goals. In line with this endeavour, eleven EU Member States have sofar adopted dedicated national bioeconomy strategies, whereas seven national strategies are under development (EC, 2022).

Slovenia (along with other Central and Eastern European countries) is among the countries with an underutilised potential of the bioeconomy

As it is described in a greater detail in the main text of this Concept Paper (sections 2 and 3), the utilisation of the potential of the bioeconomy for Slovenia is not favourable. Slovenia has **a significant but sub-optimally exploited raw material potential** (in particular wood biomass and residues in primary agricultural production). Due to **demand-push**, a growing number of manufacturing firms operating in trans-national value chains turn their operations towards circular business models and biobased technologies, which are however poorly integrated in terms of closing local (material and energy) loops in biomass use. Relatively **high inputs into RDI activities** yield in good academic performance of the leading national research institutions, whereas the results are not sufficiently integrated into the business process.

Review of statistical data and institutional overview in this Concept Paper (section 4) outlines the key challenges of bioeconomy development in Slovenia. **Factor productivity and economic performance of primary bioeconomy sectors** (agriculture in particular), is **below par with the rest of the national economy**, as well as in macro-regional comparison with other BIOEAST countries. **Synergies** between (advanced and internationally integrated, but transient) **industry and RDI sector** in the domain of bioeconomy remain **largely untapped**. Also the institutional status of bioeconomy remains poorly defined. No ministry or other government body can be described as an institutional holder of the bioeconomy portfolio. The **level of coordination** between instruments and measures supporting various aspects and sectors of bioeconomy remains **low**.

Integration of Bioeconomy into strategic development planning of Slovenia

Slovenia is one of the seven EU Member States **without a dedicated national bioeconomy strategy**. Extensive review of national strategic documents carried out in this Concept Paper reports that bioeconomy is not explicitly identified among the national strategic priorities in Slovenia. It needs to be accentuated though, that **inter-ministerial coordination on various issues related with bioeconomy development is operating**. Elements of (circular) bioeconomy have been integrated into various strategic documents and **policy instruments**. As for the letter, the **coordination between various ministry portfolios / funds is largely lacking** (eg. criteria for selection of operations, coverage of related investments from different funds).

current state of the system components, OPPORTUNITIES AND CHALLENGES

Availability and possible uses of residual biomass of agricultural origin[2]

Among the priority residual streams of agricultural biomass, we highlight **livestock excrements** with a total amount of more than 620 thousand tons of dry matter. The overall performance of its current use (organic fertilizer) can be significantly improved by **exploiting its energy content** (biogas production) and improved soil fertilization techniques, which improves the nutritional value of livestock manure and drastically reduces environmental burdens.

When selecting raw materials and preparing a technological design for the circular use of **residues and by-products of plant production**, we proceed from two principles. First, that the proposed solutions **should not threaten the balance of organic matter** in the soil. Secondly, they need to take into account the structural features of farming in Slovenia (**small-scale and fragmented property structure**). The most extensive raw material source in plant production is represented by harvest residues and secondary crops of arable production, the total amount is in the range of 700,000 tons of dry matter. The remains of vegetable, oil and root crops represent the next quantitatively and qualitatively perspective raw material source, the total amount is in the range of 100,000 tons of dry matter. Other potentially relevant raw material source, are also residues in horticulture, amounting to 30,000 tons of dry matter.

When searching for alternatives for circular use of above listed perspective groups of agricultural biomass, we must take into account either their **limitations in ensuring efficient logistics and scalability**, and **ecologic limitations**. However, these biomass streams provide the potentials for technologically and economically sound circular uses, such as: (i) cascading use of lignocellulosic residues with an emphasis on the **extraction of bioactive components** and the production of **packaging materials**; (ii) transformation of biomass with a high fiber content into **composite materials** or (iii) **biorefining** of more complex raw material sources (e.g. residues from the processing of fruits, vegetables and oilseeds into components with a high added value).

[2] The project work that forms the quantitative basis of this Concept Paper, provided estimates of the amount, composition, utilization and dynamics of the available biomass from agri-food chain. In the biomass characterization phase, we converted the data into categories relevant for planning circular use and value adding.

Considering the chemical composition and technological properties of **side streams in food processing**, there are untapped potentials in the extraction of bioactive compounds and application of various biotechnological processes. The range of compounds obtained is extensive and offers a strong potential for adding value. Our research identified unexploited reserves particularly in the sectors, which provide **homogenous streams of biomass and allow for scalability**. Such sectors are dairy, animal by-products, brewing industry and wine production.

Availability and possible uses of Forest-wood biomass

With an **exceptional forest cover** (58 % of the country area are forests with a relatively strong production capacity), wood is by far the most promising source of raw materials in the Slovenian bioeconomy. This potential is somewhat limited by a **fragmented ownership structure** (average size of a forest property is 2.9 ha), which is the main drawback for organizing cost-efficient supply of wood biomass at the industrial scale. Furthermore, the structure and production potential of Slovenian forests is irreversibly changing due to climate change. Future projections forecast an **increase of hardwood potential**, particularly from the increasing share and faster growth of the beech forests.

The average yearly production of forest wood assortments in Slovenia amounts to about 4.5 million m3, about two thirds of these are conifers. The largest domestic consumer of round wood is the sawn wood industry (over 1 million m3), followed by the wood composites, mechanical pulp and chemical industries with a total processing volume of around 0.5 million m3. Large consumers of round wood are households, which annually consume over 1 million m3 of wood for firewood. Slovenia is a prominent exporter of unprocessed round wood, which is particularly evident in the coniferous log category with about 1.3 million m3.

Looking from the viewpoint of the overall economic performance of the forest-wood related bioeconomy in Slovenia, the current situation is not favourable. Improvements are sought in particular in terms of a **higher share of harvested round wood processed domestically**, and in the strengthening of **more technologically advanced alternatives** to the current uses of round wood. Reserves exist also in the enhanced exploitation of the economic potential of the forest, as currently, only 60-70 % of the annual increment of wood is harvested. The largest potentials are estimated for the **wood categories of lower quality**. From the point of view of the long-term perspective, this category will gain in importance with changes in forest stands (increasing proportion of beech). **Unexploited possibilities** are therefore especially in the categories of wood, which are a suitable input raw material for **biorefining** processes and the subsequent production of new bio-based materials.

The potential of logging residues for collection and processing in industrially relevant quantities is limited, as their removal is not cost-efficient. Some bioeconomic potential in this category can be attributed to bark, which by volume represents around 20% of the cut and is an important category of raw materials for bio-based products due to a high content of bioactive compounds (e.g. tannins, polyphenols) and is also a good structural material for composting biogenic waste.

Structure and performance of bioeconomy –related industries

The experience of the leading EU countries and regions reveals that sectors with strong, consolidated firms in conventional bioeconomy sectors find it easier to provide leverage for the development of industrial-scale biorefineries and the resulting potentials for value-adding. Slovenia has a **vibrant structure of enterprises** engaged in conventional bioeconomy-related industries (food processing, wood processing, paper mills), but most of these operate at the **SME scale**. Conventional bioeconomy manufacturing sectors are relatively strongly represented on international markets. Enterprises operating in wood processing achieve 55 % of revenues on international markets, whereas the share of food processing sector records 34 % export orientation, which is below the par of the manufacturing sector in Slovenia.

The scale and the level of integration of industrial operations in these sectors significantly dropped throughout the political transition and economic restructuring in the 1990s. Some industrially-relevant operations that could serve as the core for future industrial-scale biorefineries, ceased with their operations in the last two decades. The **level of business integration in conventional bioeconomy-related industries is rather low** (vertically, as well as horizontally), which **prevents the scale effects** needed for a functioning of the 'enhanced' bioeconomy concept, integrating firms in the same, or complimentary sectors, with a biorefinery at its core. In the development of more diversified and innovative bio-based value chains, **two scenarios** seem feasible: (i) integration into bioeconomic clusters, with a network of **small-scale modular biorefinery operations** in its core, or (ii) integration into **wider, cross-border value chains**, supplying biomass to, and supplying intermediate outputs from industrial biorefineries, located within operating distance from Slovenia.

Apart from the 'conventional' bioeconomy sectors, integration of firms operating in technology-intensive sectors that are strongly **integrated into international value chains** (eg. chemical industry, automotive sector) may also play a **catalytic role** in the transition towards bioeconomy. Demand for biobased technologies and components in these industries is increasing at an accelerated pace. A number of factors, such as disruptions on global raw material markets, technological prowess in biobased technologies and changed price-cost relationships, are simultaneously contributing towards the accelerated turn towards innovative biobased technologies in sectors that were traditionally operating with non-renewables. Increased demand for biobased technologies and components in **technology-intensive sectors may serve as important engine of growth also in 'conventional' biobased sectors** (Lovec and Juvančič, 2021). Apart from being the providers of biomass (often with poorly-valorised side-streams), integration with technology-intensive sectors may act as a stimulus to improve their performance in several aspects (closing the material and energy loops, improved economic performance).

Catalytic role of RDI sector and commercial enabling institutions in bioeconomy development

In Slovenia, a vibrant RDI sector is operating, engaging in state-of-the art applied research and technology development in various bioeconomy-related fields of science. This sector, consisting of both, public research institutions and private companies, can play a stronger catalytic role in unlocking the bioeconomy potentials as it is currently the case. In some sectors, which can be regarded as the cornerstones of the national economy (eg. pharmaceutical industry), RDI is strongly integrated with the industry. In other sectors, these linkages are less strong, or even not adequately established. The industry is reluctant to act as the sole investor in new technologies for different reasons (eg. focus on cost efficiency, demand-side risks, lacking financial leverage), while the technology developers also seek for returns that surpass the capacities that are not attainable at the usual scale of enterprises operating in (conventional, or new) bioeconomy-related manufacturing sectors. To some extent, this gap has been successfully tackled within **industry-research partnerships, developed within the national Smart Specialisation Strategy**.

Slovenia has a vigorous network of enabling institutions supporting innovative and development-oriented entrepreneurial projects. **Technology parks and business incubators** provide professional business support services, such as favorable lease of business premises and start-up mentoring support. Business accelerators offer professional consultation and seed financing for innovative start-ups. Both programs are complemented with public funding. **Market for venture capital is less developed**, limited mainly to specialised products of banks and insurance companies. All the above described services are general, not relating specifically to bioeconomy.

Overall conclusions and strategic actions

Setting up the strategy; need for context-based solutions

The **idealized model of circular bioeconomy** is based on continuous and cost-effective access to industrially relevant quantities of biomass of homogeneous composition, its gradual decomposition in large integrated biorefineries into simpler (chemical, material) building blocks, which are then integrated a wide range of biobased products. The process is following the cascading use principles – starting with high value-added products and finishing with the energy use. Economic entities interact in the development of new technologies and processes (bioeconomic clusters) and in the exchange of material and energy flows (industrial symbiosis). The transition towards circular bioeconomy and its growth depends also on the wider supporting environment. It consists of a business supporting system supporting the early-stage companies, capable venture capital market to meet the firms' growth potentials, and the state with stable business environment, responsive legal framework, and consistent policy support.

In reality, the utilization of the **development potential of the bioeconomy is context-based**. The development of circular business models in the context of the Slovenian bioeconomy differs from the idealized model described above in practically all elements. It starts already with a small scale and fragmented production structure in primary sectors. Starting from this, it is clear that in the design of circular business models suitable for the conditions of the Slovenian bioeconomy, we will have to resort to innovative and context-adapted solutions. On the other hand, the primary sectors of the bioeconomy (agriculture, forestry) and the resulting value chains show characteristics typical of countries participating in the BIOEAST initiative: a **low level of productivity in primary production** with a relatively high share of employees in these industries, the **unused potential of residues and by-products** in production, processing and consumption, the **absence of biorefinery capacities** and the **low level of awareness of opportunities** for circular technological solutions and business models. The latter is present both on the side of industry, and on the side of public development policies. In this context, it is expedient to **cooperate with the countries of the BIOEAST macro-region**, which are facing similar challenges, in developing appropriate solutions.

SECTOR-SPECIFIC PATHWAYS AND CHALLENGES FOR UNLOCKING BIOECONOMY POTENTIALS

The current performance of bioeconomy in Slovenia can be significantly improved. This is illustrated by a relatively **low contribution of bioeconomy sectors to the overall value added** (20 % or 11 percentage points below the EU 27 average) and **low labour productivity** (11,500 EUR per employee, or less than one third of the EU 27 average). **Unlocking bioeconomy potentials** in Slovenia should take place in **two directions**. The **first** one involves agriculture, forestry and related 'conventional' manufacturing value chains (wood & paper processing, whose reserves lie in **boosting the sector's productivity and value added**, partly also in the closing the material and energy loops within their operations. The **second trajectory is more demand-driven**. Its forerunners are firms, which are integrated into international value chains and include some of the key national manufacturing (eg. chemical, automotive, electrical) and other sectors (eg. construction), where the demands and needs for the transition to bio-based materials and technological solutions is increasing. Increased demand for biobased final products from these sectors creates **opportunities for growth along its upstream** (technology developers) **and downstream** (primary and conventional manufacturing) **sectors**.

In order to unlock the potentials for a more integrated and sustainable bioeconomy in Slovenia, three challenges and opportunities can be pointed out.

First, Slovenia faces a **significant, but suboptimally utilized raw material potential** of agricultural and forest-wood biomass. The structure of practically all activities dealing with the processing of agricultural and forest-wood biomass is fragmented and produces large amounts of side streams and residues, whose current mobilisation is currently limited mostly on energy use. The added value of side-streams and residues in primary production and conventional processing sectors is therefore relatively low and poorly diversified.

Another challenge lies in a **low level of horizontal and vertical integration along the bioeconomy value chains**. This should not be misinterpreted by the general absence of technologically advanced and competitive firms in sectors operating along these chains. On the contrary, their number and significance is increasing. What is lacking however is the low level of their integration, or at least cooperation. As a result, most of the firms in bioeconomy sectors are operating at the SME scale. Consequently, a large percentage of primary products in agriculture and forestry is valorised outside the national economy, and the conditions for biorefining of biomass side-streams at industrial scale is hardly attainable. Both are limiting the potentials for sustainable valorisation of biomass and economic performance (value added, employment) of the bioeconomy sectors witin the national economy.

Comparative review of the research outputs, based on standardised quantitative criteria, reveals **a vibrant RDI activity** in the field of bio-based materials and supporting technologies in the country. Research institutions and teams are well integrated into international RDI effort. Investments in research and development and publications in this area are constantly increasing. This can be regarded as an opportunity. On the other hand, in the same field of analysis, **Slovenia performs poorly in terms of innovation adoption.** On the positive side, there is a **vigorous startup community** and many of their business ideas are inspired by biobased innovations. Although these firms are operating at the niche scale and in the early stages of the business cycle, they can be seen as the harbingers of the entrepreneurial transition to the bioeconomy

Actions to unlock the bioeconomy potentials of Slovenia

For a serious qualitative leap towards (resilient, circular, sustainable) bioeconomy, all actors operating in the bioeconomy sectors or directing the development of bioeconomy in Slovenia, need to significantly strengthen their effort. This involves reaching a social consensus on the **strategic importance and institutional consolidation** of the bioeconomy.

First, measures would be needed to **strengthen the motivation of companies for inter-sectoral and cross-sectoral cooperation** in extended bio-based value chains, adding value to locally sourced biomass in closed (material, energy) loops.

- **Establishment of the National Bioeconomy Hub** could be seen as a step in this direction. The hub would serve as a platform for mutual exchange of information, the dissemination and exchange of expertise, and the creation of business opportunities through cooperation. Institutionally, it would be expedient to assign the role of a hub to an already operating platform with similar tasks. With the implementation of the Smart Specialization Strategy, the coordinating role is attributed to Strategic development innovation partnerships (SRIPs). SRIP Networks for the transition to a circular economy, with the Focus Area Biomass and alternative raw materials seems as the most appropriate candidate for this task.
- Identification of **national industrial leaders in bioeconomy** and their motivation to commit for a long-run cooperation with local operators. They should be motivated to upgrade their activities and supporting investment decisions with financial and equity input in the form of public-private partnerships.
- Establishing a **virtual platform for exchange** (and trade?) with individual biomass waste streams.
- **Strengthening knowledge intensity** (applied research, integration of RDI and industrial partners) is one of the prerequisites for the improvement of bioeconomy performance in terms of innovation adoption. Additional funding would further stimulate these processes.
- Actions would be needed to **boost demand for biobased technological solutions and materials.** These start with institutional buyers through the system of **Green public procurements.** Part of this effort is also systematic and targeted work in terms of the regulation of data bases, evidence-based strategic planning, inter-industry and inter-institutional integration of stakeholders, development of a supportive environment and enhanced integration into processes operating at the EU-level.

When designing and implementing public policies, plans, programs and measures to unlock the development potential of the bioeconomy in Slovenia, the following points should be considered:

- The development of **systematic and coordinated measures** to support the development of more ambitious forms of cooperation between economic entities (industrial symbiosis) and development-innovation inter-industry cooperation within the framework of bioeconomy clusters;
- Encouraging the development and use of cost-effective, innovative low-carbon technological and non-technological solutions;
- Encouraging the construction of biorefinery capacities, which represent a bridge between conventional and new bioeconomy products and technologies and represent a key link in the formation of branched value chains;
- Improvement of support services (subordinate legislation, data, rules, logistics).
- Development of new business models, which include, among other things, the cascading use of resources of biological origin and digital transformation.
- Changing consumer habits towards the purchase of bio-based products and services.

IZVLEČEK

NAMEN TEGA DOKUMENTA

Ta dokument je rezultat projekta BIOEASTsUP, katerega splošni cilj je podpreti Slovenijo (in druge države, ki sodelujejo v pobudi BIOEAST) pri izkoriščanju potencialov biogospodarstva. V njem so dobro izkoriščena predhodna prizadevanja za raziskave in strateško načrtovanje s podobno usmeritvijo. V tem okviru izpostavljamo nacionalno financiran projekt BRIDGE2BIO (Juvančič et al., 2021b), projekt BBI JU CSA CELEBio (Virant et al., 2020) in nekatere strateške dokumente, predvsem Celovit strateški projekt razogljičenja (Karba, 2022). Ti dokumenti zagotavljajo trdno podlago za oblikovanje strategije biogospodarstva z opredelitvijo sektorsko specifičnih transformacijskih poti za sprostitev potencialov za bolj trajnostno, integrirano in uspešnejše biogospodarstvo v Sloveniji.

Namen koncepta je okrepiti izmenjavo mnenj med snovalci politik in deležniki o modelu prihodnjega razvoja biogospodarstva v Sloveniji. Ta izmenjava naj bi uskladila naše poglede na ustrezne poti biogospodarskih sektorjev v Sloveniji: od primarne proizvodnje (kmetijstvo, gozdarstvo, vodni proizvodni sistemi) in konvencionalnih proizvodnih sektorjev biogospodarstva (živilski izdelki in pijače, predelava lesa, celuloza in papir) do razvijajočih se "hibridnih" sektorjev biogospodarstva, kot so farmacevtski pripravki, tekstil, proizvodnja kemičnih izdelkov, gradbeništvo, pa tudi dobava energije in storitveni sektorji, vključeni v valorizacijo ekosistemskih storitev. Upamo, da bo ta izmenjava koristila podjetjem in drugim gospodarskim subjektom, ki delujejo v različnih sektorjih biogospodarstva v Sloveniji, da bodo prepoznali njihove sinergije in pospešili sodelovanje v integriranih vrednostnih verigah. To ne bi vodilo le k izboljšanju gospodarske uspešnosti sodelujočih podjetij, temveč tudi k boljšemu izkoriščanju potenciala dodane vrednosti sektorjev biogospodarstva ter k večji trajnosti gospodarskega sistema z zapiranjem (snovnih, energetskih) zank uporabe biomase.

Namen te izmenjave je tudi pregledati in kritično oceniti podporno okolje za razvoj biogospodarstva v Sloveniji. Namenski strateški okvir in usklajena politična podpora lahko usmerita in pospešita procese prestrukturiranja biogospodarstva v smeri izboljšanja gospodarske uspešnosti, odpornosti in trajnosti gospodarskega sistema. V konceptualnem dokumentu je v zvezi s tem pripravljenih nekaj predlogov. Njihov namen ni predlagati razvitega nabora rešitev, temveč intenzivirati izmenjavo mnenj o ustrezni umestitvi biogospodarstva v sedanjo institucionalno ureditev in sistem razvojnega načrtovanja v Sloveniji. Ti predlogi naj bi bili tudi korak k bolj sistematičnemu in intenzivnejšemu usklajevanju med oblikovalci politik pri načrtovanju prihodnjih ukrepov v podporo razvoju biogospodarstva in ugodnemu stanju ekosistemov.

Kontekst in cilji [3]

TRAJNOSTNO BIOGOSPODARSTVO REŠUJE TRENUTNE OKOLJSKE IN DRUŽBENE IZZIVE.

Družbeni okvir, v katerem se povečuje pomen biogospodarstva, sovpada z izkušnjo svetovne gospodarske in podnebne krize v prvih dveh desetletjih novega tisočletja, ki je med drugim razkrila ranljivost gospodarstva, usmerjenega v rast, ki temelji na neobnovljivih virih in netrajnostni uporabi obnovljivih virov. Prevladujoči vzorci proizvodnje in potrošnje povzročajo dolgoročne in nepovratne okoljske spremembe, ki se kažejo v degradaciji okolja in ekosistemov ter izgubi biotske raznovrstnosti. Globoke spremembe se dogajajo tudi v svetovnem trgovinskem sistemu in organizaciji poslovnih procesov, v katerih je v zadnjem desetletju prišlo do številnih kratkoročnih motenj, regionalnega prestrukturiranja distribucijskih verig in dolgoročnega zmanjšanja mednarodne trgovine. Če k temu dodamo še naraščajoče geopolitične napetosti in nepričakovane dogodke (pandemija COVID-19, ruska agresija), lahko ugotovimo, da vstopamo v obdobje naraščajoče negotovosti v vseh ključnih pogledih - stanje naravnega okolja, dostop do virov surovin in energije, poslovno okolje in nenazadnje v širšem družbenem kontekstu.

Razumevanje trajnostnega biogospodarstva kot gospodarske paradigme, ki obravnava različne vidike proizvodnje in predelave biomase, pa tudi trajnostno upravljanje ekosistemov in drugačno, krožno organizacijo poslovnih procesov, je lahko eden od odgovorov na naštete družbene izzive. Trajnostno biogospodarstvo omogoča sinergije med gospodarskimi (dodana vrednost, inovacije, znanje, konkurenčnost, industrijski razvoj, napredne tehnologije), socialnimi (delovna mesta, uravnotežen razvoj, razvoj podeželja, odgovorna potrošnja, zdravje) in ekološkimi (upravljanje podnebnih sprememb, ohranjanje naravnih virov, zmanjševanje odpadkov) komponentami razvoja. Hkrati ustreza tudi spreminjajočemu se geostrateškemu kontekstu z vse večjim pomenom kratkih in integriranih dobavnih verig.

RAZVITE DRUŽBE PRIZNAVAJO STRATEŠKI POMEN BIOGOSPODARSTVA PRI OBLIKOVANJU SVOJIH DOLGOROČNIH STRATEGIJ.

Glede na to, da organizacija tehnoloških in poslovnih procesov v skladu z načeli biogospodarstva vsebuje elemente tehnoloških in družbenih inovacij, verjetno ni presenetljivo, da začetki vključevanja biogospodarstva v strateške dejavnosti v Evropi sovpadajo s politiko raziskav, razvoja in inovacij (RRI) v zgodnjih 2000-ih letih. V zadnjih dveh desetletjih so tudi na večstranski ravni potekale različne dejavnosti za vključevanje biogospodarstva v strateške razvojne prednostne naloge. V tem okviru izpostavljamo zlasti doseženo soglasje držav o neizkoriščenem potencialu biogospodarstva pri doseganju ciljev trajnostnega razvoja ZN, vlogo biogospodarstva pri doseganju ciljev Pariškega podnebnega sporazuma (2015) in smernice OECD za strateško umestitev biogospodarstva v razvojne politike njenih držav članic (2009).

EU je leta 2012 objavila svojo biogospodarsko strategijo z akcijskim načrtom, kar je sovpadalo z objavo podobnih dokumentov drugih vodilnih svetovnih gospodarstev (npr. ZDA, Kitajske, Brazilije). V letu 2018 je bila objavljena prenovljena strategija razvoja biogospodarstva EU, ki vključuje mednarodno sprejete zaveze (cilji trajnostnega razvoja, Pariški podnebni sporazum) in cilje na ravni EU (evropski zeleni dogovor, energetska unija, prenovljena industrijska politika) ter bolj kot prej poudarja (eko)sistemske vidike.

S sprejetjem skupnih strateških smernic leta 2012 in njihovo spremembo leta 2018 je biogospodarstvo strateška razvojna prednostna naloga Evropske unije, ki združuje cilje zmanjšanja odvisnosti družbe od fosilnih goriv ter razvoja sektorjev, ki proizvajajo biomaso in ji dodajajo vrednost na podlagi znanja ter ob upoštevanju ciljev

[3] Poleg tega konceptualnega dokumenta se ta del v veliki meri opira na ugotovitve nacionalno financirane strateške raziskave (Juvančič et al., 2021b).

varstva okolja in narave. V skladu s temi prizadevanji je enajst držav članic EU doslej sprejelo namenske nacionalne strategije za biogospodarstvo, sedem nacionalnih strategij pa je v pripravi (EK, 2022).

SLOVENIJA (SKUPAJ Z DRUGIMI SREDNJE- IN VZHODNOEVROPSKIMI DRŽAVAMI) JE MED DRŽAVAMI S PREMALO IZKORIŠČENIM POTENCIALOM BIOGOSPODARSTVA

Kot je podrobneje opisano v glavnem besedilu tega konceptualnega dokumenta (poglavji 2 in 3), izkoriščenost potenciala biogospodarstva za Slovenijo ni ugodna. Slovenija ima pomemben, vendar neoptimalno izkoriščen surovinski potencial (zlasti lesno biomaso in ostanke v primarni kmetijski proizvodnji). Zaradi pritiska povpraševanja vse več proizvodnih podjetij, ki delujejo v nadnacionalnih verigah vrednosti, usmerja svoje dejavnosti v krožne poslovne modele in biotehnologije, ki pa so slabo integrirane v smislu zapiranja lokalnih (snovnih in energetskih) zank pri uporabi biomase. Relativno visoki vložki v dejavnosti RRI prinašajo dobre akademske rezultate vodilnih nacionalnih raziskovalnih ustanov, medtem ko rezultati niso dovolj vključeni v poslovni proces.

Pregled statističnih podatkov in institucionalni pregled v tem konceptualnem dokumentu (poglavje 4) opisuje ključne izzive razvoja biogospodarstva v Sloveniji. Faktorska produktivnost in gospodarska uspešnost primarnih sektorjev biogospodarstva (zlasti kmetijstva) sta pod ravnjo preostalega nacionalnega gospodarstva, pa tudi v makroregionalni primerjavi z drugimi državami BIOEAST. Sinergije med (napredno in mednarodno integrirano, vendar prehodno) industrijo in sektorjem RRI na področju biogospodarstva ostajajo v veliki meri neizkoriščene. Tudi institucionalni status biogospodarstva ostaja slabo opredeljen. Nobenega ministrstva ali drugega vladnega organa ne moremo označiti za institucionalnega nosilca portfelja biogospodarstva. Raven usklajevanja med instrumenti in ukrepi, ki podpirajo različne vidike in sektorje biogospodarstva, ostaja nizka.

VKLJUČEVANJE BIOGOSPODARSTVA V STRATEŠKO RAZVOJNO NAČRTOVANJE SLOVENIJE

Slovenija je ena od sedmih držav članic EU, ki nima posebne nacionalne biogospodarske strategije. Obsežen pregled nacionalnih strateških dokumentov, opravljen v tem konceptualnem dokumentu, kaže, da biogospodarstvo v Sloveniji ni izrecno opredeljeno med nacionalnimi strateškimi prednostnimi nalogami. Poudariti pa je treba, da medresorsko usklajevanje različnih vprašanj, povezanih z razvojem biogospodarstva, poteka. Elementi (krožnega) biogospodarstva so vključeni v različne strateške dokumente in instrumente politik. Kar zadeva dopis, je usklajevanje med različnimi resorji/skladi v veliki meri pomanjkljivo (npr. merila za izbor operacij, pokritost povezanih naložb iz različnih skladov).

Trenutno stanje komponent sistema, PRILOŽNOSTI IN IZZIVI

RAZPOLOŽLJIVOST IN MOŽNE UPORABE PREOSTALE BIOMASE KMETIJSKEGA IZVORA [4]

Med prednostnimi preostalimi tokovi kmetijske biomase izpostavljamo živinske iztrebke s skupno količino več kot 620 tisoč ton suhe snovi. Splošno učinkovitost njegove sedanje uporabe (organsko gnojilo) je mogoče bistveno izboljšati z izkoriščanjem njegove energijske vsebnosti (proizvodnja bioplina) in izboljšanimi tehnikami gnojenja tal, kar izboljša hranilno vrednost živinskih gnojil in drastično zmanjša obremenitev okolja.

Pri izbiri surovin in pripravi tehnološkega načrta za krožno uporabo ostankov in stranskih proizvodov rastlinske pridelave izhajamo iz dveh načel. Prvič, da predlagane rešitve ne smejo ogroziti ravnovesja organskih snovi v tleh. Drugič, da morajo upoštevati strukturne značilnosti kmetovanja v Sloveniji (majhnost in razdrobljena posestna struktura). Najobsežnejši vir surovin v rastlinski pridelavi predstavljajo žetveni ostanki in sekundarni pridelki poljščin, skupna količina se giblje okoli 700.000 ton suhe snovi. Naslednji količinsko in kakovostno perspektiven

[4] Projektno delo, ki je kvantitativna podlaga tega konceptualnega dokumenta, je zagotovilo ocene količine, sestave, uporabe in dinamike razpoložljive biomase iz agroživilske verige. V fazi opisovanja biomase smo podatke pretvorili v kategorije, pomembne za načrtovanje krožne uporabe in dodajanja vrednosti.

vir surovin so ostanki zelenjadnic, oljnic in korenovk, skupna količina se giblje okoli 100.000 ton suhe snovi. Drugi potencialno pomemben vir surovin so tudi ostanki v vrtnarstvu, ki znašajo 30 000 ton suhe snovi.

Pri iskanju alternativ za krožno uporabo zgoraj naštetih perspektivnih skupin kmetijske biomase moramo upoštevati njihove omejitve pri zagotavljanju učinkovite logistike in razširljivosti ter ekološke omejitve. Vendar pa ti tokovi biomase zagotavljajo potenciale za tehnološko in ekonomsko utemeljene krožne uporabe, kot so npr: (i) kaskadna uporaba lignoceluloznih ostankov s poudarkom na pridobivanju bioaktivnih sestavin in proizvodnji embalažnih materialov; (ii) pretvorba biomase z visoko vsebnostjo vlaken v kompozitne materiale ali (iii) biorafiniranje kompleksnejših virov surovin (npr. ostankov predelave sadja, zelenjave in oljnic v sestavine z visoko dodano vrednostjo).

Glede na kemijsko sestavo in tehnološke lastnosti stranskih tokov pri predelavi hrane obstajajo neizkoriščeni potenciali pri ekstrakciji bioaktivnih spojin in uporabi različnih biotehnoloških postopkov. Nabor pridobljenih spojin je obsežen in ponuja velik potencial za dodajanje vrednosti. Naša raziskava je pokazala neizkoriščene rezerve zlasti v sektorjih, ki zagotavljajo homogene tokove biomase in omogočajo razširljivost. Takšni sektorji so mlekarstvo, živalski stranski proizvodi, pivovarstvo in proizvodnja vina.

RAZPOLOŽLJIVOST IN MOŽNE UPORABE GOZDNO-LESNE BIOMASE

Zaradi izjemne gozdnatosti (58 % površine države predstavljajo gozdovi z relativno močno proizvodno zmogljivostjo) je les daleč najbolj obetaven vir surovin v slovenskem biogospodarstvu. Ta potencial nekoliko omejuje razdrobljena lastniška struktura (povprečna velikost gozdne posesti je 2,9 ha), kar je glavna pomanjkljivost za organizacijo stroškovno učinkovite oskrbe z lesno biomaso na industrijski ravni. Poleg tega se struktura in proizvodni potencial slovenskih gozdov zaradi podnebnih sprememb nepovratno spreminjata. Prihodnje projekcije napovedujejo povečanje potenciala trdega lesa, zlasti zaradi povečanja deleža in hitrejše rasti bukovih gozdov.

Povprečna letna proizvodnja gozdnih lesnih sortimentov v Sloveniji znaša približno 4,5 milijona m3, od tega približno dve tretjini iglavcev. Največji domači porabnik okroglega lesa je žagarska industrija (več kot 1 milijon m3), sledijo ji industrija lesnih kompozitov, mehanske celuloze in kemična industrija s skupnim obsegom predelave okoli 0,5 milijona m3. Veliki porabniki okroglega lesa so gospodinjstva, ki letno porabijo več kot 1 milijon m3 lesa za kurjavo. Slovenija je pomembna izvoznica nepredelanega okroglega lesa, kar je še posebej razvidno v kategoriji hlodovine iglavcev s približno 1,3 milijona m3.

Gledano z vidika splošne gospodarske uspešnosti z gozdom in lesom povezanega biogospodarstva v Sloveniji trenutne razmere niso ugodne. Izboljšave se iščejo predvsem v smislu večjega deleža doma predelanega posekanega okroglega lesa in krepitve tehnološko naprednejših alternativ sedanji rabi okroglega lesa. Rezerve so tudi v boljšem izkoriščanju gospodarskega potenciala gozda, saj se trenutno poseka le 60-70 % letnega prirastka lesa. Največji potencial je ocenjen za kategorije lesa nižje kakovosti. Z vidika dolgoročne perspektive bo ta kategorija pridobila na pomenu s spremembami v gozdnih sestojih (vse večji delež bukve). Neizkoriščene možnosti so torej predvsem v kategorijah lesa, ki so primerna vhodna surovina za postopke biorafiniranja in posledično proizvodnjo novih bioloških materialov.

Potencial ostankov sečnje za zbiranje in predelavo v industrijsko pomembnih količinah je omejen, saj njihovo odstranjevanje ni stroškovno učinkovito. Nekaj biogospodarskega potenciala v tej kategoriji lahko pripišemo lubju, ki po prostornini predstavlja približno 20 % poseka in je zaradi visoke vsebnosti bioaktivnih spojin (npr. tanini, polifenoli) pomembna kategorija surovin za proizvode na biološki osnovi, poleg tega pa je dober strukturni material za kompostiranje biogenih odpadkov.

STRUKTURA IN USPEŠNOST PANOG, POVEZANIH Z BIOGOSPODARSTVOM.

Izkušnje vodilnih držav in regij EU kažejo, da sektorji z močnimi, konsolidiranimi podjetji v konvencionalnih biogospodarskih sektorjih lažje zagotovijo vzvod za razvoj industrijskih biorafinerij in s tem povezane možnosti za dodajanje vrednosti. Slovenija ima živahno strukturo podjetij, ki se ukvarjajo s konvencionalnimi panogami, povezanimi z biogospodarstvom (predelava hrane, predelava lesa, papirnice), vendar jih večina deluje na ravni MSP. Konvencionalni proizvodni sektorji, povezani z biogospodarstvom, so razmeroma močno zastopani na mednarodnih trgih. Podjetja, ki delujejo v lesnopredelovalni panogi, dosegajo 55 % prihodkov na mednarodnih trgih, medtem ko delež živilskopredelovalnega sektorja beleži 34 % izvozno usmerjenost, kar je pod ravnjo predelovalnega sektorja v Sloveniji.

Obseg in stopnja povezanosti industrijskih dejavnosti v teh sektorjih sta se v času politične tranzicije in gospodarskega prestrukturiranja v devetdesetih letih prejšnjega stoletja znatno zmanjšala. Nekatere industrijsko pomembne dejavnosti, ki bi lahko služile kot jedro bodočih industrijskih biorafinerij, so v zadnjih dveh desetletjih prenehale z delovanjem. Stopnja poslovnega povezovanja v običajnih panogah, povezanih z biogospodarstvom, je precej nizka (tako vertikalno kot horizontalno), kar onemogoča učinke obsega, potrebne za delovanje koncepta "okrepljenega" biogospodarstva, ki povezuje podjetja v istih ali komplementarnih sektorjih z biorafinerijo v svojem jedru. Pri razvoju bolj raznolikih in inovativnih biotehnoloških vrednostnih verig se zdita izvedljiva dva scenarija: (i) vključevanje v biogospodarske grozde z mrežo majhnih modularnih biorafinerij v njenem jedru ali (ii) vključevanje v širše, čezmejne vrednostne verige z dobavo biomase in dobavo vmesnih proizvodov iz industrijskih biorafinerij, ki so v operativni oddaljenosti od Slovenije.

Poleg "konvencionalnih" sektorjev biogospodarstva ima lahko katalizatorsko vlogo pri prehodu v biogospodarstvo tudi povezovanje podjetij, ki delujejo v tehnološko intenzivnih sektorjih, ki so močno vključeni v mednarodne vrednostne verige (npr. kemična industrija, avtomobilski sektor). Povpraševanje po bioloških tehnologijah in sestavnih delih v teh panogah se pospešeno povečuje. Številni dejavniki, kot so motnje na svetovnih trgih surovin, tehnološka dovršenost na področju biobased tehnologij in spremenjena razmerja med cenami in stroški, hkrati prispevajo k pospešenemu prehodu na inovativne biobased tehnologije v sektorjih, ki so tradicionalno delovali z neobnovljivimi viri. Povečano povpraševanje po biobased tehnologijah in komponentah v tehnološko intenzivnih sektorjih je lahko pomembno gonilo rasti tudi v "konvencionalnih" biobased sektorjih (Lovec in Juvančič, 2021). Poleg tega, da so dobavitelji biomase (pogosto s slabo ovrednotenimi stranskimi tokovi), lahko povezovanje s tehnološko intenzivnimi sektorji deluje kot spodbuda za izboljšanje njihovega delovanja z več vidikov (zapiranje snovnih in energetskih zank, izboljšanje gospodarske uspešnosti).

KATALITIČNA VLOGA SEKTORJA RDI IN KOMERCIALNIH SPODBUJEVALNIH INSTITUCIJ PRI RAZVOJU BIOGOSPODARSTVA

V Sloveniji deluje živahen sektor RRI, ki se ukvarja z najsodobnejšimi aplikativnimi raziskavami in razvojem tehnologij na različnih znanstvenih področjih, povezanih z biogospodarstvom. Ta sektor, ki ga sestavljajo javne raziskovalne ustanove in zasebna podjetja, ima lahko močnejšo katalizatorsko vlogo pri sproščanju potencialov biogospodarstva, kot je to trenutno. V nekaterih sektorjih, ki jih lahko štejemo za temelje nacionalnega gospodarstva (npr. farmacevtska industrija), so raziskave, razvoj in inovacije močno povezane z industrijo. V drugih sektorjih so te povezave manj močne ali celo niso ustrezno vzpostavljene. Industrija iz različnih razlogov (npr. osredotočenost na stroškovno učinkovitost, tveganja na strani povpraševanja, pomanjkanje finančnega vzvoda) nerada nastopa kot edini vlagatelj v nove tehnologije, medtem ko si tudi razvijalci tehnologij prizadevajo za donose, ki presegajo zmogljivosti, ki niso dosegljive v običajnem obsegu podjetij, ki delujejo v (običajnih ali novih) proizvodnih sektorjih, povezanih z biogospodarstvom. Ta vrzel je bila do neke mere uspešno odpravljena v okviru industrijsko-raziskovalnih partnerstev, razvitih v okviru nacionalne strategije pametne specializacije.

V Sloveniji je vzpostavljena močna mreža podpornih institucij, ki podpirajo inovativne in razvojno naravnane podjetniške projekte. Tehnološki parki in podjetniški inkubatorji zagotavljajo strokovne podporne storitve za podjetja, kot sta ugoden najem poslovnih prostorov in mentorska podpora pri zagonu podjetja. Podjetniški pospeševalniki ponujajo strokovno svetovanje in začetno financiranje za inovativna zagonska podjetja. Oba programa sta dopolnjena z javnimi sredstvi. Trg tveganega kapitala je manj razvit in je omejen predvsem na specializirane produkte bank in zavarovalnic. Vse zgoraj opisane storitve so splošne in se ne nanašajo posebej na biogospodarstvo.

Splošni sklepi in strateški ukrepi

OBLIKOVANJE STRATEGIJE; POTREBA PO REŠITVAH, KI TEMELJIJO NA KONTEKSTU.

Idealizirani model krožnega biogospodarstva temelji na stalnem in stroškovno učinkovitem dostopu do industrijsko pomembnih količin biomase homogene sestave, njeni postopni razgradnji v velikih integriranih biorafinerijah v enostavnejše (kemične, snovne) gradnike, ki se nato vključijo v široko paleto bioloških proizvodov. Postopek poteka po načelih kaskadne uporabe - začne se z izdelki z visoko dodano vrednostjo in konča z uporabo energije. Gospodarski subjekti medsebojno sodelujejo pri razvoju novih tehnologij in procesov (biogospodarski grozdi) ter pri izmenjavi snovnih in energetskih tokov (industrijska simbioza). Prehod na krožno biogospodarstvo in njegova rast sta odvisna tudi od širšega podpornega okolja. Sestavljajo ga poslovni podporni sistem, ki podpira podjetja v zgodnjih fazah razvoja, sposoben trg tveganega kapitala, ki izpolnjuje potenciale podjetij za rast, ter država s stabilnim poslovnim okoljem, odzivnim pravnim okvirom in dosledno politično podporo.

V resnici je uporaba razvojnega potenciala biogospodarstva odvisna od konteksta. Razvoj krožnih poslovnih modelov v kontekstu slovenskega biogospodarstva se od zgoraj opisanega idealiziranega modela razlikuje praktično v vseh elementih. Začne se že pri majhnem obsegu in razdrobljeni proizvodni strukturi v primarnih sektorjih. Izhajajoč iz tega je jasno, da se bomo morali pri oblikovanju krožnih poslovnih modelov, primernih za pogoje slovenskega biogospodarstva, zateči k inovativnim in kontekstu prilagojenim rešitvam. Po drugi strani pa primarni sektorji biogospodarstva (kmetijstvo, gozdarstvo) in iz njih izhajajoče verige vrednosti kažejo značilnosti, značilne za države, ki sodelujejo v pobudi BIOEAST: nizko raven produktivnosti v primarni proizvodnji ob relativno visokem deležu zaposlenih v teh panogah, neizkoriščen potencial ostankov in stranskih proizvodov v proizvodnji, predelavi in porabi, odsotnost biorafinerijskih zmogljivosti ter nizko stopnjo zavedanja o možnostih krožnih tehnoloških rešitev in poslovnih modelov. Slednje je prisotno tako na strani industrije kot na strani javnih razvojnih politik. V tem okviru je pri razvoju ustreznih rešitev smiselno sodelovati z državami makroregije BIOEAST, ki se soočajo s podobnimi izzivi.

SPECIFIČNE SEKTORSKE POTI IN IZZIVI ZA IZKORIŠČANJE POTENCIALOV BIOGOSPODARSTVA

Trenutno uspešnost biogospodarstva v Sloveniji je mogoče bistveno izboljšati. To kažeta razmeroma nizek prispevek biogospodarskih sektorjev k skupni dodani vrednosti (20 % ali 11 odstotnih točk pod povprečjem EU-27) in nizka produktivnost dela (11.500 EUR na zaposlenega ali manj kot tretjina povprečja EU-27). Izkoriščanje potencialov biogospodarstva v Sloveniji bi moralo potekati v dveh smereh. Prva vključuje kmetijstvo, gozdarstvo in z njimi povezane "konvencionalne" proizvodne vrednostne verige (predelava lesa in papirja, katerih rezerve so v povečanju produktivnosti in dodane vrednosti sektorja, deloma tudi v zapiranju snovnih in energetskih zank znotraj njihovega delovanja. Druga usmeritev je bolj usmerjena v povpraševanje. Njeni predhodniki so podjetja, ki so vključena v mednarodne vrednostne verige in vključujejo nekatere ključne nacionalne proizvodne (npr. kemični, avtomobilski, elektrotehnični) in druge sektorje (npr. gradbeništvo), kjer se zahteve in potrebe po prehodu na biološke materiale in tehnološke rešitve povečujejo. Povečano povpraševanje po končnih izdelkih na osnovi bioloških surovin v teh sektorjih ustvarja priložnosti za rast vzdolž svojih predhodnih (razvijalci tehnologij) in nadaljnjih (primarna in konvencionalna proizvodnja) sektorjev.

Za sprostitev potencialov za bolj integrirano in trajnostno biogospodarstvo v Sloveniji lahko izpostavimo tri izzive in priložnosti.

Prvič, Slovenija se sooča z velikim, vendar neoptimalno izkoriščenim surovinskim potencialom kmetijske in gozdno-lesne biomase. Struktura praktično vseh dejavnosti, ki se ukvarjajo s predelavo kmetijske in gozdno-lesne biomase, je razdrobljena in ustvarja velike količine stranskih tokov in ostankov, katerih trenutna mobilizacija je trenutno omejena predvsem na energetsko rabo. Dodana vrednost stranskih tokov in ostankov v primarni proizvodnji in običajnih sektorjih predelave je zato razmeroma nizka in slabo diverzificirana.

Drugi izziv je nizka stopnja horizontalnega in vertikalnega povezovanja v vrednostnih verigah biogospodarstva. Tega si ne smemo napačno razlagati kot splošno odsotnost tehnološko naprednih in konkurenčnih podjetij v sektorjih, ki delujejo v teh verigah. Nasprotno, njihovo število in pomen se povečujeta. Manjka pa nizka raven njihovega povezovanja ali vsaj sodelovanja. Zato večina podjetij v sektorjih biogospodarstva deluje na ravni MSP. Posledično se velik delež primarnih proizvodov v kmetijstvu in gozdarstvu valorizira zunaj nacionalnega gospodarstva, pogoji za biorafiniranje stranskih tokov biomase na industrijski ravni pa so komaj dosegljivi. Oboje omejuje možnosti za trajnostno vrednotenje biomase in gospodarsko uspešnost (dodana vrednost, zaposlovanje) biogospodarskih sektorjev v nacionalnem gospodarstvu.

Primerjalni pregled rezultatov raziskav, ki temelji na standardiziranih kvantitativnih merilih, razkriva živahno raziskovalno-razvojno dejavnost na področju bioloških materialov in podpornih tehnologij v državi. Raziskovalne ustanove in skupine so dobro vključene v mednarodna prizadevanja na področju raziskav, razvoja in inovacij. Naložbe v raziskave in razvoj ter objave na tem področju se nenehno povečujejo. To lahko štejemo za priložnost. Po drugi strani pa se Slovenija na istem področju analize slabo odreže pri sprejemanju inovacij. Pozitivno pa je, da obstaja živahna skupnost zagonskih podjetij, številne njihove poslovne ideje pa so navdihnjene z inovacijami na biološki osnovi. Čeprav ta podjetja delujejo na nišni ravni in v zgodnjih fazah poslovnega cikla, jih lahko obravnavamo kot znanilce podjetniškega prehoda v biogospodarstvo.

UKREPI ZA SPROSTITEV POTENCIALOV BIOGOSPODARSTVA V SLOVENIJI

Za resen kakovostni preskok v smeri (odpornega, krožnega, trajnostnega) biogospodarstva morajo vsi akterji, ki delujejo v biogospodarskih sektorjih ali usmerjajo razvoj biogospodarstva v Sloveniji, bistveno okrepiti svoja prizadevanja. Pri tem je treba doseči družbeno soglasje o strateškem pomenu in institucionalni utrditvi biogospodarstva.

Najprej bi bili potrebni ukrepi za krepitev motivacije podjetij za medsektorsko in medsektorsko sodelovanje v razširjenih biotehnoloških verigah vrednosti, ki v zaprtih (snovnih, energetskih) zankah dodajajo vrednost lokalno pridobljeni biomasi.

- Ustanovitev nacionalnega biogospodarskega vozlišča bi lahko veljala za korak v tej smeri. Vozlišče bi služilo kot platforma za medsebojno izmenjavo informacij, razširjanje in izmenjavo strokovnega znanja ter ustvarjanje poslovnih priložnosti s sodelovanjem. Z institucionalnega vidika bi bilo smiselno vlogo vozlišča dodeliti že delujoči platformi s podobnimi nalogami. Z izvajanjem strategije pametne specializacije je usklajevalna vloga dodeljena strateškim razvojno-inovacijskim partnerstvom (SRIP). Mreže SRIP za prehod v krožno gospodarstvo s fokusnim področjem Biomasa in alternativne surovine se zdijo najprimernejši kandidat za to nalogo.
- Opredelitev vodilnih nacionalnih industrijskih podjetij na področju biogospodarstva in njihova motivacija, da se zavežejo k dolgoročnemu sodelovanju z lokalnimi izvajalci. Motivirati jih je treba za nadgradnjo njihovih dejavnosti in podporo naložbenim odločitvam s finančnim in kapitalskim vložkom v obliki javno-zasebnih partnerstev.
- Vzpostavitev virtualne platforme za izmenjavo (in trgovino?) s posameznimi tokovi odpadne biomase.

- Krepitev intenzivnosti znanja (aplikativne raziskave, povezovanje RRI in industrijskih partnerjev) je eden od predpogojev za izboljšanje uspešnosti biogospodarstva v smislu uvajanja inovacij. Dodatno financiranje bi te procese še dodatno spodbudilo.
- Potrebni bi bili ukrepi za povečanje povpraševanja po tehnoloških rešitvah in materialih, ki temeljijo na bioloških snoveh. Ti se začnejo pri institucionalnih kupcih prek sistema zelenih javnih naročil. Del teh prizadevanj je tudi sistematično in ciljno usmerjeno delo v smislu ureditve podatkovnih zbirk, strateškega načrtovanja na podlagi dokazov, medpanožnega in medinstitucionalnega povezovanja zainteresiranih strani, razvoja podpornega okolja in okrepljenega vključevanja v procese, ki delujejo na ravni EU.

Pri oblikovanju in izvajanju javnih politik, načrtov, programov in ukrepov za sprostitev razvojnega potenciala biogospodarstva v Sloveniji je treba upoštevati naslednje točke:

- Razvoj sistematičnih in usklajenih ukrepov za podporo razvoju ambicioznejših oblik sodelovanja med gospodarskimi subjekti (industrijska simbioza) in razvojno-inovacijskega medindustrijskega sodelovanja v okviru biogospodarskih grozdov;
- spodbujanje razvoja in uporabe stroškovno učinkovitih, inovativnih nizkoogljičnih tehnoloških in netehnoloških rešitev;
- spodbujanje gradnje biorafinerij, ki predstavljajo most med konvencionalnimi in novimi proizvodi in tehnologijami biogospodarstva ter ključni člen pri oblikovanju razvejanih vrednostnih verig;
- izboljšanje podpornih storitev (podzakonski predpisi, podatki, pravila, logistika).
- Razvoj novih poslovnih modelov, ki med drugim vključujejo kaskadno uporabo virov biološkega izvora in digitalno preobrazbo.
- Spreminjanje potrošniških navad v smeri nakupa proizvodov in storitev biološkega izvora.

1 INTRODUCTION

1.1 THE FOUNDATIONS AND AMBITION OF THIS DOCUMENT

This concept paper is an output of the BIOEASTsUP project, whose overall objective is to support Slovenia (and other countries participating in the BIOEAST initiative) in the unlocking of its bioeconomy potentials. It is building on the outcomes of extensive research, which included gathering and analysing quantitative evidence (Kulišić et al., 2020; Juvančič et al., 2021a), as well as engaging national stakeholders (Vitunskienė et al., 2021) and learning from transferable good practices (Kubankova et al., 2022). By doing so, the project (i) extended the evidence base on the structure and performance of bioeconomy sectors, (ii) provided an extensive expert survey on assets and transformation pathways underlying the development of the bioeconomy, (iii) allowed for macro-regional analysis and benchmarking with BIOEAST countries, and (iv) laid the foundations for strengthening macro-regional cooperation in research and innovation relating to bioeconomy.

The document makes a good use of the previous research and strategic planning effort with a similar focus. In this context, we highlight the nationally funded project BRIDGE2BIO (Juvančič et al., 2021b) in which a multidisciplinary team of researchers from the leading national RDI institutions dealing with applied life sciences (i) provided a detailed evidence base about the biomass inventories and streams, (ii) analysed economic performance of bioeconomy value chains, analysed their gaps and potentials and (iii) evaluated the current policy framework related to bioeconomy development in Slovenia.

Projects BIOEASTsUP and Bridge2BIO, together with some other research (most notably CELEBio, see Virant et al., 2020) and policy initiatives (most notably the Comprehensive Strategic Project of Decarbonisation, see Karba, 2022) provide a solid foundation to creating the bioeconomy strategy by defining sector-specific transformation pathways towards unlocking the potentials for a more sustainable, integrated and better performing bioeconomy in Slovenia.

The concept paper is synthesising key findings of the above listed research and strategic planning effort into a concise, yet comprehensive document, which may serve as a basis for the further development and implementation of national bioeconomy strategy – either as a stand-alone dedicated strategy, or integrated into a wider strategic framework. Its ambition is to expand strategic thinking about the development of bioeconomy in Slovenia that goes beyond the boundaries of the conventional bioeconomy sectors, such as agriculture and forestry with their immediate value chains (agri-food and forest-wood). The ambition is to extend strategic thinking to the manufacturing sectors that can build their value-adding strategies by switching towards bio-based technologies, and to improve the overall sustainability of the bioeconomy performance by connecting bioeconomy stakeholders. Better industrial uptake of RDI effort improves our capabilities for improving productivity in the conventional bioeconomy sectors. Improved logistics and establishment of context-relevant biorefining capacities can drastically improve the possibilities for gradual replacement of non-renewable (mainly fossil-based) inputs with biobased. Adding value of biomass of firms engaging the cascading process brings benefits in all three dimensions of sustainability: **ecologically**, by adopting environmentally sound technologies and by closing the (material and energy) loops; **economically** by strengthening intersectoral linkages and targeting products with higher value-added; and **socially** by expanding the the economic multiplying impacts (revenues, value-added) towards better quality and availability of (rural, bioeconomy-related) jobs.

The Concept Paper aims to intensify the exchange between the policymakers and stakeholders about the model of the future bioeconomy development in Slovenia. This exchange should align our views about relevant pathways of bioeconomy sectors in Slovenia: from primary production (agriculture, forestry, aquatic production systems) and conventional bioeconomy manufacturing sectors (food products and beverages, wood processing, pulp and paper), to the expanding 'hybrid' bioeconomy sectors, such as pharmaceutical preparations, textiles, manufacture of chemical products, construction, as well as energy supply, and service sectors engaged in ecosystem services valorization. We hope that this exchange will prove beneficial for enterprises and other economic entities operating in various bioeconomy sectors in Slovenia, to recognise their synergies and accelerate cooperation in integrated value chains. This would lead not just to the improved economic performance of participating companies, but also to a better exploitation of the potential for value added of the bioeconomy sectors, as well as improved sustainability of the economic system by closing (material, energy) loops of biomass utilisation.

The aim of this exchange is also to review and critically assess the supporting environment for the development of the bioeconomy in Slovenia. Dedicated strategic framework and coordinated policy support can direct and accelerate the processes of the restructuring of bioeconomy in the direction of improved economic performance, resilience and sustainability of the economic system. The Concept Paper is developing some proposals in this regard. Rather than suggesting a developed set of solutions, they are meant to intensify the exchange about the appropriate placement of the bioeconomy of the current institutional setup and system of development planning in Slovenia. These proposals are meant also as a step towards a more systematic and intensified coordination among policy makers in planning future actions to support the development of the bioeconomy and the favourable state of ecosystems.

1.2 The context of the transtion to (circular) bioeconomy in Slovenia

The rough assessment of the utilisation of the potential of the bioeconomy for Slovenia (substantiated in a greater detail in Chapter 2 of this document) is not favourable. Slovenia has a significant but sub-optimally exploited raw material potential (in particular wood biomass and residues in primary agricultural production). Due to demand-push, a growing number of manufacturing firms operating in trans-national value chains turn their operations towards circular business models and biobased technologies, which are however performing poorly in terms of closing local (material and energy) loops. Relatively high inputs into RDI work yield in good academic performance of the leading national research institutions, whereas the results are not sufficiently integrated into the business process (Juvančič et al., 2021a).

In terms of utilising the potential of the bioeconomy, Slovenia stands alongside other Central and Eastern European countries. While the updated strategy for the development of the bioeconomy in the EU (2018) finds that *"…the low added value of the bioeconomy in Central and Eastern European countries contrasts with their high and - compared to other European regions - underutilised biomass potential"* a widening gap with the leading European regions can be perceived in the development of the bioeconomy across all key indicator groups - from the structure of material flows to technological and economic parameters of productivity and investment and innovation intensity in bioeconomy industries. In general, the European Union is one of the regions where the differences in approaches to the bioeconomy in terms of the strategy, type and complexity of measures and available data at national level are greatest, which is somewhat inconsistent with policy harmonization in other economic areas. Previous studies (Piotrowski and Dammer, 2018; Ronzon et al., 2022) as well as results of the previous BIOEASTsUP project effort (in particular deliverables D1.2 and D1.4) show that due to various structural, administrative and other constraints neither the general market approach, which is based on the restructuring of the primary sector, nor the approach based on the EU's R&D incentives (Lovec and Juvančič, 2021), enable the gap to be bridged easily. Together with its Central and Eastern European counerparts, Slovenia joined the BIOEAST initiative, which covers activities to strengthen communication between bioeconomy actors at the national and macro-regional level, build a public support environment at the national level and represent the macro-region's interests in designing support policies for the bioeconomy at the EU level. However, these are only the starting steps in terms of recognising the role of the bioeconomy in the country's future economic development.

With the adoption of joint strategic guidelines in 2012 and its amendment in 2018, the bioeconomy represents the strategic development priority of the European Union, which combines the goals of the reduction the society's dependence of fossil fuels, and the development of sectors that produce and add value to the biomass, based on knowledge and taking into account the environment and nature conservation goals.

While the leading European countries build on the EU's strategic approach in the field of bioeconomy and circular economy by strengthening the role of research and innovation and added value and jobs within the involved sectors, Slovenia is one of the Member States that are lagging behind in this area, and their potential remains untapped. Authors cited above seek the key reasons for unbalanced performance among Member States in (i) varying level of technological development, and economic performance of bioeconomy sector; (ii) functioning of the research, innovation and development system and (iii) the institutional capacity for successful strategic coordination of the cross-sectoral area, which can act as a structural obstacle.

As substantiated with statistical data and institutional overview in the following chapters, Slovenia is facing challenges on all three above listed levels of a successful transition to the bioeconomy. Particularly in the primary bioeconomy sectors, the technological level, as well as economic performance is below par with the rest of the economy, as well as in macro-regional comparison with other Central and Eastern European countries. Synergies between (advanced and internationally integrated, but transient) industry and RDI sector in the domain of bioeconomy remain largely untapped. Also the institutional status of bioeconomy remains poorly defined.

Slovenia is one of the seven EU Member States without a dedicated national bioeconomy strategy. Sofar, the bioeconomy-related development goals and priorities and instruments have been emerging in national development strategies with different foci (Smart specialisation strategy, Strategic project for decarbonisation, Circular economy strategy), covering individual sectors (agriculture, industry, forest-wood value chain), or financial resources (CAP, ESIF, RRF). Although these strategies generally follow the approach of inter-ministry consultation and coordination, the level of coordination at the level of instruments and implementing provision is low.

The context outlined above, and elaborated in greater detail in the following sections of this concept paper, clearly indicates the need to rethink the strategic importance, and potentials of (circular) bioeconomy for a more resilient and sustainable development of Slovenia.

1.3 The Structure of the document

The Concept Paper starts by summarising the evidence base about the land use in Slovenia, and corresponding availability and current use of (mainly agriculture- and forestry-based) biomass in Slovenia. With this, the document sets a starting point for evidence-supported discussion about the material, energy and economic (in)efficiency of the current use of biomass in Slovenia, about realistically feasible scenarios of the further development of the bioeconomy in Slovenia. Description of the status quo is followed by an insight to the current structure and performance of the bioeconomy sectors in the national economy. As the future performance of the bioeconomy sectors and the pace of decarbonisation of the economy is inexplicably linked to the quality of RDI work and innovation adoption, the Concept Paper delves into the corresponding indicators. This allows us to assess more realistically the pathways of bioeconomy development that relate with technological progress and innovation adoption.

The generic overview of indicators describing the current status of the bioeconomy in Slovenia is followed by a more context-related insight. We do this by applying the approach of bioeconomy-related assets, developed for analysing bioclusters in the EU (BERST, 2015). A more qualitative assessment of the status of the Bioeconomy in Slovenia is described through the system of the 'generic' elements of the innovation helix (industry, government bodies, R&I institutions, society) and a set of context-specific assets (biomass supply, Infrastructure/logistics, commercially viable biobased products, competitive 'conventional' bioeconomy production, funding and support environment. Such insight allows us to continue with a substantive discussion of the bioeconomy-related transformation pathways. Those pathways are sector-specific and may follow different routes. The Concept Paper attempts to assess sector-specific suitability of the following pathways: (i) boosting primary productivity, (ii) production of biofuels, (iii) more efficient uses of biomass, (iv) specialising in low-bulk-high VA, and (v) valorisation of ecosystem services.

Institutional networks are pivotal for sustaining competitive bioeconomy growth. Folowing this, the Concept Paper provides a comprehensive and up-to-date insight to the institutional environment that shapes the development of the bioeconomy in Slovenia. It starts with the overview of the governmental institutions and their competences for different sectors and aspects of the bioeconomy. This is followed by a review of the strategies that address various aspects of bioeconomy development (sectoral and industrial development, RDI, management of natural resources), and an assessment of their coordination. Same approach is applied in the review of the public policies, i.e. instruments and measures measures that shape the direction and scope of the bioeconomy development. Along with the recent findings of the conceptual work on innovation systems in bioeconomy (Lovec and Juvančič, 2021), more than the public institutions and policies, the level of technological sophistication and overall performance of the bioeconomy may depend on the general level of technological sophistcation of the industry, and its integration into international value chains, as well as on the institutions and (financial) services supporting technology firms in the early stages of their development. For this reason, the Concept Paper describes also the wider (private) enabling environment available for firms engaged in commercialisation of (bioeconomy-related) innovations.

The Concept Paper takes a conventional approach towards setting the strategic objectives by synthesing the findings of the above described analyses in the format of SWOT analysis. SWOT elements were grouped grouped into consistent content sets (sectors, biomass streams, problem groups) for formulating strategic propositions. Those are translated into actions to unlock the bioeconomy potentials of Slovenia.

The concluding part of the Concept paper deals with the technologies and organisational models, which have been identified in the Strategy chapter either (i) the most relevant for major biomass streams with untapped potential (systemic solutions), or (ii) lucrative niche strategies, enabled by good RDI fundations, and (already existing) network of innovating firms. Four pathways (two for each of the two groups) are identified in this respect and described in the chapter Promising opportunities in the bioeconomy.

2 CURRENT STATE OF THE SYSTEM COMPONENTS

2.1 Biomass availability, current use and potentials[5]

2.1.1 Forests and grassland prevail in Land use, scattered ownership structure

In 2018, for which is the last available data, more than half of Slovenia's land area was covered by forests (58%). The second largest category of land use is agriculture 34%, in which grassland largely prevails (58%), followed by arable land (36%) and permanent plantations (6%). Over the last two and a half decades, the changes in land cover and use were relatively small

Due to a fragmented ownership structure in agriculture and forestry (average size of agricultural holding is 6.9ha, while the average size of a forest property is 2.9 ha, sources of primary biomass in Slovenia are extremely scattered, which is one of the main drawbacks for organizing cost-efficient supply of biomass at the industrial scale. Standardized statistical surveys provide time series of data about the (quantity, composition, utilization) biomass from primary production (agriculture, forestry) and user-specific datasets can be retrieved from the Knowledge Centre for Bioeconomy or similar metabases. Obtaining data about the biomass side streams is more demanding and often requires own research. This study largely draws such information from the recent efforts conducted within the project Bridge2BIO (Stare et al., 2020). While the reader interested in the data on specific biomass flows is advised to consult the abovementioned sources of data, this study attempts to succinctly summarise some main findings relevant for unlocking the potentials of national bioeconomy, especially in terms of its overall economic performance (value-added, employment) and in terms of successful closing of biomass loops at the local level.

2.1.2 Forestry based biomass

Exceptional forest cover, but real structural limitations, marked impact of natural disasters and climate change

Slovenia is one of the most forested European countries, as the forest covers more than half of the area, the forest cover is as much as 58.2%. Most of the forests are located in the area of beech (44%), fir-beech (15%) and beech-oak forests (11%), all of which have a relatively strong production capacity. Slovenia ranks among the European countries with the lowest share of national forests. Today, 77% of forests in Slovenia are privately owned, 20% of forests are owned by the state and 3% of forests are owned by local communities. Private forest estates are small, the average area is only 2.9 ha. Only 11% of private owners in Slovenia own a forest larger than five hectares, and they manage more than half of privately owned forest land. This is reflected in a relatively low utilization of wood potential (60-70%). In the last decade, Slovenian forests have been affected by a chain of intense weather events (large-scale ice breaks in 2014, storms in 2017, extensive fire in 2022 affected around 2000 ha), combined with intense attack of bark beetles, has irreversibly interfered with the species structure of the forests (drastically thinning the stands of conifers, especially spruce). Future projections, taking into account the combined impact of above events and climate change forecast increase of hardwood potential, particularly from the increasing share and faster growth of the beech forests.

Low added value of forest wood assortments

In 2021, the removal in Slovenian forests amounted to 4.1 million cubic meters of timber, of which 2.2 million cubic meters of coniferous trees and 1.9 million of non-coniferous trees were felled. Sanitary felling amounted

[5] Chapter largely builds on Juvančič et al. (2021a) and Kocjančič et al. (2021)

to 26% of the total timber removals. The total removals represented 57% of the allowable removals under forest management plans (SiStat Database: General data about forestry, 2021). The structure of the production of forest wood assortments in Slovenia from 2017 to 2021 is presented in Figure 1 (SURS).

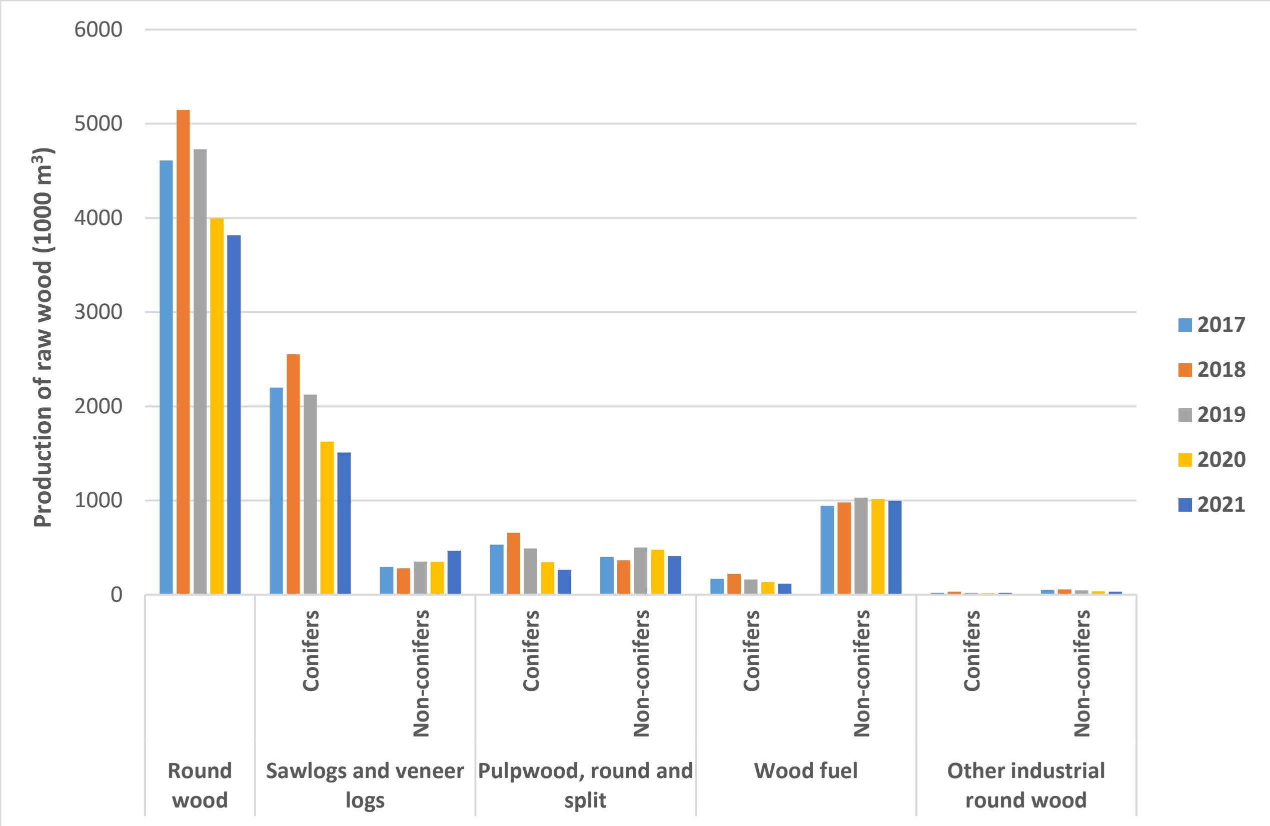

Figure 1: production of forest wood assortments in Slovenia from 2017 to 2021

Among conifers, logs dominate the production of forest wood assortments with a share of 76%, wood for pulp and boards represents a further 17%. More than half of hardwood wood (55%) is currently used for firewood, the rest is divided between wood for pulp and boards (24%) and logs (19%). The total share of other round industrial wood amounts to around 2% of the total production. The largest domestic consumer of round wood is the sawn wood industry (1.74 million m^3in 2021; wcm.gozdis.si), followed by the wood composites, mechanical pulp and chemical industries with a total processing volume of 0.513 million m^3. Large consumers of round wood are households, which annually consume over one million m^3 of wood for firewood. With this, the domestic consumption of wood is more or less rounded up, while all the remaining part of forest and wood production is intended for export. With the annual volume of exports, Slovenia is at the level of 3 million. Slovenia is a prominent exporter of unprocessed round wood, the volume of which in 2021 amounted to 1.35 million m^3. Looking from the viewpoint of the overall economic performance of the forest-wood related bioeconomy in Slovenia, the current situation is not favourable. Improvements are sought in particular in terms of a higher share of harvested round wood processed domestically, and in the strengthening of more technologically advanced alternatives to the current uses of round wood.

Unexploited potentials are highest in the categories of low-quality wood, as well as in by-products and residues from the wood processing industry

In order to assess the market potentials of the forest-timber chain, the information about the theoretical potential of forests needs to be substracted by own consumption by forest owners for their own needs, such as construction wood and firewood). According to the assessments (eg Stare et al., 2020), the largest differences between the estimated potentials and the quantities that actually entered the market are recorded for wood of lower quality. From the point of view of the long-term perspective, this is the category that will gain in importance with changes in forest stands (increasing proportion of beech). Unexploited possibilities are therefore especially in the categories of wood, which are a suitable input raw material for biorefining processes and the subsequent production of new bio-based materials.

Secondary sources of raw materials (waste biomass, wood, lignocellulosic fibers) that are produced in the processes of extraction, processing and consumption in the forest-wood-paper chain are also prospective raw materials for adding value in the cascade processing process. In 2017, the total amount of processed wood waste amounted to almost 119 thousand tons. The processing consisted of incineration and co-incineration of waste as fuel (36%), recycling including composting of waste (10%), and the rest (54%) was intended for other preprocessing methods.

Limited bioeconomic potential of wood cutting residues

The potential of logging residues for collection and processing in industrially relevant quantities is limited, as the removal of logging residues in (predominant) tractor harvesting is not cost-efficient. In addition to this, most of the logging residues in mechanical logging and harvesting are used for soil protection. The greatest bio-economic potential in this category can be attributed to bark, which by volume represents around 20% of the cut. It is an important category of raw materials for bio-based products due to its content (e.g. tannins) and is also a good structural material for composting biogenic waste. We also point out the (niche) commercial potential of logging residues, such as knots and bark of certain tree species, which, with their rich content of polyphenols, have wide applicability in the chemical and pharmaceutical industry, as well as nutritional supplements.

Among wood processing residues and end-of-life wood, the key challenges are in replacing landfilling and incineration with processing

The bio-economic potential of residues in wood processing is eloquently testified by the data on material yield, which in the primary processing of log wood into sawn assortments amounts to approximately 50%, while in the production of solid wood furniture it varies between 5 and 20%. When we add to this the discarded wood, we arrive at the current annual amount of processing of 40,000 tons. The predominant ways of using discarded wood and wood residues today are disposal in the form of inert waste and incineration in domestic boilers. In both cases, it is a questionable use in terms of harmful effects on the environment, low energy and practically no material utilization. Alternatives to the current use of wood residues and discarded wood have already been tested in practice: various processing procedures (physico-chemical, thermal and electrochemical procedures), production of composites, thermal processing into activated carbon or wood gas, biorefining (processing into methanol, ethanol), use in agriculture and environmental applications (bedding, mulch, greening of degraded areas), last but not least also energy use in specialized heating devices.

The same applies to waste biomass and waste from paper production

Considering the fact that more than half (57%) of the raw materials in the Slovenian paper industry come from paper for recycling, we can say that it is an industry that already works largely in line with the principle of circularity. In the production and processing of paper or cardboard, various wastes are generated, which represent a secondary source of biomass or cellulose fibers. The main sources of waste biomass are primary sludge (generated during the removal of printing ink from recycled fibers), secondary sludge (generated during the wastewater treatment process), wood waste (generated in paper mills with integrated wood production) and smaller amounts of paper dust (generated during paper cutting). Paper mills use part of the waste biomass as an energy source in their own production, while significant amounts of ash remain. The delivery of primary sludge to different consumers for further use is decreasing due to various reasons, so the need for cross-border disposal is increasing, which is an expensive and unsustainable solution. Primary sludges offer several more interesting alternatives depending on their physical, chemical and microbiological properties. Sludges with a high carbohydrate content are suitable for the production of biofuels and as fertilizers in agriculture, while sludges with a predominantly inorganic character can be used in the construction industry. Due to the higher content of organic matter, secondary sludge is interesting for the production of biogas and, in combination with waste ash, as a building material.

2.1.3 Agriculture-based biomass

The diverse products of primary agricultural production are primarily destined for the food supply chain, where the potential for value adding remains unexploited

Natural limitations (58% of utilised agricultural area is dominated by grassland, three quarters of agricultural land is located in areas with natural and other restrictions) determine the scope and structure of primary agricultural production. A more detailed evidence on the use of agricultural land is presented in Table 1.

Table 1: Area (ha) and shares (%) of Utilised Agricultural Area (UAA) by land categories (Source: SORS, 2021).

Use of agricultural land	Farm Structural Survey 2016	
	Area (ha)	Share (%)
Arable land	176.518	36,8
Nurseries and mother plants	288	0,1
Intensive orchards	3.856	0,8
Extensive orchards	6.405	1,3
Olive groves	1.037	0,2
Vines	15.241	3,2
Permanent grasslands and meadows	276.244	57,6
Total Utilised Agricultural Area	479.589	100,0

Two-thirds of agricultural holdings are engaged in livestock production, where (increasingly specialized) cattle breeding for meat and milk production domine. Animal production, together with own feed production, contributes the largest share (56%) to the value of agricultural production. In terms of the role of agriculture as a key link in the food supply chain and the utilization of the added value potential, it is worth noting that in the above-mentioned branches of agriculture, almost a third of the total production is exported as a basic raw material (raw milk or live animals). On the other hand, even in the sectors facing steep growth in demand (eg. fresh vegetables, organic food), the supply-side is struggling to establish systems suitable for that would be able to supply the most frequent retail formats. This observation can be extended to the entire agri-food sector in Slovenia: weak vertical integration along the food value chain, is a key obstacle in the operation of the Slovenian food system.

Table 2: Structure of agricultural holdings in Slovenia with respect to the production types (Source: SORS, 2021).

Production types	Farm Structural Survey 2016	
	Number of farms	Share (%)
Crop production	13.413	19,2
Vegetable production	432	0,6
Permanent plantations (orchards, vine)	9.189	13,1
Grazing livestock	24.983	35,7
Pig breeding and poultry	410	0,6
Mixed plant production	5.720	8,2
Mixed livestock production	3.793	5,4
Mixed arable & livestock production	11.962	17,1
Total	69.902	100,0

Exploitation of the bioeconomic potential of residues and by-products of crop production is expedient to the extent that it does not threaten the balance of organic matter in the soil

Considering the above mentioned limited resources for crop production in Slovenia, and taking into account the 'food first' principle by which primary agricultural products should be intended for the food chain (SCAR, 2015), better exploitation of agricultural biomass relates primarily to the residues and side streams of agricultural biomass. Residues from the horticultural production offer a greater potential for value adding (bioactive compounds, extractives), but quantities are low (about 83,000 tons of vegetables and 20,000 tons of fruit). Since this is a rapidly perishable and heterogeneous biomass, the most rational solution remains composting, or biogas production. Among the secondary crops and harvest residues, grains (300,000 t dry matter of straw) and corn (250,000 t dry matter of corn stems) stand out in terms of quantity. In the conditions in which Slovenian agriculture operates, it is expedient to continue to use the majority of harvest residues to maintain the balance of organic matter in the soil, whereby the dominant method of use (plowing, litter) could be replaced by conservation farming methods. Hops, the remains of vegetables, oilseeds and root crops represent additional 100,000 t dry matter of biomass. In addition to the use of residues for fodder or for plowing, residues of various crops can have potential uses in (lingo-cellulose) biorefining, or energy use. This type of use is also possible with the green cuttings of vines and fruit plants (30,000 t dry matter annually), in the case of vine cuttings, due to the content of bioactive compounds, a combination with prior extraction is also advisable.

With respect to the commercial of residues and by-products of horticultural, or arable production, examples of good practices can be found in the production of own packaging from fibrous waste streams and in the extraction of bioactive compounds.

The bioeconomic potentials of by-products of livestock production are primarily related to the energy sector

By far the most extensive by-product of livestock production are livestock excrements, the annual amount of which (expressed in tons of dry matter) is in the range of 500,000 t for slurry, 60,000 t poultry manure and 65,000 t stable manure. Livestock excrement is, of course, a key component of organic fertilizers, important for the growth and development of plants or crops, as well as improving soil quality (organic matter, water retention capacity and reducing soil compaction). Livestock manure can also be an important source in obtaining heat, electricity (and potentially also biogas), the utilization of which today is well below 10% of the potential (slightly higher only in the case of pig farming). The existing network of biogas plants (predominantly those with a size between 1 and 4 MW) is oversized for the way and organization of agricultural production in Slovenia, which causes point excessive environmental loads (insufficient areas for fertilizing with digestate from biogas plants). In the prevailing conditions of Slovenian agriculture with relatively small and spatially dispersed farms, the key challenge is the establishment of smaller biogas plants (of the 250 kW range) on larger farms, or the connection of farms and other users (e.g. local communities) in group investments and the operation of smaller biogas plants. In the case of the latter, if it were to be combined with other organic waste as a substrate, it would be an additional challenge in the environmentally friendly use of digestate.

Homogenous structure and valuable compounds reveal bioeconomic potentials of residues in food production, which are however difficult to assess due to data limitations

In the material sense, residues in the food processing (eg. processing of meat, milk, fruits, vegetables, bakery and confectionery products, alcoholic and non-alcoholic beverages industry) are extremely diverse. Two properties common to most of this kind of residues are relatively homogenous composition, and high water content. For their efficient further use, it is necessary either to enable rapid use or to include various measures to prolong stability. At the same time, some side streams provide a very good source of antioxidants with antibacterial and antifungal activity, and could be used as stabilizers.

Determining the available quantities of food processing residues, which is essential for the planning of their further valorization, is difficult. It is often the case with these residues that, depending on the use, the same substances can be by-products (when they are used) or waste (when they are thrown away). A publicly accessible database is maintained only for the latter. In order to plan economic activities that would effectively exploit the bioeconomic potential of side streams in food production, it would therefore be necessary to improve the method of collecting data on side streams, preferably in interaction between the food processing industry (simplicity, up-to-date flow) and interested users of these streams.

More than half of the waste in food production relates to the processing of meat and milk, energy use (biogas plants) dominates

The annual amount of side streams in the food processing industry, which is classified as waste in the current classification, is around 30,000 t annually. The main source of waste is the production of food of animal origin (31%) and the production of dairy products (22%), followed by the production of alcoholic and non-alcoholic beverages (17%), and other activities that together contribute the remaining 10%. Stare et al. (2020), the prevailing use of this type of waste is biogas (50-100%, for most streams between 70-90%). The exception is waste edible oils, where the main method of processing is refining, or other methods of reuse and by-products of animals that are processed into various products with added value (production of proteins and fats as raw materials for animal nutrition, chemical, pharmaceutical and cosmetic industries etc.).

Various possibilities for valorising waste and side streams in the food processing industry, most prominently in the dairy and brewing industries

Considering the chemical composition and technological properties of side streams in food processing, there are untapped potentials in the exploitation of bioactive components or substances with added value before their final use for energy purposes (which is the predominant use today). Usually, these preliminary processes of extraction of target substances do not affect the substrate properties for its (final) use in the biogas plant. In the case of animal by-products, improvements (of the already well functioning processing system) could lead to the strengthening of production possibilities and the quality of the final products, as well as to new methods of enzymatic processing and fermentation.

Unexploited reserves are pronounced in the side streams of milk processing, where the most interesting substrate is whey. The processing options are diverse and are linked either to the extraction of individual fractions (e.g. lactose, proteins, bioactive peptides) or to biotechnological processes, the associated extraction of platform chemicals (e.g. alcohols, polysaccharides, organic acids, biosurfactants, biologically active components and enzymes) or as a raw material for the production of microbial biomass (e.g. meat substitute).

The quantity, potential for further processing, homogeneous composition, continuous inflow of biomass and consolidated industry characterize the good bioeconomic potential of the residues of the brewing industry. Beer grounds are an interesting raw material source for a wide range of products, e.g. as a protein component in cereal products, a substrate for the production of enzymes and organic acids, a raw material source for obtaining fractions (e.g. various sugars and organic acids) and in the production of bioadsorbents. Another promising residue of beer production is excess brewer's yeast, the possible uses of which range from a functional additive in food to an additive to animal feed to a substrate for microbial cultures. Other beverage production residues offer similar different application possibilities, among which it is worth mentioning the extraction of oligosaccharides (emulsifiers) from fruit pomace and the extraction of antioxidants from wine production residues.

Other side streams of the food processing industry do not lack bioeconomic potential, but quantities and logistical complexity are the limiting factors

The processing of fruits and vegetables also yield in residues with interesting bio-economic potential, which, however, are limited due to smaller quantities and demanding logistics. The possibilities of use are diverse, from the isolation of biologically active compounds or the production of microbial enzymes from residues (eg. potato processing), to the isolation of fibers, polysaccharides, polyphenols and other bioactive components from residues in the processing of fruits and vegetables. This group also includes oil cakes and pulp, which are partly already used as food or fodder as well as in fertilization and plant protection, but also offer possibilities for processing into products with high added value (e.g. production of antibiotics, biological pesticides, enzymes, biodegradable polymers, bioadsorbents, etc.). The remains of the milling industry are also an interesting raw material, especially bran, which enables the isolation of fractions or the enrichment of foods with proteins and dietary fibers, polysaccharides, sugars and phytosterols. Bran is also interesting as a substrate for the production of a wide range of enzymes, organic acids (succinic acid, lactic acid, etc.) and antibiotics. Interesting applications are also the use of obtained fibrous material for the production of paper and packaging, as well as the production of yeast from bakery waste.

In the case of discarded food, the priority should be given to reduce the quantity and to incorporate it into the food cycle as much as possible

Discarded food represents a significant source of waste, the current amounts of which (on average 130,000 tons/year) are a multiple of the amount of waste in food production. In relation to wasted food, due to the high nutritional value, ethical aspects, as well as the high energy and development input in the preparation of the final food, it is expedient to develop strategies in the following order: (1) minimizing the amount of wasted food; (2) inclusion of usable food waste for human consumption; (3) the use of waste food for animal nutrition and only lastly (4) the use of waste food not related to nutrition. In the case of streams of discarded food that are not suitable for consumption, from a technological point of view, it is also necessary to take into account that their use is limited by short or questionable stability (need for hygienization or additional stabilization) and high heterogeneity. The current use of waste food, which is not suitable for consumption, is at best energy (biogas), but it could also potentially be used to obtain valuable components in the fractionation process.

2.2 Structure and performance of the national bioeconomy

2.2.1 Employment

In 2017, 131,719 people were employed in the bioeconomy in Slovenia. More than half (58.1%) were employed in agriculture, 14.1% in food production, 7.6% in wood processing and processing and 6.3% in forestry. All other industries employ three percent or less of people, which is a total of less than 14% of all employees in the bioeconomy (**Error! Reference source not found.**).

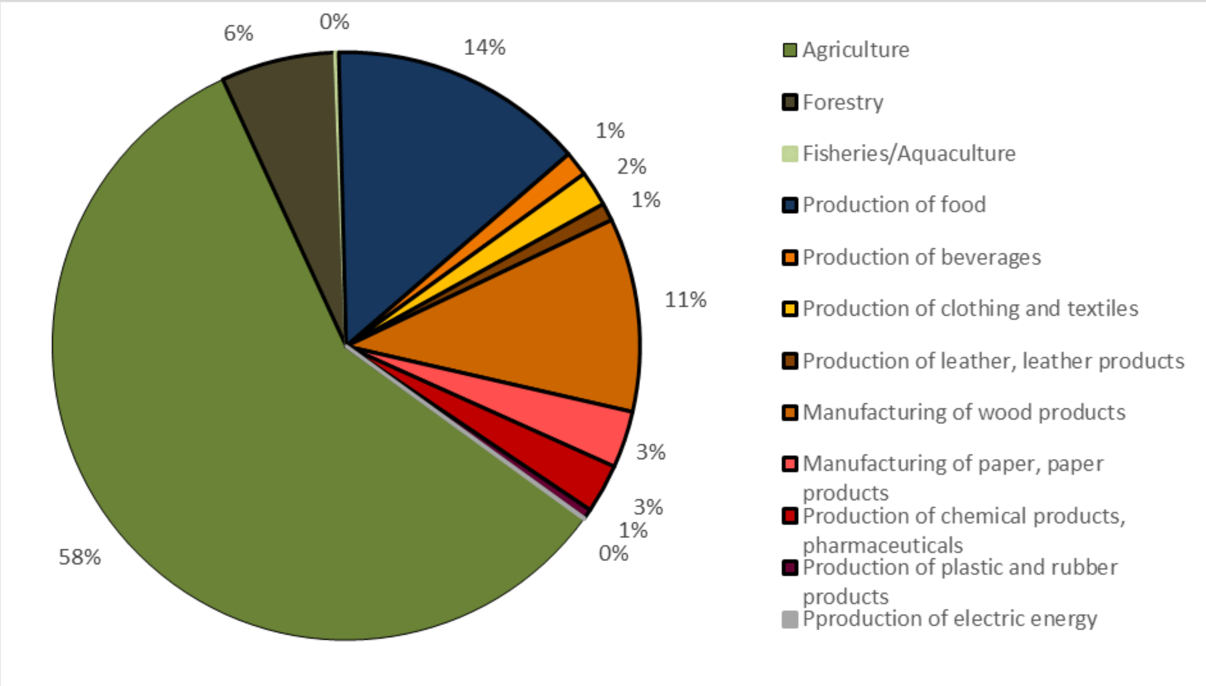

Figure 2: Structure of employment in bioeconomy sectors in Slovenia in 2017 (source of data: Ronzon et al., 2020).

The share of employment in primary sectors (agriculture, forestry and fishing) in Slovenia is (65%), which is below the average of the BIOEAST region (70%), but in comparison with the EU27 average (57%) and especially with the reference countries (AT, DE, NL, FI), where the primary sectors represent between 31% and 51% bioeconomy employment, this is still quite high. Employment in the food and beverage production in Slovenia is low (15%) when compared with the EU27 average (25%), and reference countries (about 25% in Austria, 20% in Finland, 33% in the Netherlands, and 45% in Germany. The textile production industry, which includes the production of textiles, clothing and leather, leather and related products, employed 3% of people in the bioeconomy in 2017, which is slightly less than the BIOEAST region (3.5%) and EU27 (4%) and slightly more than the rest of the reference countries, where the share of employees in this industry varies between 1.3% (Netherlands) and 2.1% (Austria). With 11% of all employees in the bioeconomy in Slovenia, the wood processing industry (processing and treatment of wood and wood products and furniture) is above the European average (8%) and comparable to Germany and Finland (10%, 12%). For Slovenia, employment in paper production amounts to a good 3% of total employment in the bioeconomy. This is approximately at the level of the EU27 average and above the average of the BIOEAST region (1.8%), but less than the reference countries (from 4% in the Netherlands to 13% in Finland. In 2017, slightly above 3% was the employment in the industries, which include the chemical industry, pharmaceuticals and the production of rubber and plastic products. Mainly due to the number of people employed in the pharmaceutical industry, as well as in the production of rubber products, this share in Slovenia is relatively high compared to the BIOEAST region (1%) and also above the EU27 average (2.5%). The share of the number of employees in this aggregate is comparable to Austria and Germany, but these two countries exhibit greater importance of the chemical industry and the production of liquid biofuels, which is not present in Slovenia. The number of employees in bio-based electricity production in Slovenia in 2017 was negligible (0.05% of all employees in the bioeconomy). At the EU27 bioeconomy level, the production of bio-based electricity contributes 0.13% to employment (with Austria (0.20%) and Finland (0.68%) exceeding the European average the most).

The dynamics of employment by the bioeconomy sectors in the period 2008 and 2017 are shown in **Error! Reference source not found.**. In aggregate, the period 2008 – 2017 sought a 17% decrease in employment in the bioeconomy in Slovenia. The drop is particularly pronounced in the manufacturing sectors: clothing (-75%) and textiles (-59%) and in the production of furniture (-58%), while the decline in employment is the smallest in agriculture (-14%). Forestry and electricity production recorded an increase in employment during this period (17% and 15%, respectively).

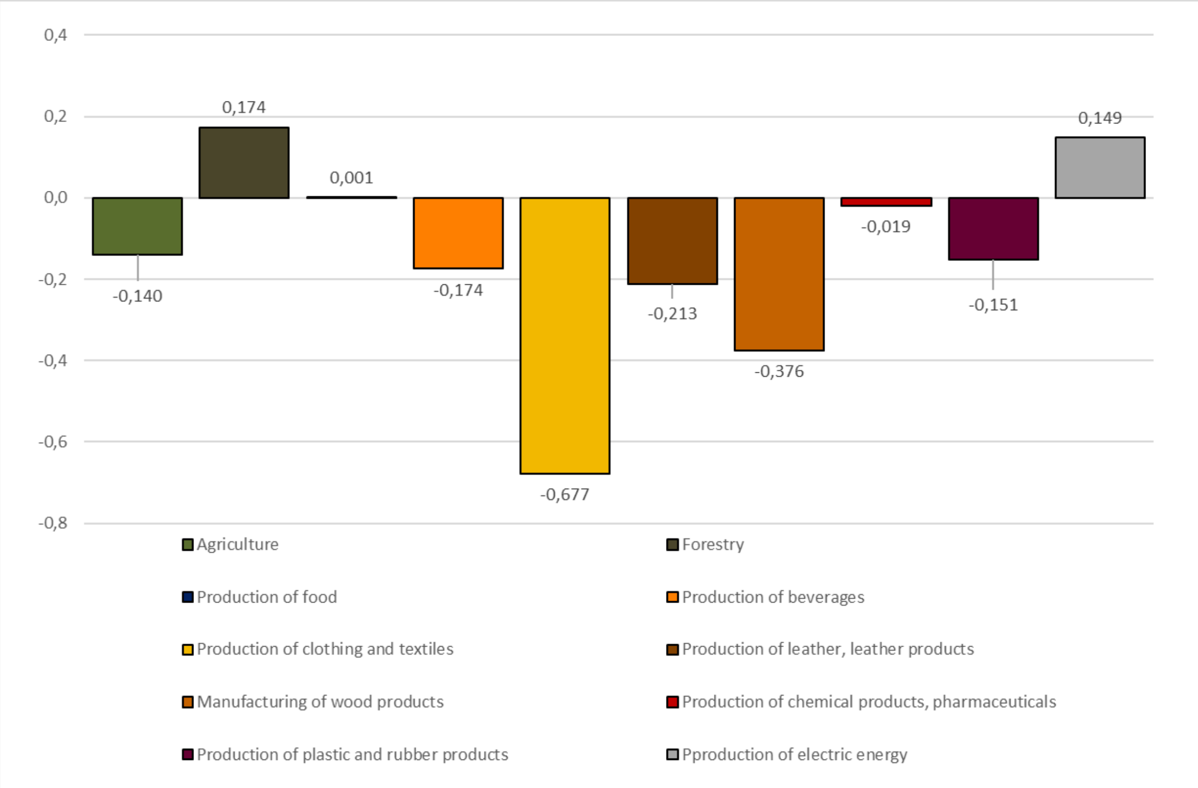

Figure 3: Employment dynamics in bioeconomy sectors in Slovenia between 2008 and 2017 (source of data: Ronzon et al., 2020)

At the level of the bioeconomy, the decline in employment between 2008 and 2017 in Slovenia is slightly greater than in the EU27 countries, where employment fell by 13%, but smaller than in the BIOEAST region, which recorded a 21% decline in employment in this period.

2.2.2 Value added

The added value of the bioeconomy in Slovenia amounted to €2,333 million in 2017, which represents approximately 0.5% of the added value of the bioeconomy in the EU27. **Error! Reference source not found.** shows the structure of added value in the bioeconomy in Slovenia by sectors. From the point of view of added value, agriculture and food production have the greatest importance in the bioeconomy, each contributing a fifth of the added value to the total added value (20% and 19.5%). Production of pharmaceutical raw materials and preparations (17%), forestry (13%) and processing and processing of wood (10%) also have a more pronounced importance in the (potential) bioeconomy sectors. Paper production contributes slightly less than 6% to the total added value of the bioeconomy, the contribution of the remaining industries is less than 4% and amounts to approximately 10% in total.

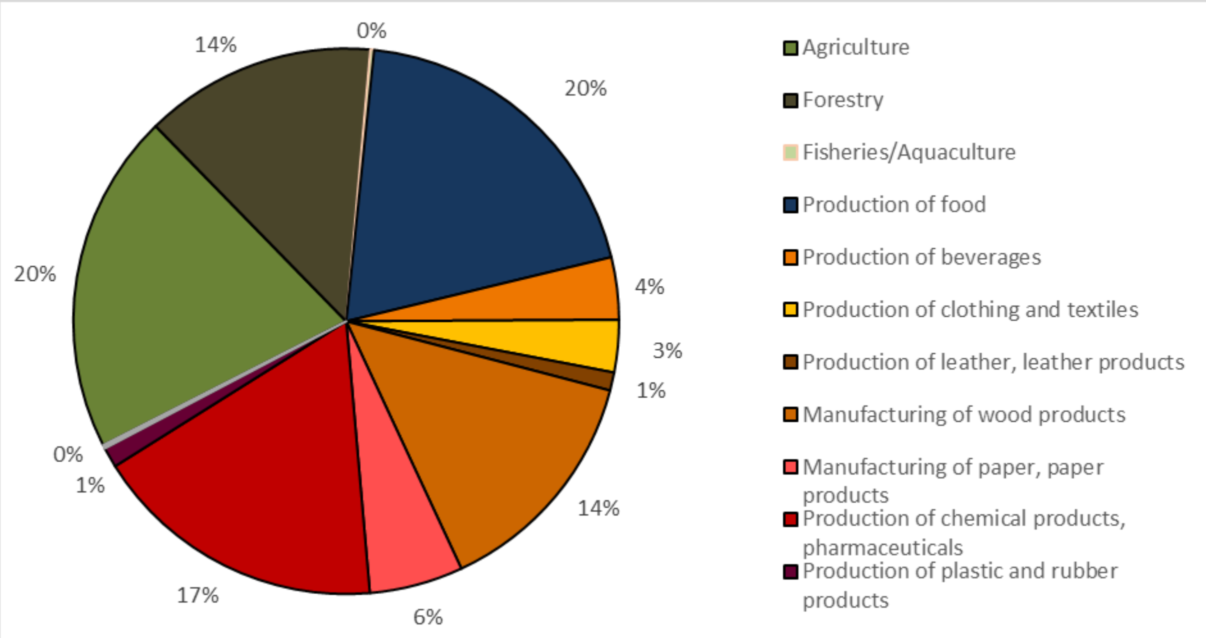

Figure 4: Structure of value added in bioeconomy sectors in Slovenia in 2017 (source of data: Ronzon et al., 2020).

The contribution of agriculture to the total value added of bioeconomy in Slovenia (20%) is below the EU27 average (31%). At the level of the BIOEAST region, this contribution is almost twice as high (39%) as in Slovenia. Forestry also contributes a relatively high share of added value to the Slovenian bioeconomy (14%). In the manufacturing sectors that are directly related to forestry (wood processing industry and paper production), slightly smaller deviations can be discerned between Slovenia (14%), the BIOEAST region and the EU27. The largest contributor to the total added value of the bioeconomy in Slovenia is the food and beverage production industry (24%). This share is otherwise comparatively low in comparison with the EU27 and the BIOEAST averages. The importance of the chemical industry, pharmaceuticals and the production of rubber and plastic products, which is attributed to the bioeconomy (18%), stands out significantly, mainly at the expense of the added value in the pharmaceutical industry (17%). The importance of the textile industry in the bioeconomy is smaller in Slovenia and amounts to about 4%, which is comparable to the EU27 and slightly more than in the BOEAST region (2-3%). Production of bio-based electricity in Slovenia has an almost negligible importance in the aggregate bioeconomy value added (0.21%).

The structure and dynamics of value added in the period 2008 and 2017 is presented in Figure 5. In the period 2008-2017, the aggregate value added of the bioeconomy in Slovenia grew by €91.6 million, or 4%. The growth of added value during this period is significantly lower in comparison to the BIOEAST region (16%) and EU27 (21%). During the period 2008-2017, fishing (89%) and the production of leather, leather and related products (29%) recorded relatively high growth of value added, but their importance of these industries in the bioeconomy (0.2% and 1% of value added) is very low. Forestry (25%), food production (22%) and agriculture (8%) made a greater contribution to the increase in value added. The relatively low growth of the bioeconomy was contributed by a drop in added value in the production of textiles and clothing (34%), in the paper industry (-

12%), in the production of beverages (-10%), in the wood processing industry (-10%), in the product manufacturing industry from rubber and plastics (-2%) and in the chemical industry and pharmacy (-0.4%).

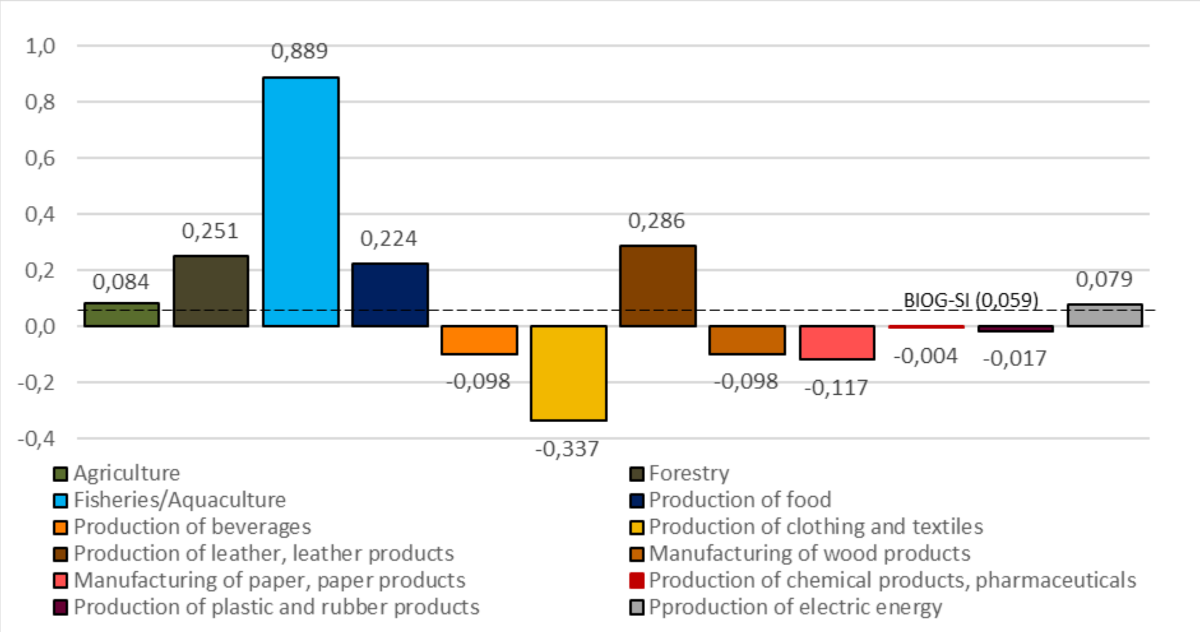

Figure 5: Dynamics of value added in bioeconomy sectors in Slovenia between 2008 and 2017 (source: Ronzon et al., 2020)

2.2.3 Labour productivity

Value added per employee as a measure of labor productivity in the bioeconomy in Slovenia in 2017 reached €20,519. The sector with the highest labor productivity is pharmaceutical industry, where the added value per employee is more than €135,000 (Figure 6). This is followed by electricity production with almost €90,000/employee, chemical industry with €64,200/employee and beverage production with €55,800/employee. In the production of rubber and plastic products, forestry, paper production and textile production, the added value per employee varies between €35,500 and €45,500. Industries with labor productivity below €30,000/employee are food production, wood processing industry, leather production, fishing and clothing production (between €18,150 in clothing production and €28,600 in food production). Agriculture records the lowest added value per employee, namely €7,130.

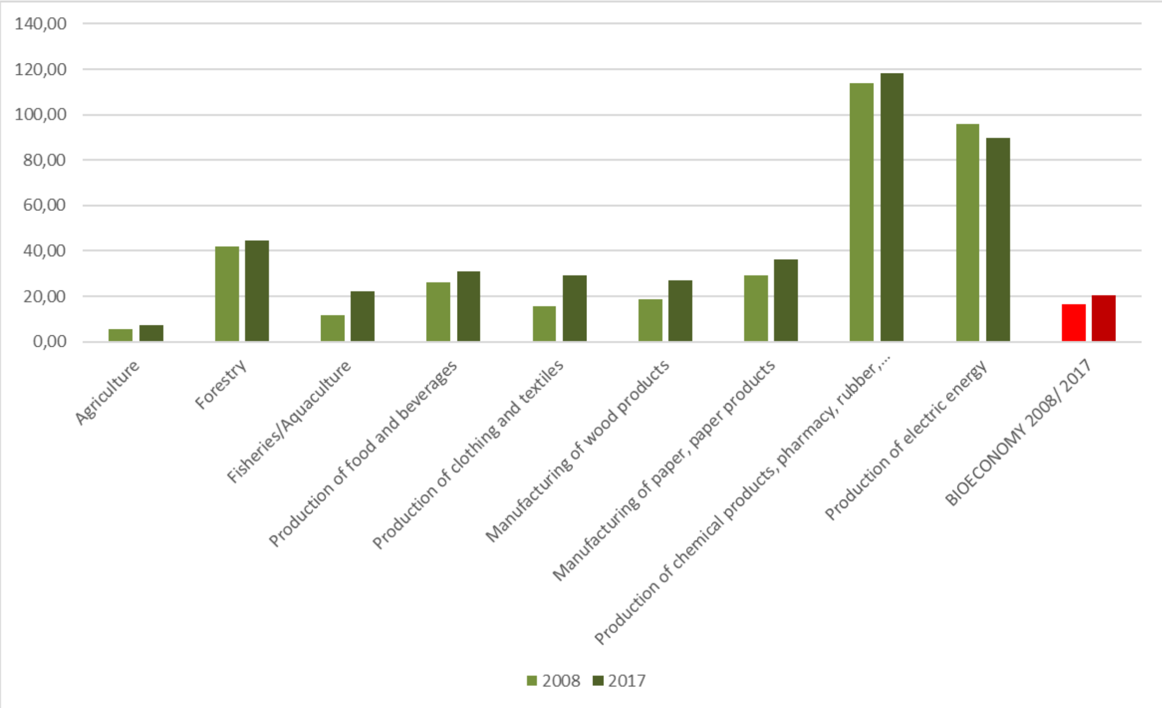

Figure 6: Value added per employee (labour productivity) by bioeconomy sectors and bioeconomy aggregate in Slovenia between 2008 and 2017 (source of data: Ronzon et al., 2020)

In general, labor productivity in bioeconomy in Slovenia is relatively low. It is almost as twice as large as in the BIOEAST region (€11,500/employee) but lags far behind the EU27 average of €35,000. Compared to the EU27, labor productivity is particularly low in agriculture, in electricity production and in the paper industry (

Figure 7). At EU27 level, the added value per employee in agriculture amounts to €20,300. In the food production, labor productivity at the EU27 level is approximately 60% higher than in Slovenia. Productivity in forestry and textile production is more comparable to the EU27. In textile production, the added value per employee in Slovenia (€42,500) is even slightly higher than the EU27 average (€38,500). In forestry, labor productivity in the EU27 with €49,000/employee does not deviate much. The high added value per employee in pharmacy, which is the most pronounced in terms of productivity in Slovenia, is still below the EU27 average.

Figure 7: Comparison of labour productivity (VA/employee) by bioeconomy sectors in Slovenia, EU27 and BIOEAST (source of data: Ronzon et al., 2020)

The growth rate of labor productivity by bioeconomy sectors in Slovenia between 2008 and 2017 is shown in Figure 8.

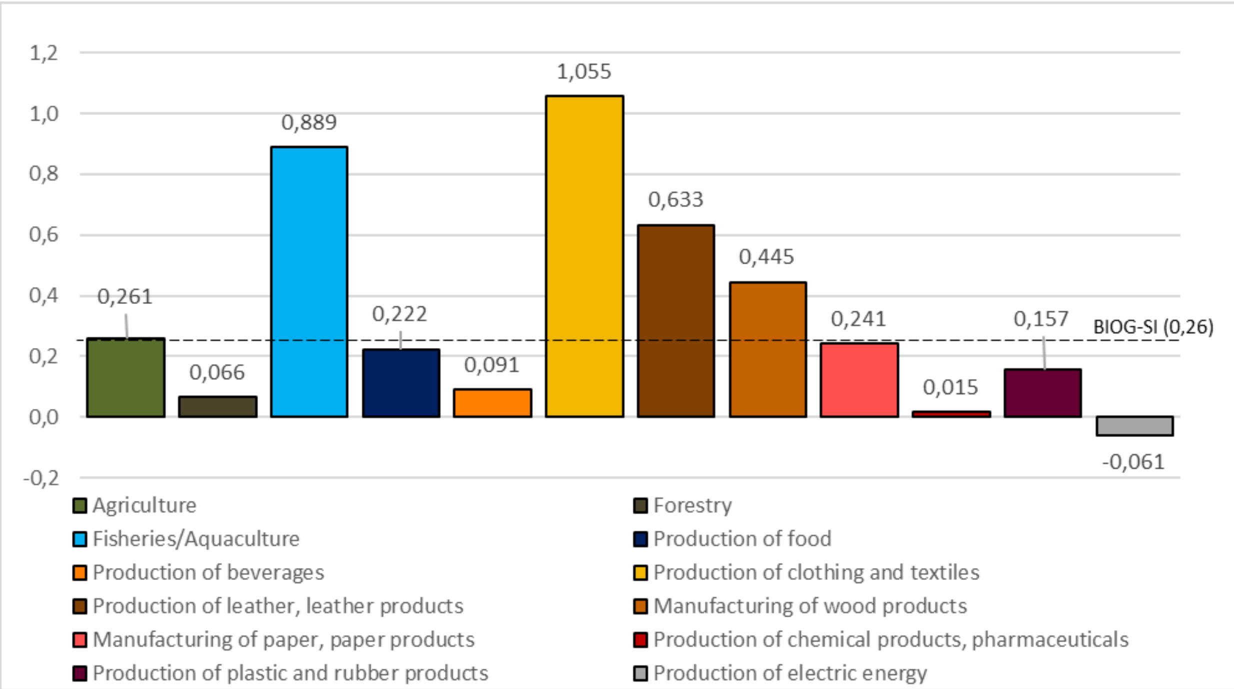

Figure 8: Dynamics of labour productivity (VA/employee) by bioeconomy sectors in Slovenia between 2008 and 2017 (source of data: Ronzon et al., 2020)

The highest growth in added value per employee during the period 2008-2017 was recorded in the production of textiles and clothing, which is the result of an intense decline in the number of employees (-60%) (Figure 9). The same applies to the wood processing industry and paper production. In the wood processing industry, the relatively high increase in productivity (40%) is the result of a simultaneous decrease in added value and a more pronounced decrease in employment, while in paper production the decrease in added value and employment is somewhat less pronounced, which is why productivity growth is also lower (24%). Fishing records the highest labor productivity growth (89%), which is clearly the result of an equally intense increase in added value. Stable employment and an increase in added value during the observed period is also the reason for the increase in productivity in the food industry (13%). In agriculture, a simultaneous decrease in employment (-14%) and an increase in added value (8%) contributed to the relatively moderate increase in productivity (26%). A greater increase in value added than the increase in employment in forestry contributed to the 7% growth in the productivity of this industry. In the chemical industry and pharmacy, productivity growth in the period 2008-2017 is even less noticeable (1.5%). The only industry that is characterized by a decline in productivity in the period under consideration is the production of electricity. The latter is the result of a slightly more pronounced increase in employment in bio-based electricity production (15%) than in added value (8%) in this sector.

Figure 9: growth of productivity (VA/employee) between 2008 and 2017 by sectors in relation to the changes in the employment and value added, reference values for 2008 normalised at the value of 1 (source of data: Ronzon et al., 2020)

2.2.4 Structure of enterprises in bioeconomy sectors

In Slovenia, there were 10,492 active companies in bio-based industries in 2019, which is around 6% of all active companies in the country. Of these, 99.8% were medium, small, and micro enterprises (SMMEs; up to 250 employees) or more than 90% were enterprises with up to 9 employees (micro enterprises). In the economy as a whole, the number of SMMEs per 1 000 inhabitants was 98.4. In the bio-based industries, the number of SMMEs per 1 000 inhabitants was 5.5, which is proportional to the share of these enterprises in the national economy.

The number of active enterprises in the bio-manufacturing industries experienced a major increase between 2012 and 2013 (+ 85%) and then, with the exception of 2016, a less intense decline. In 2018, there were 15% more active firms in the bio-based industries than in the previous decade (Figure 10). The trend in business start-ups is similar to that of active firms, but both the increase in 2013 and the subsequent decline in business start-ups are markedly more intense. In 2013, there were 150% more start-ups than n 2009, while the number of start-ups in bio-based industries has fallen by more than 50% since then until 2018. In 2018, there were 18% more start-ups in Slovenia than in 2009.

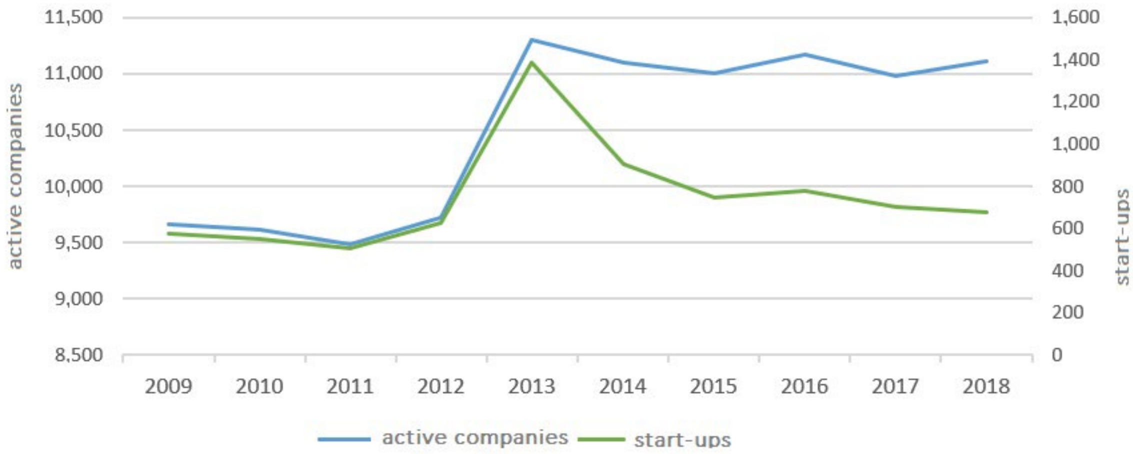

Figure 10: Evolution of the number of active and newly created enterprises in the bio-based manufacturing industries in Slovenia in the period 2009-2018 (data source: EUROSTAT, 2021f).

The largest share of active enterprises in the bio-based manufacturing industries was in food and beverages (25%), wood processing (20%) and furniture (19%). (**Error! Reference source not found.**). The largest share of new start-ups among manufacturing industries in 2018 was also in food and beverage manufacturing, at 38%. As with active firms, wood processing (18%) and furniture manufacturing (16%) accounted for a larger share of new start-ups. In textiles and paper, the share of new start-ups was around 9%, while the share of new start-ups in the remaining bio-manufacturing industries was less than 5%.

Table 3: Number and structure of active and newly created enterprises by bio-based manufacturing industries in Slovenia in 2018 (data source: EUROSTAT, 2021f).

	Active companies		Start-ups	
	number	%	number	%
Food and drink production	2,596	25%	257	38%
Manufacture of textiles and clothing	1.053	10%	63	9%
Manufacture of leather and leather products	150	1%	12	2%
Manufacture of wood and of products of wood	2,080	20%	119	18%
Manufacture of paper and paper products	1,353	13%	60	9%
Chemical industry and pharmaceuticals	257	2%	29	4%
Manufacture of rubber and plastic products	966	9%	32	5%
Manufacture of furniture	1,986	19%	106	16%
Together:	10,441	100%	678	100%

Figure 11 shows the structure of SMMEs by bioeconomy sector in 2019. In 2019, almost a quarter of SMMEs were registered in the food processing industry. A larger share of SMMEs was also contributed by the wood and wood products processing and manufacturing industry (18%) and the agricultural production and related services industry (15%). Around the same share of SMMEs was registered in 2019 in the furniture manufacturing industry (10%), the forestry industry (9%), the textiles industry (9%) and the rubber and plastics products manufacturing industry (9%). The latter, however, has a slightly lower importance in the bioeconomy

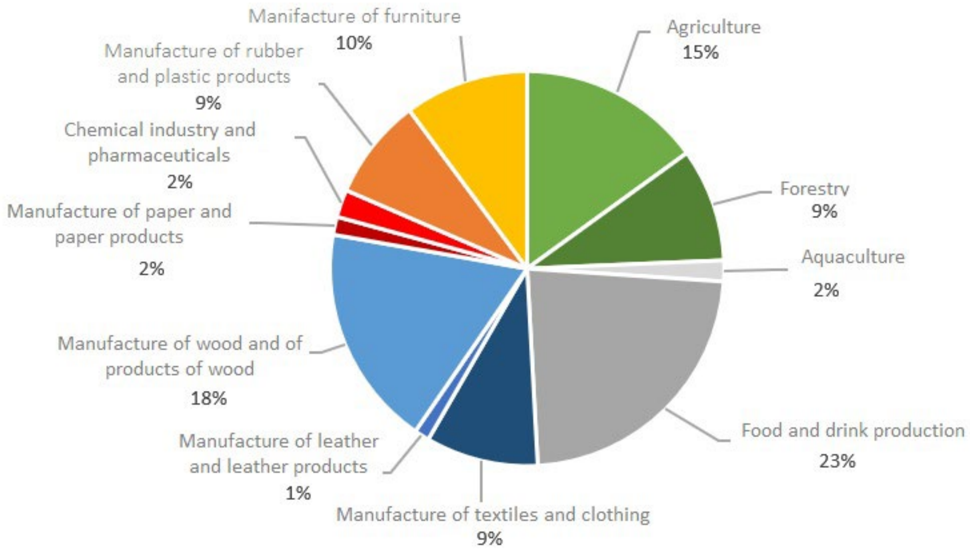

Figure 11: Structure of SMME by bioeconomy sector in Slovenia in 2019 (SiStat-SURS, 2021a)

2.3 Knowledge, innovations, technologies

2.3.1 State of the art – RDI indicators

RDI Expenditure

Gross Expenditure on Research and Development (GERD) in 2019 amounted to 989.26 million €. The BIRR is made up of the total internal expenditure of 4 sectors: business, government, higher education, and private non-profit sectors.

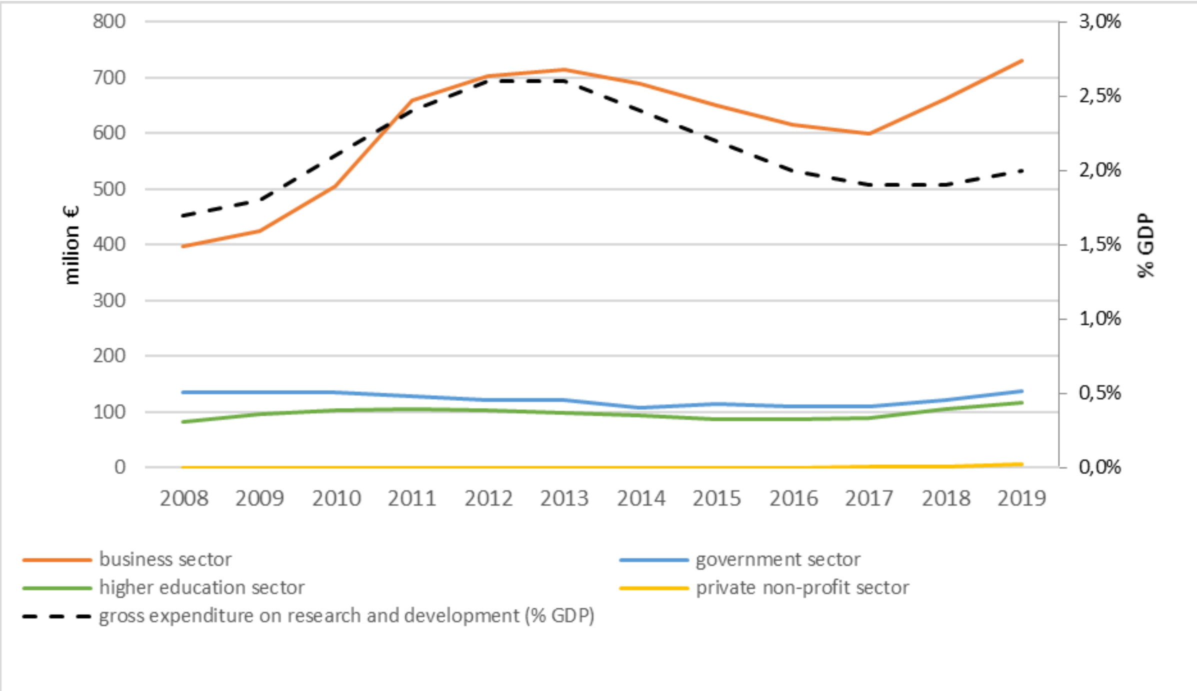

Figure 12: Trends in gross expenditure on research and development (GERD) by investment sector (in million €; primary axis) and GERD as a share of gross domestic product (% of GDP; secondary axis) in Slovenia over the period 2008-2019 (data source: EUROSTAT, 2021).

shows the evolution of the GERD by sector over the period 2008-2019.

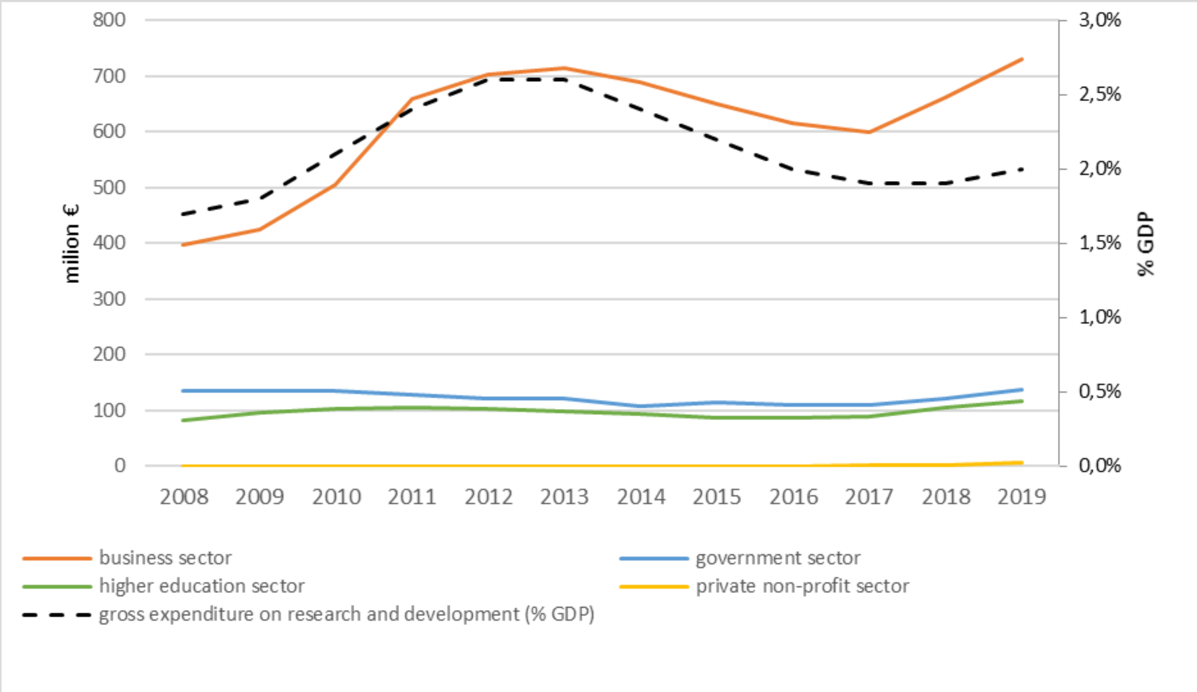

Figure 12: Trends in gross expenditure on research and development (GERD) by investment sector (in million €; primary axis) and GERD as a share of gross domestic product (% of GDP; secondary axis) in Slovenia over the period 2008-2019 (data source: EUROSTAT, 2021).

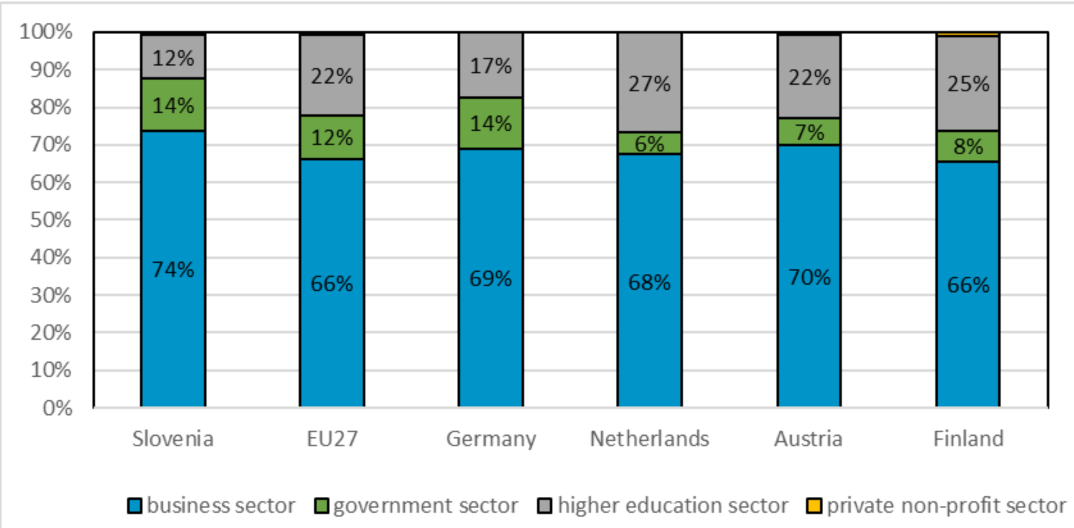

Figure 13: Structure of Gross Expenditure on Research and Development (GERD) by investment sector for Slovenia, EU27 and selected reference countries in 2019 (data source: EUROSTAT, 2021)

Over this period, total GERD increased by 60%, mainly due to a more pronounced increase in business expenditure on research and development (BERD) (+ 83%), which represents the most important sector for investment in research and development (R&D) with 74% of total GERD. (

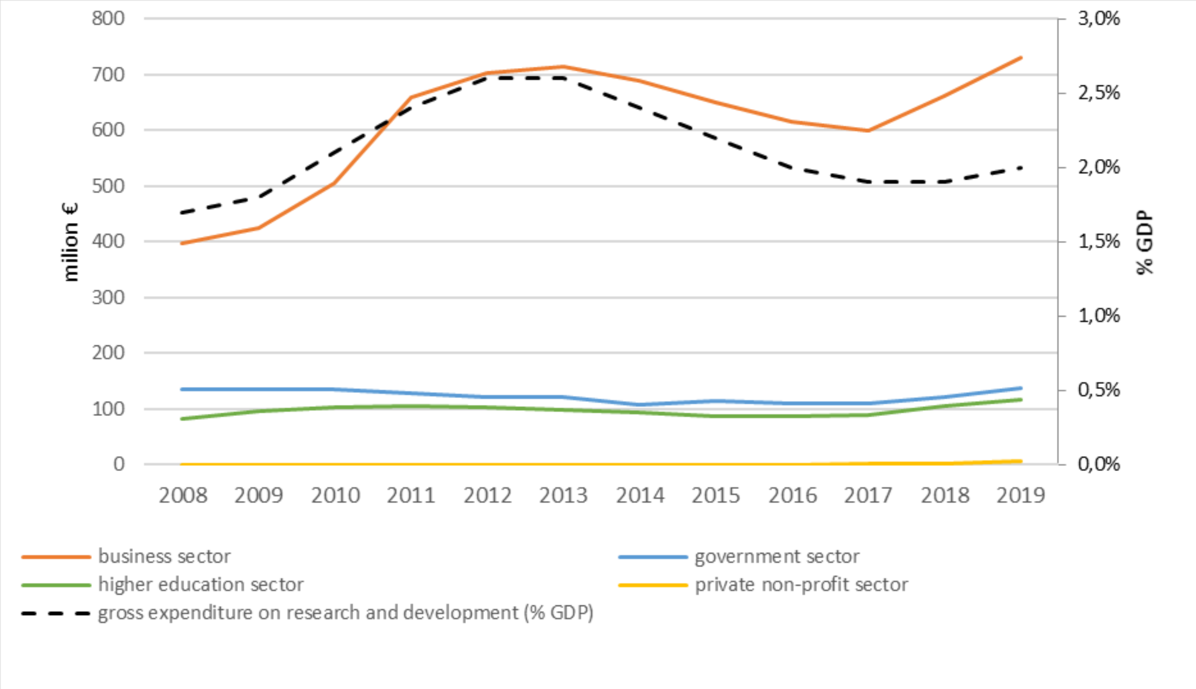

Figure 12: Trends in gross expenditure on research and development (GERD) by investment sector (in million €; primary axis) and GERD as a share of gross domestic product (% of GDP; secondary axis) in Slovenia over the period 2008-2019 (data source: EUROSTAT, 2021).

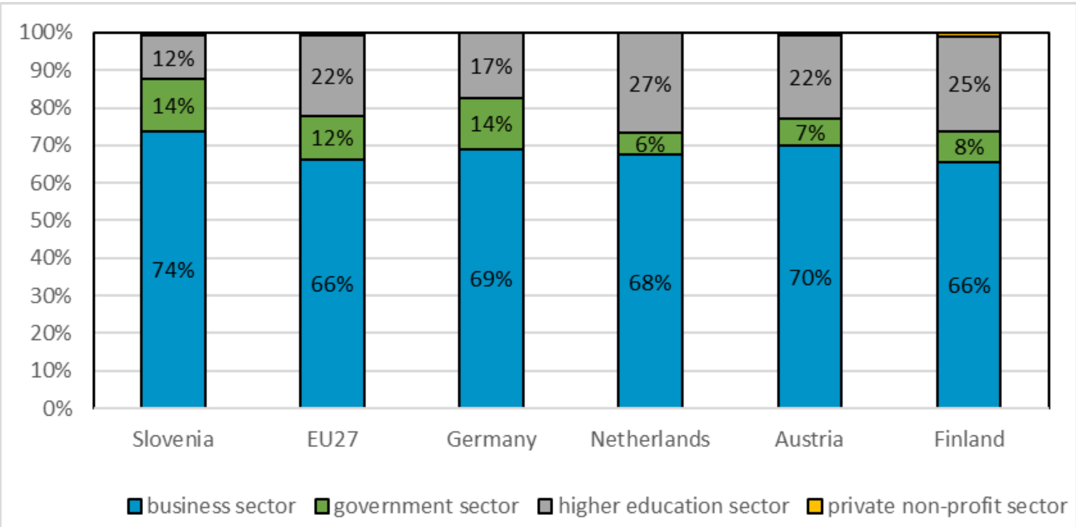

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Figure 13: Structure of Gross Expenditure on Research and Development (GERD) by investment sector for Slovenia, EU27 and selected reference countries in 2019 (data source: EUROSTAT, 2021)

). R&D expenditure in the general government sector accounted for around 14% of total GERD in 2020 and shows a less pronounced trend over the observation period. In 2019, R&D expenditure in the general government sector was 1% higher compared to 2008. The higher education sector (+41%), where R&D investments account for 12% of total GIRR, registers the largest increase in R&D expenditure over the period. Although the value of gross R&D expenditure in the private non-profit sector in 2019 is more than 8 times higher than in 2008, the share of this expenditure in total GERD is still virtually negligible (0.6%).

Compared to the EU27 and selected reference countries, Slovenia has the lowest share of GERD in GDP in 2019 (2%). In the EU27 and in the Netherlands it was 2.2%, in Finland 2.8%, while the highest share of GERD in GDP was recorded in Germany and Austria at 3.2%. There are also differences in the structure of GERD by investment sector (

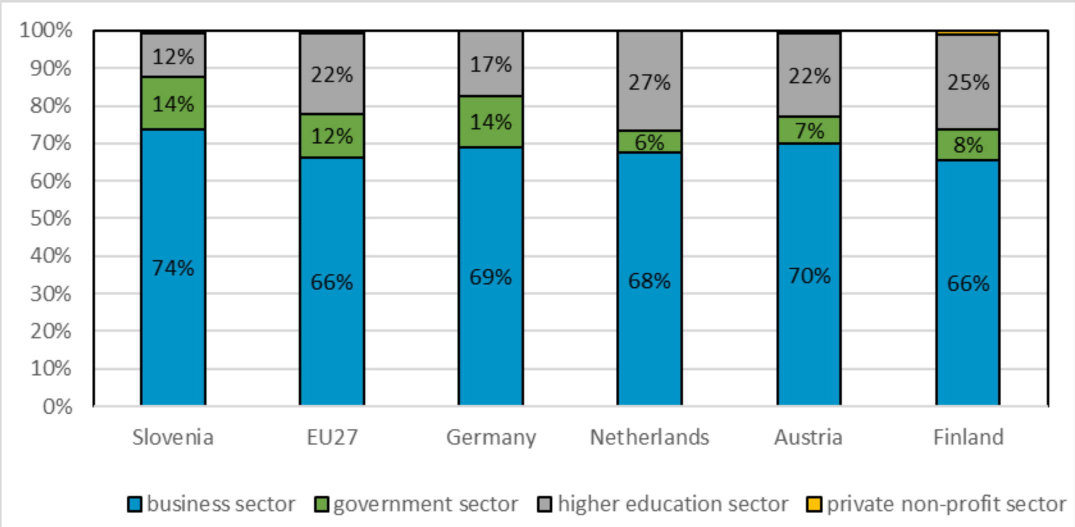

Figure 13: Structure of Gross Expenditure on Research and Development (GERD) by investment sector for Slovenia, EU27 and selected reference countries in 2019 (data source: EUROSTAT, 2021)

). Business R&D expenditure represents a significantly higher share of total GERD in Slovenia than in the EU27 and reference countries. The opposite is true for the share of R&D in the higher education sector, which is relatively low in Slovenia. The role of the public sector in R&D is markedly lower in the Netherlands, Austria, and Finland compared to Slovenia. In Germany and the EU27, the share of R&D in the public sector is comparable to Slovenia.

Error! Reference source not found. shows the structure of business expenditure on research and development (BERD) by industries where at least part of the production is based on bio-based raw materials (bio-based industries). The left graph shows the structure of BERD in fully bio-based industries, the right graph shows the structure of BERD in hybrid bio-based industries, excluding pharmaceuticals. This industry is excluded only to gain a better insight into the BERD of the remaining industries, as business R&D expenditure in pharmaceuticals and pharmaceutical raw materials and preparations manufacturing strongly dominates, contributing 79% of business R&D expenditure in 2016 in the all bio-based industries group and 83% of business R&D expenditure in the hybrid bio-based industries group. R&D expenditure in food and beverages manufacturing amounts to around €6 million, which is more than half of the BERD in the full bio-based industries. Wood products manufacturing contributes almost a third of the BERD of fully bio-based industries, paper 16%, and primary industries 1% of R&D expenditure. Among the hybrid industries, besides pharmaceuticals, chemicals, rubber and plastics, and textiles play a more important role in terms of BERD.

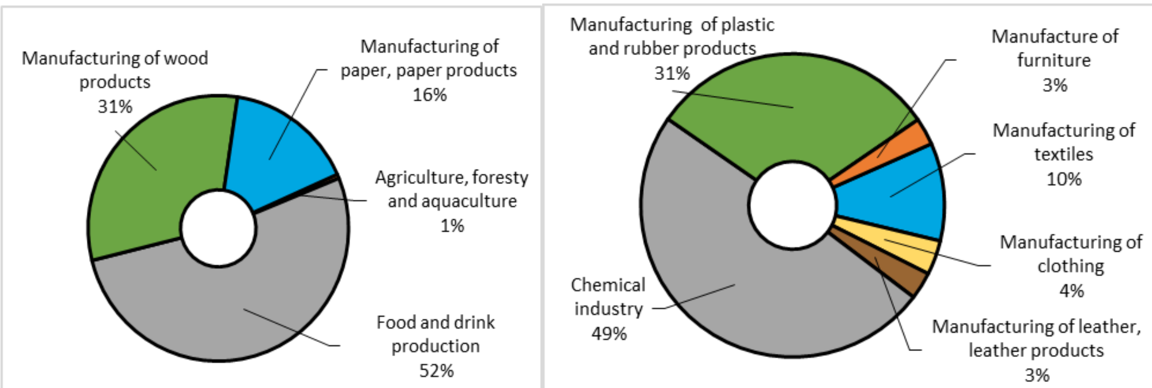

Figure 14: Structure of business expenditure on research and development (BERD) by fully bio-based industries (left) and partially bio-based (hybrid) industries (excluding pharmaceuticals) in Slovenia in 2016 (data source: EUROSTAT, 2021c).

The evolution of business expenditure on R&D over the period 2008-2019 varies across bio-based industries but is most evident in the food processing industry. In fact, the food and beverages manufacturing industry shows a clear positive trend over the period and also the highest growth in R&D expenditure among the bio-based industries. (**Error! Reference source not found.**). Business R&D expenditure in this industry in 2018 was more than 6 times higher than R&D expenditure in 2008. The intensive increase in BERD over the period is also characteristic of the clothing manufacturing industry (5 times increase) and the wood and wood products processing and transformation industry (4.5 times increase).

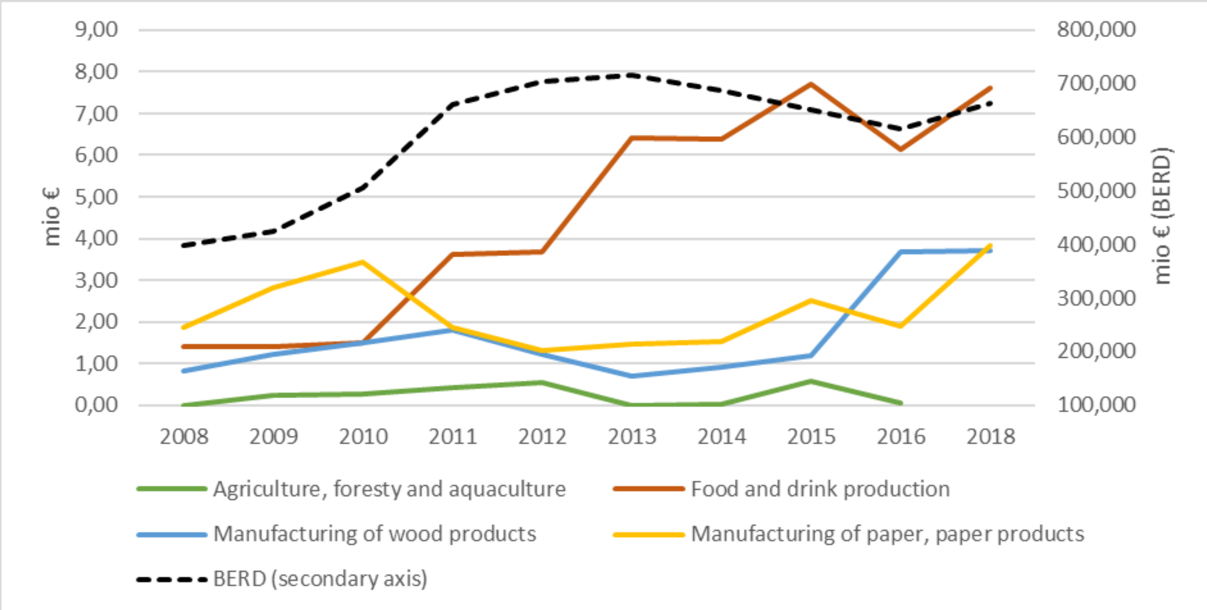

Figure 15: Trends in business expenditure on research and development (BERD) at country level and in fully bio-based industries 2008-2019 (€ million) (Data source: EUROSTAT, 2021c)

The share of business R&D expenditure in GDP for Slovenia in 2019 was fairly comparable to the EU27 level (1.5%) but lower than in most of the benchmark countries, where it was also more than 2.2% (**Error! Reference source not found.**). Although the share of BERD in GDP in Slovenia has increased by almost half compared to 2008, the dynamics of the indicator's value over the period under review is relatively high. In fact, the share of BERD in GDP grew intensively from 2008 to 2013, reaching 2% in that year, followed by a decline (until 2017) and then a return to growth. Apart from Finland, where the BERD as a share of GDP has been declining over the period under review, and the Netherlands, which has seen an intense increase in the indicator's value, the dynamics are less accentuated in the other reference areas.

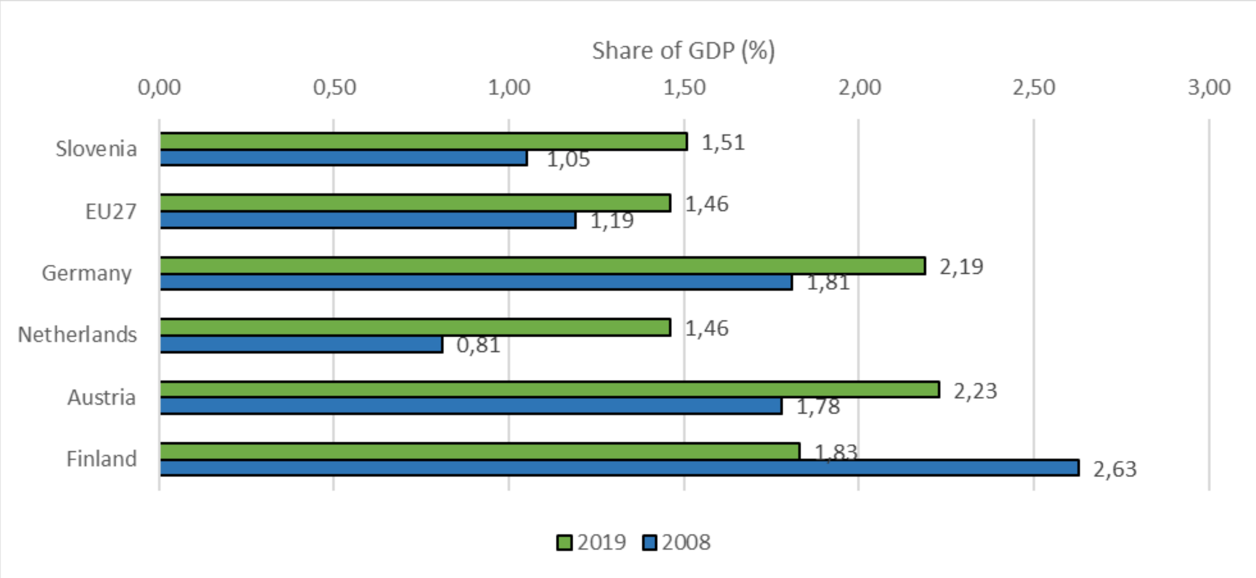

Figure 16: Business expenditure on research and development (BERD) as a share of gross domestic product (GDP) for Slovenia, the EU27 and selected reference countries in 2008 and 2019 (data source: EUROSTAT, 2021c)

Patent applications

Error! Reference source not found. shows the trend in the number of patent applications from 2008 to 2017. The number of patent applications peaked at the beginning of the period under consideration (139 applications). After a decrease in 2010 and a subsequent increase, the number of applications in 2014 was close to the number in 2008 (135 applications). In 2017, there were 82% fewer patent applications (114 applications) than in 2008. Patent applications per million € of gross R&D expenditure (GERD) and business R&D expenditure (BERD) in the years up to 2010 reflect a simultaneous decrease in the number of patent applications and an increase in GERD and BERD (Section 4.1.2). The less distinct upward trend in the number of applications relative to R&D expenditure between 2011 and 2014 can be attributed to a more intense increase in the number of patent applications and, at the same time, a more noticeable increase in R&D expenditure. After 2014, the decline in the number of applications relative to R&D expenditure is the result of a larger decrease in the number of patent applications than in R&D expenditure.

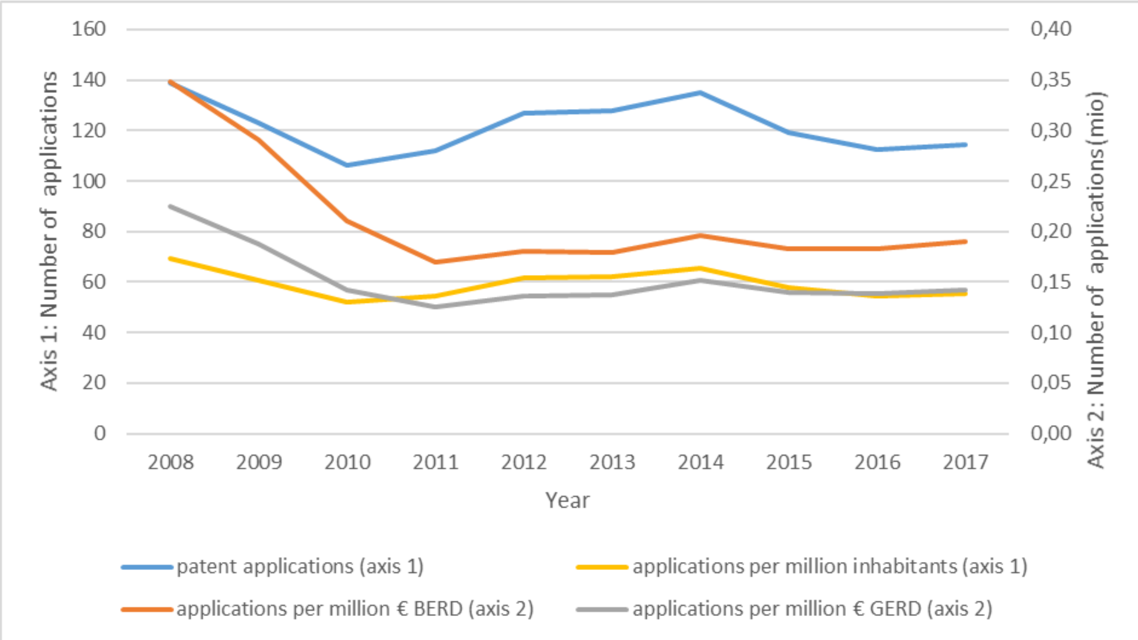

Figure 17: Trend in the number of patent applications in Slovenia 2008-2017. BERD - Business Expenditure on Research and Development; GERD - Gross Expenditure on Research and Development (data source: EUROSTAT, 2021d).

Slovenia has the lowest values of indicators related to the number of patent applications compared to the selected reference countries (**Error! Reference source not found.**). In 2017, the number of patent applications per million inhabitants in Slovenia was between 72.8% and 76.5% lower than elsewhere. Mainly due to the low number of patent applications, the number of patent applications relative to R&D expenditure in Slovenia was also relatively low. The number of applications in relation to business R&D expenditure is 58% lower in Slovenia than in the Netherlands, which has the highest values for this indicator, and 30% lower than in Austria, where the differences with Slovenia are smallest. The differences are least evident in the number of applications in relation to gross R&D expenditure. Slovenia is 24% behind Austria in the number of applications, while Slovenia has 57% fewer patent applications than Finland, which has the highest number of patent applications in relation to the GERD.

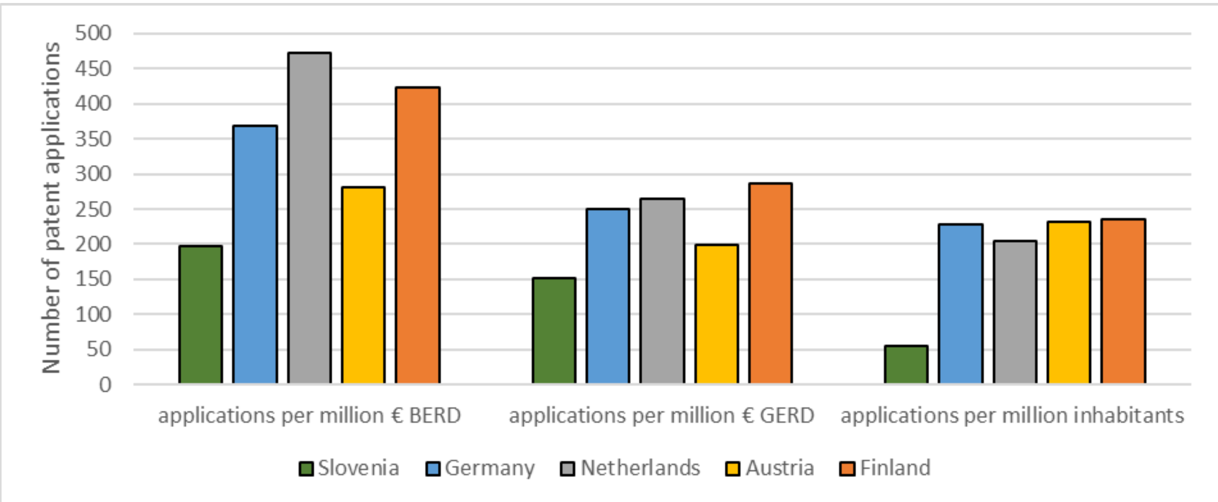

Figure 18: Number of patent applications in Slovenia and selected reference countries. The data for the number of applications per million inhabitants are for 2017, while the data on applications in relation to R&D expenditure refer to 2014. BERD - business expenditure on R&D; GERD - gross expenditure on R&D (data source: EUROSTAT, 2021).

RDI employment

In 2019, 16,984 people were employed in research and development (R&D), or around 2% of all employed people in Slovenia. Of these, two-thirds were employed in the business sector (67% in 2019 and 2018), with the majority of employees being researchers (62% in 2019; 64% in 2018) (**Error! Reference source not found.**).

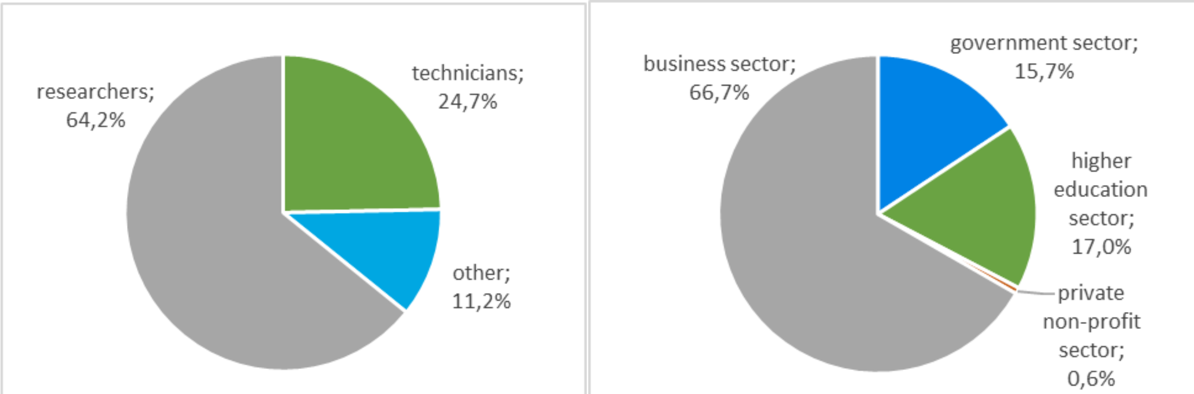

Figure 19: R&D employees by type of work (left) and by R&D investment sector (right) in 2018 (data source: EUROSTAT, 2021).

The number of people employed in R&D is generally increasing over the 2008-2019 period, with R&D employment in 2019 46% higher than at the beginning of the period under review (**Error! Reference source not found.**). Growth in R&D employment is present in all occupational groups, with researchers (+49%), technicians (+13%) and other employees (+53%) (**Error! Reference source not found.** in **Error! Reference source not found.**).[6] Employment growth is also evident in all sectors, with the exception of the government sector, where the number of people employed in R&D is almost 20% lower in 2018 than in 2008 (Figure 21).

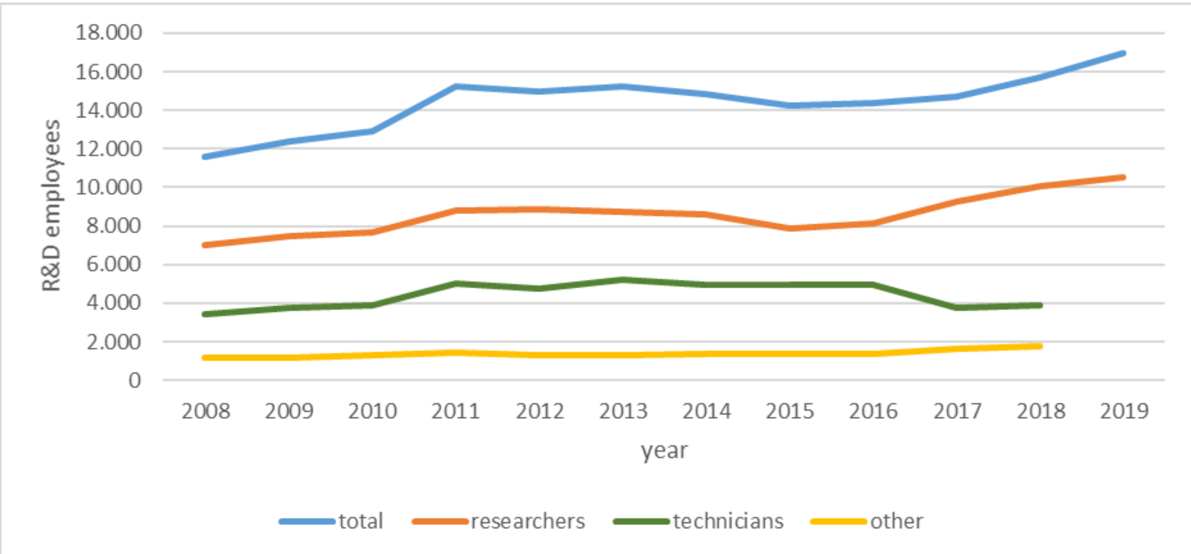

Figure 20: Trends in the total number of R&D employees by type of work in Slovenia, 2008-2019 (data source: EUROSTAT, 2021e).

The private non-profit sector in particular has seen a significant increase in the number of people employed in R&D over the period (3.6 times increase), although it still employs only 0.4% of R&D employees in 2018. The business sector has seen an increase of over 80% in the number of people employed in R&D, while the higher education sector has seen an increase of slightly more than a third in the number of people employed in R&D.

[6] Data for the groups "technicians" and "other employees" are only available until 2018.

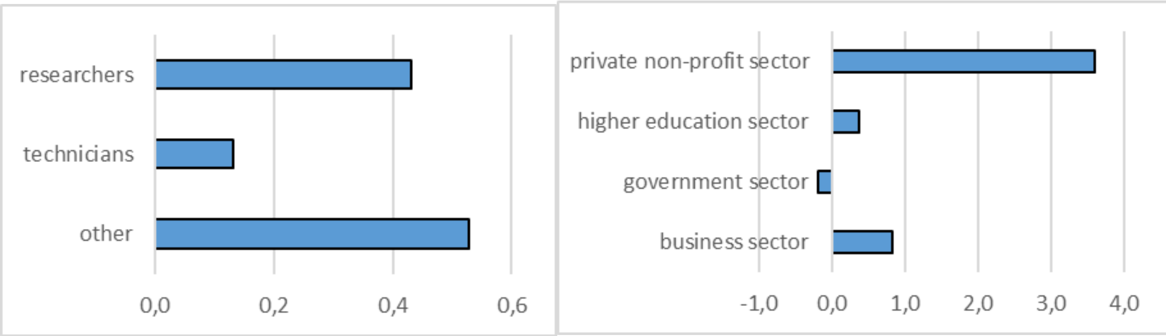

Figure 21: Growth rate of persons employed in research and development (R&D) in 2018 compared to 2008 by type of work (left) and sectors (right) (data source: EUROSTAT, 2021e).

Error! Reference source not found. shows the structure of R&D employment by sector in Slovenia, the EU27 and selected reference countries for 2019. Compared to the EU27, Slovenia has relatively fewer people employed in the higher education sector (- 10.5 percentage points), at the expense of a noticeably higher share of R&D employees in the business and government sectors (+7.2 and +3.5 percentage points, respectively). The share of R&D employees in the government sector is comparable only to Germany, while the other reference areas also have more than 2 times lower percentages of employees in this sector. Similarly, intense differences exist for R&D employees in the higher education sector, where only Slovenia has a share of less than 20%.

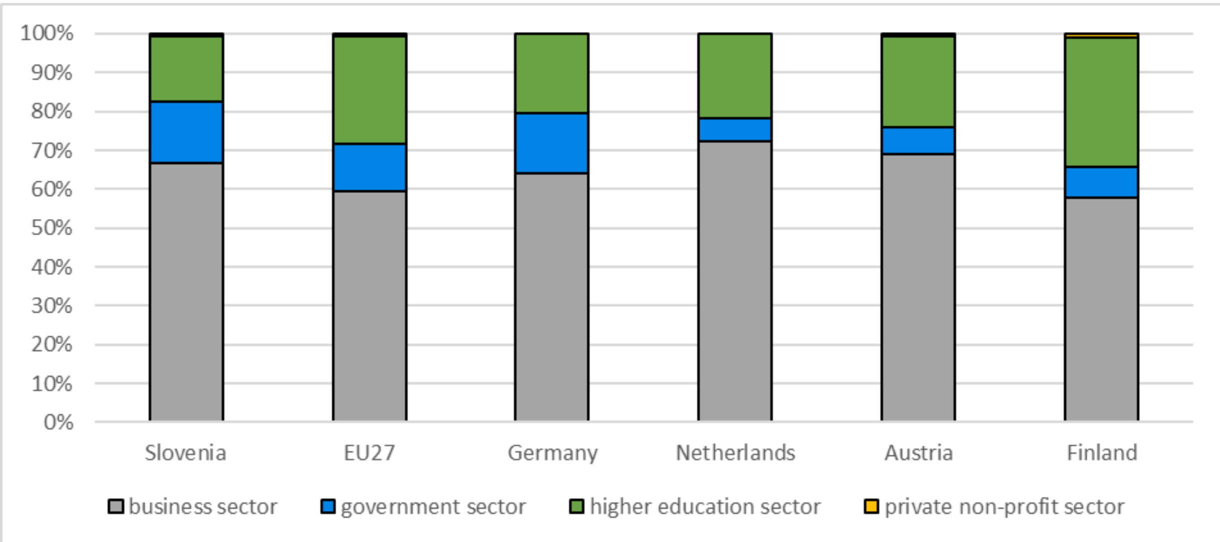

Figure 22: Structure of R&D employment by sector in Slovenia, EU27 and selected reference countries in 2019 (data source: EUROSTAT, 2021e).

In 2019, the share of employees in the business sector in Slovenia was more comparable or higher than in some of the reference countries. With the exception of the Netherlands, which recorded a 140% growth in the business sector over the period 2008-2019, Slovenia also had relatively high growth in R&D employees in the business sector over this period. (**Error! Reference source not found.**).

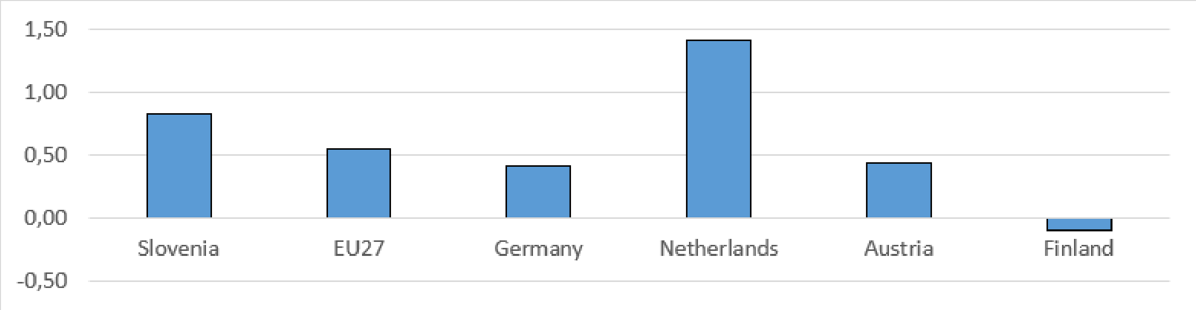

Figure 23: Growth rate of R&D employment in the business sector for Slovenia, the EU27 and selected reference countries in 2019 and 2008 (data source: EUROSTAT, 2021e).

2.3.2 State of the art - description

Research and development represents fundamental research at universities and research institutes that underpins technological developments and drives innovation and thinking.

There is a vibrant **RDI sector** in Slovenia, engaged in bioeconomy-related applications, consisting of both, public research institutions and private companies. In some sectors, which can be regarded as the cornerstones of the national economy (eg. pharmaceutical industry), RDI is strongly integrated with the industry. In other sectors, these linkages are less strong, or even not adequately established. The industry is reluctant to act as the sole investor in new technologies for different reasons (eg. cost efficiency, demand-side risks, lacking financial leverage), while the technology developers also seek for returns that surpass the capacities that are not attainable at the usual scale of enterprises operating in (conventional, or new) bioeconomy-related manufacturing sectors.

There are however emerging **industrial initiatives** for bio-based transformations. Most prominently, they develop in public-private partnerships developed within the national Smart specialisation strategy (S3). Those partnerships operate within the so called 'Strategic development and innovation partnerships'. Out of 9 strategic priorities of the national S3, four of them are directly integrating bioeconomy elements (Circular economy, smart homes + wood value chain, sustainable food provision). In close cooperation between RD institutions and firms, they develop circular bioeconomy technological solutions and business models.

The level of innovation and technology absorption capacity of SMEs in Slovenia was low. They were weakly integrated in domestic, regional and international clusters, with low potential of attracting critical mass investments and developing large-scale innovations. This was especially true for low-tech bioeconomy industries. SMEs were on average less innovative than in the past. Science-industry links were considerably stronger amongst businesses of the medium- and high-tech segments (e.g. manufacture of pharmaceuticals). Various types of innovations took place through a wide variety of Slovenia’s bio-based business practices. The results of Community Innovation Survey (CIS) in 2018, presented in Figure 14.21 and Figure 14.22, revealed several specific features of innovation activities in the reporting industries that were fully or partly included in the bioeconomy, for which data of 2018 were available.

In reported Slovenia’s fully and partly bio-based industries, the highest proportion of innovative enterprises (which had either introduced an innovation or had any kind of innovation activity) were observed in the manufacture of chemicals and manufacture of pharmaceuticals (88.3 and 85.7% of all enterprises engaged in those activities during the 2016-2018 period, respectively). High proportion of 65.3% of all enterprises in the manufacture of rubber and plastics also recorded some form of innovation activity. The lowest levels of innovation were recorded in the manufacture of wood and wood products, sewerage and waste management as well as in electricity, gas and steam industries (34.1, 36.3 and 43.6% of all enterprises reported some form of innovative activity). Compared with the period 2008-2010, the share of innovative enterprises increased insignificantly, i.e. rose by 4 to 6 percentage points, and in the manufacture of wood and wood products it even fell by almost 16% in individual reported fully and partly bio-based industries for which the CIS-2018 data were available.

3 INFLUENCING FACTORS AND TRANSITION PATHWAYS OF BIOECONOMY IN SLOVENIA

3.1 KEY INFLUENCING FACTORS AFFECTING THE DEVELOPMENT OF BIOECONOMY IN SLOVENIA

In addressing key factors affecting the development of the bioeconomy sectors and their interactions, we are adopting the approach originally developed for analysing bioclusters in the EU (BERST, 2015). In the visual presentation of key assets affecting the pace and direction of the transition to the bioeconomy (Figure 24), the core consists of the elements of quadruple helix of innovation (entrepreneurs, policymakers, knowledge institutions, consumers).

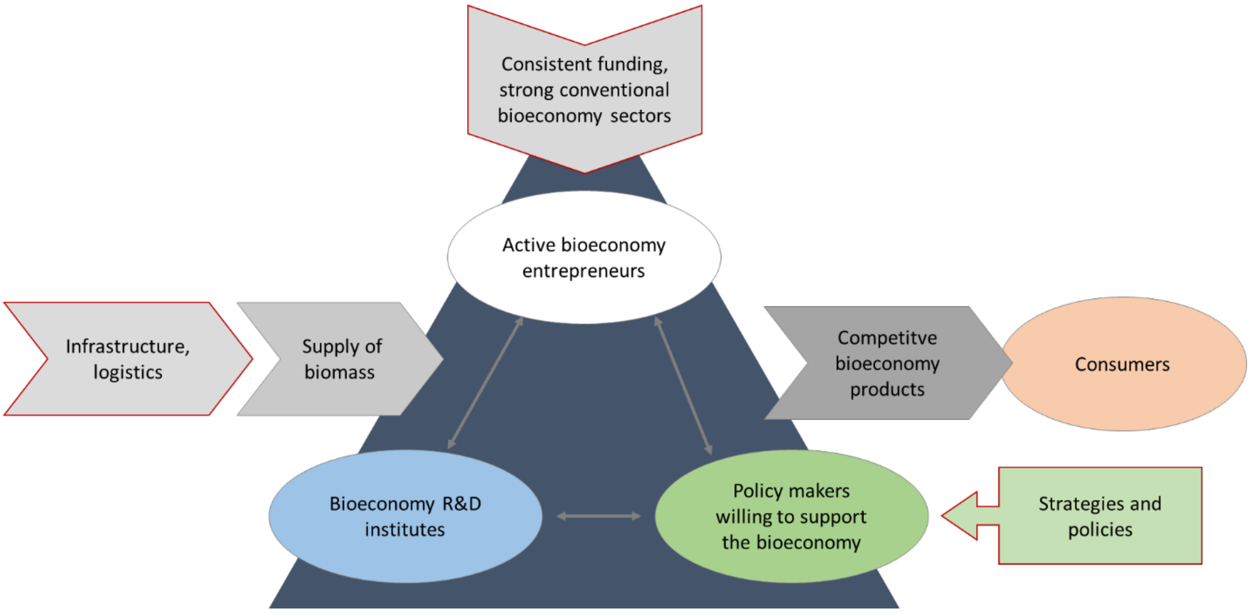

Figure 24: Generic presentation of factors affecting the development of bioeconomy (source: Berst (2016), further developed by Juvančič et al. (2021))

The generic core is enhanced by assets that are case-specific for bioeconomy. Their role in unlocking the potentials for further development of bioeconomy in Slovenia is described in described in sub-sections that follow.

3.1.1 BIOMASS SUPPLY, INFRASTRUCTURE AND LOGISTICS

Stable supply of homogenous biomass streams is a source of comparative advantage especially for regions and sectors, building their bioeconomy strategies along the pathways of more efficient biomass uses, or fossil fuel substitution. Ideally, biomass production should take ecological, social and health aspects into consideration and be internationally competitive. While competing claims on the use of biomass (particularly between material and energy use) are a challenging issue in the process of unlocking the bioeconomy potential, benchmarking with good practice cases (BERST, 2015) underlines the importance of efficient collection and distribution of biomass streams from the point of origin to the locations of intermediate (e.g. biorefinery) and final transformation (e.g. bio-based materials and products, energy)

Considering its natural endowments (58 % of country's area are forests, 3rd most forested country in the EU), wood and other sources of ligno-cellulose biomass (residuals from agricultural and horticultural production, landscape management) are the most abundant ant thus the most perspective raw material for bioeconomy applications in Slovenia. Other **biomass sources**, such as eg. residues from food processing (eg. dairy-whey; cereals, fruit and oil pomace) are also significant. The challenging task however is that the **logistics**. As the land ownership structure is scattered, and the biomass sources are relatively varied (esp. in the case of ligno-cellulose biomass), organising cost-efficient provision of biomass at the industrial scale is a challenge. In addition to this, there is a well-functioning market for biomass in the region (eg. strong demand for coniferous wood in Austria, and for softwood in Italy), which makes the market for biomass a very competitive one.

3.1.2 Strong conventional bioeconomy sectors, consistent funding

This asset entails a chain of enterprises operating along various bioeconomy value chains, providing a wide range of commercially viable bio-based products, ideally produced along the cascading use of biomass. The experience of best performing EU countries and regions highlight two success factors: strong leadership (often deriving from firms operating in 'conventional' bioeconomy manufacturing sectors), and high level of (vertical, horizontal) integration among the actors along the value chains.

The evidence reveals that sectors with **strong, consolidated firms** find it easier to provide **leverage for the development of bioeconomy clusters**. Slovenia has a vibrant structure of enterprises engaged in **'conventional' bioeconomy-related industries** (food processing, wood processing, paper mills), most of which operate at the SME scale. The scale and the level of integration of industrial operations in these sectors significantly dropped throughout the political transition and economic restructuring in the 1990s. Some industrially-relevant operations that could serve as the core for future industrial-scale biorefineries, ceased with their operations in the later period, such as the closure of the sugar mill Ormož (batch production capacity 100.000 tonnes) in 2007, closure of the chemical wood pulp in Krško (capacity 110.000 tonnes) in 2006, or plywood in Otiški vrh (capacity 100.000 m3) in 2016. The **level of business integration in 'conventional' bioeconomy-related industries is rather low** (vertically, as well as horizontally), which prevents the scale effects needed for a functioning 'standard' bioeconomy concept, integrating firms in the same, or complimentary sectors, with a biorefinery at its core. In the development of more diversified and innovative bio-based value chains, two scenarios seem feasible: (i) integration into bioeconomic clusters, with a network of small scale modular biorefinery operations in its core, or (ii) integration into wider, cross-border value chain, supplying biomass to, and supplying intermediate outputs from industrial biorefineries, located within operating distance from Slovenia.

Slovenia has a **vigorous network of enabling institutions** supporting innovative and development-oriented entrepreneurial projects. Technology parks (eg. https://www.tp-lj.si/en), business incubators (eg. https://www.lui.si/) provide professional business support services, such as favorable lease of business premises and start-up mentoring support. Business accelerators (eg. https://www.startup.si/en-us) offer professional consultation and seed financing for innovative start-ups. Both programs (technology parks and business accelerators) are complemented with public funding (eg. https://podjetniskisklad.si/en). Market for **venture capital is less developed**, limited mainly to specialised products of banks and insurance companies. All the above-described services are general, not relating specifically to bioeconomy.

3.1.3 Competitive bioeconomy products

Conventional bioeconomy manufacturing sectors are relatively strongly represented on international markets. Enterprises operating in wood processing achieve 55 % of revenues on international markets, whereas the share of food processing sector records 34 % export orientation, which is below the par of the manufacturing sector in Slovenia. Both industries, together with their upstream and downstream sectors face the challenge of achieving greater competitiveness and resilience. This requires a higher level of (horizontal, vertical) integration along the value chains, as well as the improvement of (technological, economic) efficiency of their operations. Operation in line with the principles of circular bioeconomy is a pathway towards the achievement of these aims.

Apart from the ‘conventional’ bioeconomy sectors, integration of firms operating in **technology-intensive sectors** that are strongly **integrated into international value chains** (eg. chemical industry, automotive) may also play a catalytic role in the transition towards bioeconomy. Demand for biobased technologies and components in these industries is increasing at an accelerated pace. A number of factors, such as disruptions on global raw material markets, technological prowess in biobased technologies and changed price-cost relationships, are simultaneously contributing towards the accelerated turn towards innovative biobased technologies in sectors that were traditionally operating with non-renewables. Increased demand for biobased technologies and components in **technology-intensive sectors** may serve as important engine of growth also in ‘conventional’ biobased sectors. Apart from being the providers of biomass (often with poorly valorised side-streams), integration with technology-intensive sectors may act as a stimulus to improve their performance in several aspects (closing the material and energy loops, improved economic performance).

Another catalyst in this process is also a vibrant **RDI sector** in Slovenia, engaged in bioeconomy-related applications consisting of both, public research institutions and private companies. In some sectors, which can be regarded as the cornerstones of the national economy (eg. pharmaceutical industry), RDI is strongly integrated with the industry. In other sectors, these linkages are less strong, or even not adequately established. The **industry is reluctant to act as the sole investor in new technologies** for different reasons (eg. focus on cost efficiency, demand-side risks, lacking financial leverage), while the technology developers also seek for returns that surpass the capacities that are not attainable at the usual scale of enterprises operating in (conventional, or new) bioeconomy-related manufacturing sectors. This gap has been successfully tackled within **industry-research partnerships**, developed within the national **Smart Specialisation Strategy** (described in greater detail in Section 4.2.1). Those partnerships operate within the so called 'Strategic development and innovation partnerships'. Out of nine strategic priorities of the national Smart Specialisation Strategy, four of them are directly integrating bioeconomy elements. In close cooperation between RD institutions and firms, they develop circular bioeconomy technological solutions and business models.

3.2 Sector-specific pathways of bioeconomy development

Bioeconomic transformation processes depend on a number of factors, including on the development level, resources and political system of a given state, and can be triggered by the interaction of various forces such as demographic change, technological development and democratic shifts (Dietz et al., 2018). While bioeconomic transformation thus depends on the specific country context, Dietz et al. (2018) have identified possible transformation pathways that can be driven by both demand- and supply-side dynamics; to their four ((i) Fossil fuel substitution, (ii) Boosting primary sector productivity, (iii) New & more efficient biomass uses, (iv) Low bulk / high-value biobased applications), Lovec and Juvančič (2021) added another element, (v) valorisation of non-commodity aspects of the benefits of the bioeconomy.

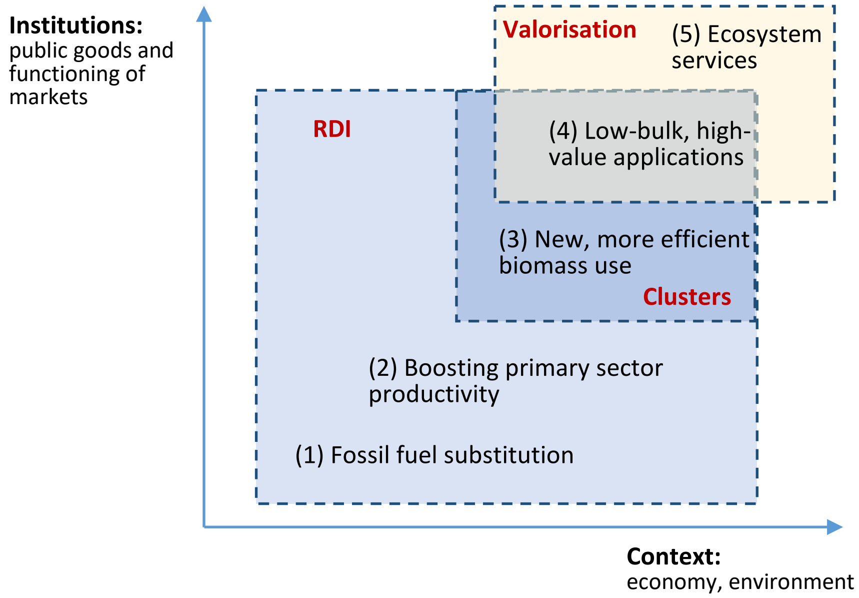

Figure 25: Contexts (axes), specific drivers (in bold), and pathways (1–5) of bioeconomy development (source: Lovec and Juvančič, 2021)

Pathways (i) to (iv) are particularly related with institutions and policies that promote research, development, and innovation adoption (RDI). In addition, pathways (iii) and (iv) are characterised by the interaction of supply and demand through enabling institutions, such as economic clusters. Pathways (iv) and (v) are again context-dependent, building on the demand-side trends that allow for the market valorisation of technological advances (iv) or ecosystem services (v) through their market valorisation (eg. gastronomy, leisure industries).

In the text below, we are assessing the relevance of the above listed bioeconomy transition pathways for the bioeconomy sectors in Slovenia. The findings are largely building on the results of the survey, in which the national bioeconomy experts assessed the potentials of the bioeconomy sectors. The survey (Juvančič et al., 2021) was conducted between December 2020 and February 2021 within the H2020 funded project BIOEASTsUP.

3.2.1 Boosting primary sector productivity

By all means, **boosting primary sector productivity** is the prerequisite for a more vibrant and competitive primary sectors. This holds particularly in the agriculture sector, where, despite a strong investment cycle that the sector experienced throughout the previous decade, there remains a lag in applying efficient and environmentally sustainable production practices. The sectors that need to improve their performance on this issue, include also other primary bioeconomy sectors. In forestry, this is particularly linked with improved mobilisation of wood biomass from private forests (appr. 50% of forest area, but only appr. 20% of wood biomass), and improved productivity, cost-efficiency and environmental sustainability in 'conventional' bioeconomy sectors (food, feed&drinks, wood processing, paper&pulp).

Boosting the productivity in Slovenian agriculture is very relevant transformation pathway toward efficient usage of its bioeconomy potential, as it is facing quite low labor productivity. In the EU-28, one full-time workforce cultivates 19 ha of UAA on average, but in Slovenia only 5.9 ha (EUROSTAT, 2019). In other primary sectors, this transformation pathway is not as relevant, especially in the fisheries, aquaculture and algae sector where the majority of experts assessed that is not relevant at all.

Among manufacturing sectors, the boosting of productivity is the most relevant for its development in food products, beverages and tobacco sector. In the contrast, this transformation pathway is not relevant in the manufacture of textile and wearing apparel. In the case of the manufacture of wood and wood product, this is relevant, and in the manufacture of paper and paper products is moderately relevant but, in the latter, the assessments differ considerably.

In comparison to BIOEAST microregion assessments, in Slovenia, as already stated, the boosting sector productivity is more relevant for unlocking the sectors' bioeconomy potential in the agriculture sector and manufacture of food, beverages and tobacco. The similar dynamic among Slovenia and BIOEAST is noticeable in the manufacture of textile and wearing apparel since is not as relevant in both observation areas. The most significant variation is in the fisheries, aquaculture and algae sector, where Slovenian experts attributed much more insignificant relevance to this factor than in the entire BIOEAST macro-region.

3.2.2 Biofuel production

With regard to relative scarce and scattered biomass resources that could form a basis for **biofuel production**, this is a strategy that is feasible only for small-scale operators to improve the (energy, ecological, economic) performance of their biomass side-streams. One obvious strain are micro-biogas instalments on larger agricultural holdings engaged in livestock production (production of energy + application of digestate as fertilisers), while the other one is with the waste management sector; the separate waste collection system, including biological waste is well established and functioning. For this reason, this is the biomass stream that, with regard to its quantity, and heterogeneous structure, acts as a perspective source for energy production.

In public debates on the topic of the bioeconomy so far, the opinion has been formed that Slovenia has no opportunities for industrial production of biofuels due to limited areas and the conflict with food use, but there are opportunities in niche high-tech production and forest biomass. There was a lot of talk about connecting to the circular economy and exploiting side streams.

Among the primary sectors in Slovenia, the biomass flows of the forestry can offer the most relevant potential for advanced energy use (biofuels, biogas, green electricity). Interestingly. Among the biomass flows in Slovenian agriculture, animal waste large untapped potentials for energy production. With respect to the endowments and the organisation of agricultural production, a rational strategy would be to establishing a network of small-scale biogas installations.

3.2.3 New, more efficient use of biomass streams

New, more efficient use of biomass streams through the cascading use of biomass side-streams is the challenge, which spans over all bioeconomy sectors in the country. As described in the 'assets' part of this section, the level of inter-sectoral cooperation (let alone integration) is rather low, resulting in broken, unfinished value chains.

According to the expert survey carried out within this project (Juvančič et al, 2021), the sectors where cascading use of biomass and its biorefining have the most relevant potential to expand the possible alternative use are agriculture, manufacture of food products, beverages, and tobacco, manufacture of wood and wood products, manufacture of chemicals and chemical products, sector of renewable energy and organic waste management. The "conventional" bioeconomy sectors (agriculture, manufacture of food products, wood manufacturing, paper production) are main sources for mobilization of biomass side streams. For other sectors, e.g., renewable energy and organic waste, biobased technologies have only recently started to gain its relevance and the use of biomass is being increasingly commoditized.

3.2.4 Low bulk / high-value biobased applications

There is a number of operators (public&private) engaging in R&D, enterprises engaging in innovation transfer & technology development, and a (less numerous) enterprises engaging in manufacturing of **low bulk / high-value biobased applications** (pharmaceutical industry as an obvious exception to this observation). There is an obvious untapped potential in integrating a relatively well developed RDI sector with the industry.

As revealed by the expert survey (Juvančič et al., 2021), the untapped potential for improving product functionalities and adding value with technologically advanced biobased solutions is recognized in the majority of manufacturing sectors in Slovenia. Among them, the sectors that stand out are manufacture of textiles, wearing apparel and leather, manufacture of paper and paper products, and manufacture of pharmaceutical products. This transformation pathway is more moderately relevant in the primary sectors and the manufacture of other non-metallic mineral products, manufacture of machinery and equipment, and the construction sector.

3.2.5 Valorisation of ecosystem services

Natural endowments structural conditions, and production practices in which both main primary bioeconomy sectors (agriculture, forestry) are operating, result in an exceptional quality of ecosystem services. Although there are increasing efforts engaged in the **valorisation of ecosystem services** (eg. environmental labelling, quality schemes, strongly developed leisure and recreation services in rural areas), there are still untapped potentials in this aspect. Among the sectors that deserve more attention, is the organic sector (8.8 % of agricultural land is engaged in certified organic production, while the market penetration of organic products is significantly lower).

Expectedly, results of the expert survey (Juvančič et al., 2021) in the sector of green care, nature tourism and recreation, valorization of ecosystem services (such as e.g. biodiversity, water regimes, rural vitality, tradition) is the most applicable for adding value to its products and services. In other sectors concerned, these services are relevant and present a meaningful opportunity for unlocking the bioeconomy potentials.

4 SYSTEM GOVERNANCE

4.1 THE INSTITUTIONAL CONTEXT OF BIOECONOMY IN SLOVENIA

According to the latest available information (April 2022), Slovenia is one of the seven EU Member States without a dedicated national bioeconomy strategy adopted (in 11 Member States) or under development (in 7 Member States). The EC JRC Bioeconomy Knowledge Centre as the central reference on strategies and other policy initiatives dedicated to the bioeconomy places Slovenia among the Member States with 'other policy initiatives dedicated to the bioeconomy'. No tangible progress can be reported with the respect with the long-term strategic orientation of bioeconomy among the national strategic priorities in Slovenia. It needs to be accentuated however that bioeconomy-related priorities are defined in a number of strategic documents and policy initiatives, which are outlined in next section of this concept paper (3.2).

The status of bioeconomy in Slovenia is elusive also in the institutional sense. There is no ministry or other government body that can be described as an institutional holder of the bioeconomy portfolio. This may be explained by the fact that bioeconomy is a cross-sectoral policy concept that spans over a number of policy areas. The institutional status of bioeconomy appears to be challenging particularly in governance systems that prefer clear sectoral boundaries. What is more important though, is the fact that inter-ministerial coordination on various issues related with bioeconomy development is operating. It includes several portfolios, among them most prominently the following ones: (i) Environment and spatial planning, (ii) Agriculture, forestry and food, (iii) Economy and technology development, (iv) Science and education, and (v) European Affairs. No clear leadership can be identified in this coordination; rather, the leadership/coordination role of institutions changes from one case to another. Elements of (circular) bioeconomy have been integrated into various strategic documents (see section 3.2 of this document) and policy instruments (see section 3.3). While this coordination has not (yet?) converged towards a dedicated national bioeconomy strategy, the coordination is largely lacking when it comes to the level of policy instruments and measures (eg. criteria for selection of operations, coverage of related investments from different funds).[7]

There are two government-led initiatives, which should be highlighted in terms of their potential role in terms of the promotion of circular economy and bioeconomy principles. The **Smart Specialisation Strategy for Slovenia** defines nine focus areas, three of which embrace various facets of bioeconomy (sustainable food systems, smart home and wood value chain, networks for circular economy). Each focus area established Strategic Development Innovation Partnerships (SRIP), which serves as a platform for integration of stakeholders from various industries, knowledge institutions and public policies in joint planning, capacity building and RDI effort. The three abovementioned SRIPs can be seen as RDI engines for a more ambitious and comprehensive development of bioeconomy. Science-industry partnerships are developing and adapting context-specific solutions techniques (eg. extraction of bioactive compounds and other biorefining processes, development of advanced biobased materials, industrial biotechnology applications, biofuels and bioenergy), and enabling technologies (eg. digitalisation, advanced materials and technologies, efficient energy networks).

The second initiative is the EIT Climate **Deep Demonstration Project of the Decarbonisation of Slovenia**. It is a pilot project at the European scale, the goal of which is to create the conditions for a systemic transition to a circular, regenerative, low-carbon economy in Slovenia. Activities within this initiative include cross-sectoral and cross-disciplinary exchange with a sizable number of stakeholders, from local communities and businesses to science institutions and policy makers. The aim of this exchange, which took place between 2019 and 2022 was to identify and activate a coordinated portfolio of innovation actions that will tackle production and waste flows across key economic systems and selected value chains. Agriculture vand Forestry were nominated among five key value chains of the Deep Demonstration project. The next stage of the project, which is scheduled for the period 2023 to 2025, sectoral focused transition is planned to take place across five key value chains for Slovenia

[7] A typical case illustrating the lack of coordination can be observed in the case of structural measures for strengthening the competitiveness of forestry and primary wood processing (eligible for co-financing from the European Agricultural Fund for Rural Development, led by the Ministry of Agriculture, Forestry and Food), and similar measures for strengthening the competitiveness of the downstream sectors of the forest-wood value chain (eligible for co-financing from the European Regional Development Fund, led by the Ministry of Economic Development and Technology).

to create value via project implementation and opportunity generation in local communities across Slovenia, building on existing collaborations and previous research and existing programmes and projects.[8]

The institutional and strategic frame outlined above is setting itself the challenge to improve the performance of bioeconomy in Slovenia. Its current performance, illustrated by a 6 % contribution of woodworking and papermaking, and a 4 % contribution of food and beverage sector to all manufacturing exports, can be significantly improved. This entails unlocking bioeconomy potentials in two main directions. The first one involves **agriculture, forestry and related 'conventional' manufacturing value chains** (wood & paper processing, whose reserves lie in **boosting the sector's productivity and value added**, partly also in the closing the material and energy loops within their operations. The other trajectory is more **demand-driven**. Its forerunners are firms, which are integrated into international value chains and include some of the key national manufacturing (eg. chemical, automotive, electrical) and other sectors (eg. construction), where the demands and needs for the **transition to bio-based materials and technological solutions** is increasing. Increased demand for biobased final products from these sectors creates opportunities for growth along its upstream and downstream sectors.

In order to unlock the potentials for a more integrated and sustainable bioeconomy in Slovenia, three challenges and opportunities can be pointed out.

First, Slovenia faces a **significant, but suboptimally utilized raw material potential** of agricultural and forest-wood biomass. The structure of practically all activities dealing with the processing of agricultural and forest-wood biomass is fragmented and produces large amounts of side streams and residues, whose current mobilisation is currently limited mostly on energy use. The added value of side-streams and residues in primary production and conventional processing sectors is therefore relatively low and poorly diversified.

Another challenge lies in a **low level of horizontal and vertical integration along the conventional bioeconomy value chains** (food, paper&pulp, wood processing). This should not be misinterpreted by the general absence of technologically advanced and competitive firms in these sectors; on the contrary, their number and significance is increasing. What is lacking however is the low level of their integration, or at least cooperation. As a result, a large percentage of primary products in agriculture and forestry is valorised outside the national economy, and the conditions for biorefining of biomass side-streams at industrial scale is hardly attainable. Both are limiting the potentials for sustainable valorisation of biomass and economic performance (value added, employment) of the bioeconomy sectors witin the national economy.

Comparative review of the research outputs, based on standardised quantitative criteria, reveals a **vibrant research and development activity** in the field of bio-based materials and supporting technologies in the country. Research institutions and teams are well integrated into international RDI effort. Investments in research and development and publications in this area are constantly increasing. This can be regarded as an opportunity. On the other hand, in the same field of analysis, Slovenia is placed **at the bottom of the EU-27 ranking in terms of innovation adoption** by the industry. On the positive side, there is a **vigorous startup community** and many of their business ideas are inspired by biobased innovations. Although these fiems are operating at the niche scale and in the early stages of the business cycle, they can be seen as the harbingers of the entrepreneurial transition to the bioeconomy

Among the non-governmental organisations and other stakeholder groups performing an active role in economic policy, promotion of bioeconomy and circular econopmy do not seem to attract a lot of attention. There are bright exceptions to this observation, though: CircularChange, Slovenia-based private non-profit organisation with a strong international network serving is recognised as one of the best entry points for circular economy projects not just nationally, but across Europe. Their case is also clearly showing the importance of trans-boundary operation, both in terms of sectors and academic disciplines, as well as in geographic terms, ie. internationally. In terms of awareness raising of the general public and motivating industrial actors for biobased transition, we can point out also the importance of (applied) research and community support actions, funded either nationally (eg. Bridge2Bio) or within EU programmes (eg. Cele.BIO, BIOEASTsUP, BioAPP).

Based on the above, there is an opportunity to accelerate the transition to a circular bioeconomy, in a strategic approach and a supportive environment that will encourage the realization of the existing potentials. It is necessary to strengthen the integration of stakeholders (industry, research and development institutions and

[8] The Smart Specialisation Strategy for Slovenia and Deep Demonstration Project of the Decarbonisation of Slovenia are described in a greater detail later in this report (see sections 3.2.1 and 3.2.6 respectiely)

the state) along the entire rational span of biomass use and even more intense integration into international value chains.

While Slovenia has not yet contemplated a dedicated bioeconomy strategy, there is a number of strategic and programming documents that set the priorities and shape the current supporting environment. Due to the multi-sectoral and multi-disciplinary character of the bioeconomy, it is often hard and somehow artificial to draw a clear line between the (bioeconomy-related) sectoral strategies and policy instruments, and those that are tackling bioeconomy development in the wider sense (ie. adding value to biomass through circular business models and by closing the material and energy loops). The section that follows (3.2) offers a brief overview of the national strategies, plans and projects which we consider to be the most relevant in terms of the supportive environment for the development of bioeconomy in the wider sense. Brief presentation of the documents and their scope is followed by more detailed insights to the implementing provisions. Special attention is devoted to the potential gaps or overlaps that would require a more coordinated action as is the case currently.

4.2 Strategic framework, instruments and measures

4.2.1 Slovenian Sustainable Smart Specialisation Strategy 2021-27 (S5)

Smart specialization represents a platform for focusing RDI efforts in priority areas, for which Slovenia has identified a critical mass of knowledge, capacities and competences and in those where it has innovation potential for positioning on global markets.

Slovenian Smart Specialization Strategy introduced a new model of development cooperation between key innovation stakeholders within the framework of Strategic Development and Innovation Partnerships (most often referred to in Slovene abbreviation SRIP) and managed to integrate significantly better into European and international development and innovation networks, platforms and consortia. Strategic Development and Innovation Partnerships were formed in all nine priority areas with the aim of promoting the integration of stakeholders from the economy, knowledge institutions and policies for joint planning and directing investments in capacity building, creating development initiatives and inclusion in international value chains. SRIP created Action Plans, which represent a common agreement between stakeholders (RRI, economy, state) on directions, goals and investments in individual areas.

In the Smart Specialization Strategy, the bioeconomy is not explicitly mentioned, but it is implicitly referred to in several of (altogether nine) priority areas, which have remained unchanged in subsequent updates of the Strategy (S4 in 2017 and S5 in 2021). From the point of view of bioeconomy as a multi-sectoral concept that connects several value chains through the cascading use of material and energy (side-)streams, the most relevant is the priority area that addresses **Networks for the transition to a circular economy**. Here, the field of bioeconomy is not considered as specifically as for example, by the EU bioeconomy development strategy, but rather emphasizes its technological component (bio-based economy). Its general objective is *"…to increase efficiency and competitiveness through the use of advanced technologies and optimal industrial processes for the production of high-quality products while reducing the consumption of resources, especially of non-renewable fossil origin, and transitioning to renewable energy/raw material sources and reducing unused waste.*" The concepts emphasized by this priority are renewable resources, industrial symbiosis, closed material flows and cascading use of resources.

Among the industries on which the Action Plan focuses, in addition to the competitive and high-tech chemical industry, five traditional industries are outlined: paper, wood and textile industry, agriculture and food processing industry and service activities (energy, waste management, engineering and ICT). Strategic Development and Innovation Partnership operating within the strategic priority area ‘Networks for the transition to a circular economy’ has defined three target technological areas: (1) technologies for biomass processing and the development of new biological materials; (2) technologies for the use of secondary raw materials and reuse of waste, and (3) obtaining energy from alternative sources. Their importance to the bioeconomy follows this order. Two target indicators were defined: improvement of the material efficiency index and new value chains with completed material flows.

In terms of their significance for bioeconomy development, two more priority areas of the Slovenian Smart Specialization Strategy can be highlighted. The priority area **Provision of sustainable food** which sets its focus to (inter alia) new technologies and materials, advancing circular business models and innovative packaging materials, and the priority area **Smart homes and wood value chain** in the part, which emphasizes increased use of wood and wood composites in construction.

Three additional priority areas of the Slovenian Smart Specialization Strategy relate to bioeconomy to a certain extent. These priorities relate to **Transport and mobility** (light materials, such as eg. biocomposites and use of advanced coatings, incl. biobased ones); **Smart cities and Communities** (smart energy grids, incl. green energy) and **Sustainable tourism** (sustainable initiatives, schemes and practices, such as valorisation of ecosystem services through tourism).

The second update of the Slovenian Smart Specialization Strategy (2021) points out that *"Slovenia is one of the material- and energy-intensive economies, which in the long term can affect competitiveness, therefore it is necessary to support instruments to support the transformation of the economy in the direction of circularity and low-carbon, and to target these measures in the priority areas of S5.*" For this reason, the revised strategy for the **period 2021-27** puts the sustainability aspect in the foreground. This is reflected also in the title of the strategy. The **Slovenian Sustainable Smart Specialization Strategy** identifies the green transition as its basic goal and is consequently renamed from S4 to S5. For the programming period2021-2027, the S5 has set itself the goal of a green transition, which is defined as "*innovative, low-carbon, digital and knowledge-based transformation of the economy and society*".

S5 is primarily understood as the national platform for the coordination of development and innovation activities between different governmental institutions and portfolios. Nevertheless, in its implementation part, S5 defines also a set of measures relating directly to the realisation of the objectives set in the strategy. The central package of measures is divided into four substantive areas of investment, which are listed in the Table 4: Envisaged EU Cohesion Policy expenditure intended for co-financing of the investment measures of the Smart Specialization Strategy of Slovenia for the period 2021-2027 together with the estimated allocation of ERDF funds in the period 2021-2027.[9]:

[9] In addition to these funds, the co-participation from the state budget of the Republic of Slovenia should be taken into account, which will presumably mean additional available funds, at least for the Western Cohesion Region due to only 40% co-financing at the level of the total eligible costs.

Table 4: Envisaged EU Cohesion Policy expenditure intended for co-financing of the investment measures of the Smart Specialization Strategy of Slovenia for the period 2021-2027

Area of investments S5	Envisaged expenditure ERDF 2021-2027 (mio. EUR)		
	Eastern Slovenia	**Western Slovenia**	**Total**
Improving research and innovation capabilities and introducing advanced technologies	280,67	131,36	412,02
Improving the growth and competitiveness of SMEs and creating jobs in SMEs	121,50	65,86	187,36
Development of knowledge and skills for smart specialization, industrial transition and entrepreneurship	11,50	5,76	17,26
Digital transformation	49,84	36,95	86,80
Total	463,51	239,93	703,44

In order to achieve maximum synergistic effects, S5 accentuates the need to supplement its own measures with instruments and actions financed from other policy domains and defined in relevant documents. Among these documents, the following ones are pointed out: (i) Plan for the recovery and resilience of Slovenia; (ii) Action plans of the Just Transition Fund, (iii) complementary measures of the Cohesion Policy related to the policy of human resources development (mainly the horizontal content of education, career centers and lifelong career orientation, adult education, scholarship policy, etc., financed from the funds of the European Social Fund plus), (iv) National Strategic plan of the Common Agriicultural Policy (in particular its Rural Development component, financed from the EAFRD), (v) national development policies, (vi) European, centrally managed policies (e.g. Horizon Europe).

In the area of the transition to low carbon production and energy transition, Slovenia, together with EIT and KIC Climate and KIC Raw Materials, started implementing a major project titled Comprehensive strategic project of decarbonization of Slovenia through the transition to a circular economy (more on this project in section **Error! Reference source not found.**), whose key measures are complementary to S5. In particular, this refers to support in the decarbonization and transformation of selected value chains, which arise from the areas of S5 and will build on and incorporate the findings of the SRIP - Networks for the transition to a circular economy, and other relevant SRIPs.

4.2.2 Slovenian Development Strategy 2030

Slovenian Development Strategy 2030 (SDS 2030), which was adopted in end-2017 is the country's umbrella strategic development document. According to SDS 2030, Slovenia's central goal is to provide *"a quality life by 2030 for all that can be achieved through balanced economic, social and environmental development that respects the limitations and capabilities of the planet and creates the right conditions and opportunities for present and future generations"*. At the individual level, quality of life is reflected in good opportunities for work, education and creativity, in a decent, safe and active living, in a healthy and clean environment, and involvement in democratic decision-making and co-management of society.

Slovenia's strategic orientations for achieving a quality life by 2030 are: (i) an inclusive, healthy, safe and responsible society, (ii) learning for life and all life, (iii) a highly productive economy that creates added value for all, (iv) preserved healthy natural environment, (v) high level of cooperation, competence and management efficiency.

Five strategic orientations for achieving the central goal of the Strategy will be implemented by Slovenia acting in various interconnected and interdependent fields covered by the twelve development goals of the Strategy. Each of these goals also relates to the Sustainable Development Goals of the 2030 Agenda and identifies key areas that will need to be worked on to achieve a quality life for all. The objectives form the basis for the formulation of priorities and actions of the Government of the Republic of Slovenia, regional development actors, local communities and other stakeholders.

A high quality of life for all	Inclusive, healthy, safe and responsible society	Highly productive economy that creates added value for all	Learning for and through life	Well-preserved natural environemnt	High level of cooperation, competence and governance efficiency
Goal 1: Healthy and active life	●		●	●	
Goal 2: Knowledge and skills for a high quality of life and work	●	●	●		
Goal 3: Decent life for all	●				●
Goal 4: Culture and language as main factors of national identity	●		●		
Goal 5: Economic stability		●			●
Goal 6: Competitive and socially responsible entrepreneurial and research sector		●	●		●
Goal 7: Inclusive labour market and high-quality jobs	●	●	●		
Goal 8: Low-carbon circular economy	●	●	●	●	
Goal 9: Sustainable natural resource management	●	●		●	
Goal 10: Trustworthy legal system	●	●			●
Goal 11: Safe and globally responsible Slovenia	●	●		●	●
Goal 12: Effective governance and high-quality public service		●	●		●

Figure 26: Slovenian Development strategy: linkages between the development goals with strategic orientations

Linking SDS 2030 to the field of bioeconomy: development goals 8 and 9

There are two development goals of SDS 2030 that resonate with the bioeconomy development. The first one is the development goal 8 (Low-carbon circular economy), which tackles the problem of poor performance in terms of efficiency of consumption of resources and energy, and low productivity of carbon consumption. This challenge calls for a transition to a low-carbon circular economy along the the entire economy. In order to make a successful transition to a low-carbon circular economy, it will be necessary to eliminate the connection between economic growth and growth in the consumption of raw materials and non-renewable energy sources, and the associated increased environmental load. This will not be possible without fundamental changes in consumption and production patterns, improved utilisation of resources which are already integrated into systems (e.g. mobility, the built environment, food supply chains, production chains), preventing the generation of waste, using waste as a source of secondary raw materials and establishing an effective waste management system.

Actions to achieve this development goal are listed as follows:

a) breaking the link between economic growth and growth in consumption of resources and GHG emissions;
b) promoting innovation, the use of design and information and communications technologies to develop new, energy efficient business models and products;
c) replacing fossil fuels through the promotion of energy efficiency and the use of renewable energy sources in all areas of energy use;
d) ensuring that infrastructure and energy use in transport support the transition to a low-carbon circular economy and allow sustainable mobility;
e) using spatial planning to design nodes for the low-carbon circular economy and development solutions at the regional and local levels.

The development goal 9 of SDS 2030 refers to the sustainable natural resource management. It is associated with the increased demand for food, water, wood, fibres, minerals, land and fuels, which has over decades profoundly changed ecosystems. The sustainable protection and planned use of natural resources are critical to the longterm preservation of natural resources, which are one of the key pillars of ensuring a healthy living environment and food production, and carrying out economic activities with high value added and creating high-quality jobs. Among the greatest challenges is the harmonisation of the various legitimate but conflicting interests of individual groups of stakeholders in natural resource management. High-quality natural resources are also essential to ensuring a resilient food and water supply systems, which have both strategic importance.

The following actions are envisaged to further contribute to sustainable natural resource management:

a) introducing an ecosystem-based approach to the management of natural resources and by moving past the sectoral way of thinking, among other ways through the timely harmonisation of national and cross-border interests in cross-cutting areas with regard to water – food – energy – ecosystems, which will also have to change and adapt in the future due to the consequences of climate change;
b) effectively managing surface water and groundwater, coastal and maritime resources, and achieving their good status;
c) ensuring the sustainable development of forests as ecosystems from the perspective of their ecological, economic and social functions;
d) Slovenia's future development will depend very much on its ability to respond and adapt to trends and challenges in the global environment. Co-operation and Cohesion at global, European and national levels and cross-border co-operation are increasingly important;
e) preserving a high level of biodiversity and quality of natural features and strengthening ecosystem services;

f) sustainably managing soil and preserving soil ecosystem services, preventing further soil degradation and rehabilitating degraded soil;
g) sustainably protecting and preserving high-quality farmland and promoting agricultural practices in order to increase supply with local sustainable supply, particularly the production of organic foods;
h) management, priority use of functionally degraded areas, on the basis of harmonized priority and counterbalancing tasks, including in the light of more harmonised regional development.

4.2.3 Slovenian Industrial Strategy 2030[10]

The Slovenian Industrial Strategy 2030 (hereinafter: SIS), adopted in December 2021 represents an upgrade in accordance with the current European and domestic strategic documents and guidelines with the common denominator "green, creative and smart development". The key objective is to strengthen the competitiveness, productivity and innovation of the economy, which is reflected in a larger proportion of high technology products and high added value services, greater inclusion in international value chains and better positioning of Slovenian enterprises within these value chains.

By stimulating a green and digital transformation, SIS will contribute to the implementation of the European Green Deal and Slovenia's Recovery and Resilience Plan after the COVID-19 Pandemic in accordance with EU recommendations and measures in this area. As indicated in Figure 26, SIS in well integrated and aligned with the system of the national strategic and programming documents.

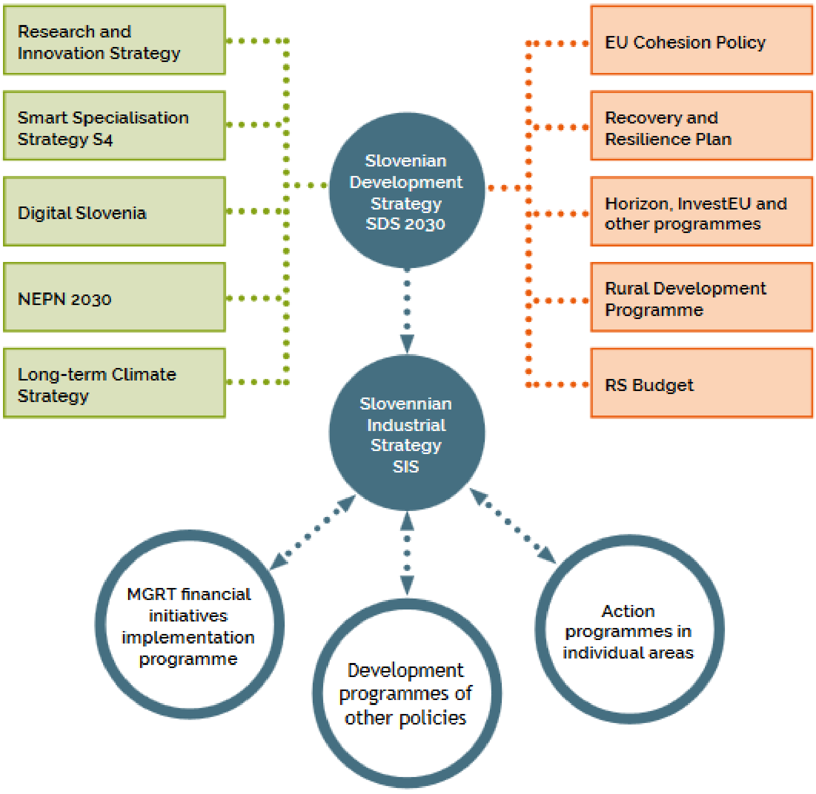

Figure 27: Placement of the Slovenian Industrial Strategy 2030 into development planning documents (source: Ministry of Economic Development and Technology)

[10] The text summarizes the essential elements of the Slovenian Industrial Strategy and outlines its main bioeconomy-related contents by largely drawing from the English translation of the document, see https://www.gzs.si/Portals/206/Slovenska%20industrijska%20strategija.pdf

In accordance with the mega trends that are important for industrial development in Europe and uncertainty of predicting future development (eg. Disruption of supply chains and global crises due to unexpected events, such as COVID-19 and Russian attack on Ukraine), the SIS addresses:

1. The horizontal aspect of industrial policy and the need to improve framework conditions and business environment;
2. A themed approach that is a response to social challenges (managing climate change, pollution, transition to a low-carbon circular economy, digital transformation);
3. The strengthening of strategic value chains, especially in the priority areas of the Slovenian Smart Specialisation Strategy (S4) and
4. The increase of resilience and responsiveness to external factors brought by global mega trends and unexpected disturbances (i.e. black swans).

In its **vision** statement, SIS puts in the foreground **green, creative and smart development**, which interconnect and supplement each other in the SIS. The transition to a low-carbon circular economy can not be achieved without understanding the comparable advantages in terms of raw materials, without a systemic approach and without a high rate of creativity and digital-based smart solution support. Each of the implementing solutions, designed on the basis of SIS, will rationally include all three components and aspects thus contributing to the achievement of synergy effects and a more effective spending of public and private sources

The **mission** of the the Slovenian Industrial Strategy is to ensure the competitiveness of the economy and create the conditions for industrial **restructuring by promoting of all three components of sustainable development** (society, environment, economy).

The SIS sets out a set of dedicated **instruments and measures** to promote green, creative and smart development. They are outlined in Table 5 together with the ministries in charge and estimated amounts of public funding, while for the sake of brevity, more interested leaders are directed to the chapters sorted by its vision descriptors (Green, Creative and Smart development) in the source document.

Table 5: Areas of support, measures/instruments, responsible ministries and projected public funds for the realisation of the SIS

Areas	Measures/instruments	Responsible line ministries*	Evaluation of financial assets 2021–2030
RDI	1. Research, development and innovation	MGRT, MIZŠ, SVRK	EUR 4 billion (including tax relief for RDI and return resources)
	2. Demonstration and pilot projects	MGRT, MIZŠ, MOP, MZI, MJU	EUR 250 million
	3. Inclusion in international research and development as well as innovation projects and programmes	MGRT, MIZŠ	EUR 30 million
	4. Networking and cooperation in RDI	MGRT, MIZŠ, SVRK, MJU	EUR 25 million
ENTREPRENEURSHIP	5. Supporting environment for enterprises	MGRT, MJU	EUR 50 million
	6. Promotion of entrepreneurship and innovation	MGRT	EUR 10 million
	7. Promotion of startups and enterprises with rapid growth potential	MGRT	EUR 40 million
	8. Support to SME growth and development	MGRT, MOP, MZI, MJU	EUR 150 million + repayable funds
	9. Non-technological innovation and business models	MGRT	EUR 60 million
	10. Promotion of investments	MGRT	EUR 300 million
INTERNATIONALISATION	11. Support to internationalisation	MGRT, MZZ	EUR 100 million
HUMAN RESOURCES	12. Strengthening competences, training, requalification, adaptation to demographic change	MGRT, MDDSZ, MIZŠ	EUR 30 million
BUSINESS ENVIRONMENT	13.Infrastructure	MGRT, MOP, MZI, MJU	EUR 300 million
	14. Legislation and business environment	All line ministries	

* The table keeps Slovene abbreviations for the ministry portfolios. Their full name are as follows: MGRT – Ministry of Economic Development and Technology; MIZŠ – Ministry of Education, Science and Sport; SVRK – Government Office for Development and Cohesion; MOP – Ministry of Environment and Spatial Planning; MZI – Ministry of Infrastructure; MJU – Ministry of Public Administration; MZZ – Ministry of Foreign Affairs; MDDSZ – Ministry of Labour, Family, Social Affairs and Equal Opportunities.

The institutional framework of SIS implementation is created by the ministries in charge listed along the instruments and measures in the above table. Apart from the ministries, the following institutions have an important role in individual areas: Public Agency for Entrepreneurship, Internationalisation, Foreign Investments and Technology – SPIRIT Slovenia; Slovenian Enterprise Fund – SPS; Slovenian Regional Development Fund – SRSS; Slovenian export and development bank – SID; Slovenian Research Agency – ARRS; Eco-Fund etc.

Linking SIS to the field of bioeconomy: green development

The link of the SIS to the bioeconomy is best recognized in the section of the document, which refers to Green development. Within this section, it defines and further describes four priority areas of action. They are summarized in the text below.

A) Transition to a low-carbon circular economy

SIS stipulates the new investment cycle, based on the principles of inclusiveness, climate neutrality, concern for the protection of biodiversity and quality of living for all, which is the umbrella goal of the Strategy of the Development of Slovenia 2030. This involves a transition from the linear economic model into a circular economic model that is based on extended preservation of the value of materials and products, replacing products with services, transition from ownership to co-use and digitalisation usage.

The circular concept (also called the "3R – reduce, reuse, recycle) focuses on closing material flows by minimising the quantity of waste or using it as a source. The products are designed to be repaired, upgraded, restored, reused and recycled in the last phase. Therefore, the integration of eco-design into the search for solutions in products, services or business models is an essential building block of the transition to a low-carbon economy. Positive impacts of CO2 storage and the cascading use of wood are pointed out as especially efficient with regard to its potentials for a negative carbon footprint.

Within this priority area, the field of bioeconomy is particularly highlighted as an important part of a circular economy. SIS defines the bioeconomy along the lines of the European Bioeconomy Strategy (EC, 2018), in which the bio-economy *"comprises all sectors and systems that are based on acquiring and processing biological resources (genetic resources, animals, plants, microorganisms and acquired biomass, including organic waste), their functions and principles"*. Besides primary production, the bioeconomy includes other sectors in which the inputs and technologies are based on natural resources of biological origin. SIS emphasizes the need to improve the accessibility and the sustainable use of biomass as a primary, natural and renewable raw material resource. The importance of the bio-based chemical and pharmaceutical industry must also be mentioned within this scope.

B) Decarbonisation of energy intensive industry

The energy-intensive industry - EII (metal, non-metal, chemical and paper) is an important part of Slovenian industry. Annually, EII consume less than one sixth of the final used energy in Slovenia. These activities employ around 27,500 people and create 2.5% GDP. The Energy-intensive industry in Slovenia is very effective in Slovenia compared to plants in the EU and mostly uses the best available technologies (BAT). From this point of view, a major transition to a low-carbon circular economy is highly dependent on the development of new breakthrough technologies that are not yet on the market or are just beginning to be developed in the field of heat, electrification and production processes. Certain developed technologies, from production to the use of hydrogen and the collection, storage and use of carbon still await an affordable and proper integration into the production processes of energy intensive industry.

In accordance with wider European forecasts, breakthroughs and greater affordability of new low-carbon technologies are expected in the coming years that will fundamentally transform production in energy-intensive industry. These technologies are, specifically: (i) use of climate-neutral hydrogen (heat and/or processes); (ii) use of biomass and biotechnologies; (iii) further heat electrification; (iv) further process electrification (electrolysis, electrochemistry); (v) capture and utilisation of carbon (CCU); (vi) capture and storage of carbon (CCS). In accordance with broader European forecasts, a breakthrough and greater affordability of new low-carbon technologies are expected in the coming years, which will fundamentally transform production in the energy-intensive industry. In line with these expectations, SIS points out the need to accelerate developmental and innovation activities as well as pilot and demonstration activities.

c) Sustainable mobility

In the future, mobility will remain the foundation of society and the economy. This priority action of the SIS addresses the following components of sustainable mobility:

(i) Reduction of greenhouse gas emissions from traffic by green and digital transformation;
(ii) Investments in clean transport and logistics, including the setup of e-charging stations, initiatives for railway transport and clean mobility in towns and regions
(iii) Investments in upgrading in the direction of a green and digital transition of the Slovenian car industry (approximately 10% of Slovenian gross value added and approximately 20% of Slovenian exports).

d) Industry based on wood and other natural renewable materials

Wood is the key strategic raw material and industrial material in Slovenia and is a natural and renewable source (see section 2.1 of this Strategy Paper). Wood is a material with at least two or three useful cycles of the cascading use. First, it is used as a product (cut wood, building component, furniture), secondly as material in the recycling process (panels or paper) and lastly for acquiring energy. The SIS primarily recognises wood as material for industrial processing and not as energy source; the latter role is left for the wood that is not suitable for further industrial processing or discarded wood.

In the segment of using natural renewable materials that store carbon, the SIS sees great opportunities in wood processing, as sustainable forest management and improving the preservation of biodiversity allows for sufficient long-term potential of domestic raw materials. Since the climate change impacts the tree composition, the need of the wood industry and forest management planning to adapt to the new situation is recognised. Slovenian forests are also an immense pool of gene sources for research and development in various segments (e.g. pharmaceutical and food industry, biofuels, synthetic components industry, pest control, etc.).

The construction and furnishing of smart wooden buildings is recognised as an growing market opportunity. The vision of SIS joins that of the Forest-Based Industries 2050 that envisages that the proportion of construction wood to grow from the current 10% to 30%. Greater processing of wood felled in Slovenia can additionally contribute to reducing emissions or increasing carbon sinks in forests in accordance with the LULUCF (EU 2018/841) Regulation.

With the aim of increasing wood processing in Slovenia, investment will have to be made in primary wood processing and other wood processing areas which is directly connected to strengthening the so-called soft capital – research, development, innovation, human resources, etc. The vision of the wood processing industry is to increase the level of wood construction with RDI activities. New business models should be encouraged will thus form to enable a competitive performance of consortia with investors in Slovenia and in foreign markets. In this way, the Slovenian wood processing industry will also secure a market for the sale of large quantities of wood with high added value. In addition to wooden construction, which also includes joinery, the furniture industry is still very prominent in Slovenia. The key emphasis is on new technologies and business models in production and development processes, whereby it is necessary to take into account the principles of circular and digital development ("creative and digital by design").

The wood processing industry in Slovenia is important also from the aspect of a high number of SMEs, in which there are almost 1,500 sole entrepreneurs, for whom the key is to strive for a friendlier business environment and to promote consumption from renewable sources. It should be emphasised that there are more than 400,000 forest owners in Slovenia. They should be mobilised and connected to intensify forest management and increase wood use in Slovenia.

Wood is the output material for many technologically advanced co-natural materials and products (composite products, modified wood, insulation and polymer materials, fibres, solvents, liquefied wood, carbon fibres, medicines, pyrolysis – wood gas, etc.). In addition to the material use of wood, wood can be used to acquire bio components (bio derivatives), the products of which can replace synthetic chemicals. SIS envisages strengthening of education and biomaterial research to utilise all opportunities in this area (e.g. in architecture, construction and machine-building). Development potential of wood is further extended to the cellulose and paper industry, some construction, and the creative industry (design, architecture, research art ...).

The basic goals by 2030, connected to wood exploitation, are to increase the amount of round wood in Slovenia for non-energy use to 3 million 3 per year, to reach a 30-percent share of wood in all new public buildings, to develop new ways to use wood, to increase the number of employees in forest-wood value chain and to increase the realisation of sales in the wood industry to EUR 2.5 billion per year.

4.2.4 Comprehensive national energy and climate plan 2030 (NEPN 2030)

The comprehensive national energy and climate plan (NEPN) is an action plan that is adopted by each EU member state in accordance with the EU Regulation 2018/1999 on the management of the energy union and climate measures. The NEPN for the period up to 2030 (with a view to 2040) sets goals, policies and measures on five dimensions of the energy union: (i) decarbonization (GHG and RES emissions), (ii) energy efficiency, (iii) energy security, (iv) internal market and (v) research, innovation and competitiveness.

The key goals of NEPN 2030 are: reduction of total greenhouse gas emissions by 36%, of which 20% in the non-ETS sector (which is 5 percentage points above Slovenia's accepted commitment), at least a 35% improvement in energy efficiency, which is higher from the target adopted at EU level (32.5%), at least 27% of renewable energy sources, where due to relevant national circumstances - primarily environmental restrictions - Slovenia had to agree to a lower target than the target at EU level (32%), with an effort, that the ambition is increased in the next update of the NEPN (2023/24), 3% investment in research and development, of which 1% are public funds.

Provisions of the NEPN are fully coordinated with the **Climate strategy 2050**, which sets out the goal **to achieve net zero emmissions by 2050**. In fact, NEPN can be seen as the action plan for the implementation of the climate strategy until 2030.

NEPN, adopted by the Government of Slovenia in february 2020, has set out operational objectives classified into **five thematic areas**. Thematic area **Decarbonisation: climate change mitigation and adaptation** sets the objective of reducing GHG emissions in sectors not covered by the trading scheme by 2030 by at least 20% compared to 2005, with a more detailed breakdown by sectors, such as transportation, agriculture, waste management, industry and energy. The objective for LULUCF sectors is to become emissions neutral by 2030. Further reduction of the use of fossil energy sources and the dependence on their import is envisaged with phasing out of coal by at least 30% by 2030, and a ban on the sale and installation of new fuel-oil boilers by 2023. Support is envisaged for the implementation of pilot projects for the production of synthetic methane and hydrogen (indicative target is a 10% share of methane or hydrogen of renewable origin in the transmission and distribution network by 2030).

Thematic area **Decarbonisation: renewable energy** sets out an indicative target to reach at least a 27% share of renewable in energy end-use by 2030, i.e. at least 2/3 buildings energy use from RES by 2030 (the share of RES end-use in energy without electricity and district heat), at least a 30% share of RES in industry, 43% share in the electricity sector, 41% share in the heating and cooling sector and 21% share in transportation).

The next thematic area applies to the **Energy Eficiency**. The objective is to improve energy and material efficiency in all sectors until 2030 by at least 35% compared to the 2007 baseline. It further stipulates reduction of the final energy use in buildings by 20% by 2030 compared to 2005 and ensure a reduction of GHG emissions in buildings by at least 70% by 2030 compared to 2005.

The other two thematic areas, Energy security and the **Internal Energy Market**, and **Research, innovation and competitiveness** have no direct links to the bioeconomy and are therefore not elaborated further in this Section.

For the implementation of NEPN measures, the estimated total investments for the period 2021 - 2030 are almost EUR 22 billion. Together with investments in transport infrastructure and sustainable mobility, the total estimated investment volume is over EUR 28 billion. About a half of this sum is allocated to the energy efficiency expenditure in the housing sectors. About 6.5 billion EUR is allocated for sustainable mobility and standard transport infrastructure. Slightly above 1 billion EUR has been earmarked to industrial investments

The implementation of the planned NEPN and its measures is projected to yield positive effects on the neighbouring Member States and the entire EU area, due to increased investment and energy services and reduced imports of primary energy to the region.

4.2.5 Roadmap towards the circular economy in Slovenia

The document titled 'Roadmap towards the circular economy in Slovenia' was created as part of the activities of the Partnership for a Green Economy of Slovenia, with the aim of implementing the strategic direction of the Government of the Republic of Slovenia for Slovenia's transition to a circular economy. The process under the leadership of the Cabinet of the Prime Minister of the Republic of Slovenia took place from autumn 2017 to spring 2018. The consortium of authors was led by the Circular Change platform, contributors to the document consisted of representatives of the leading national research institutes, public officials and experts.

Within the framework of 12 regional consultations across Slovenia, which were aimed at identifying and evaluating the potential of each of the regions, both in terms of natural resources and economic activities, expertise and good practices, **four priority areas of the circular transition** of Slovenia were formed. These are: the food systems, forest-wood value chains, processing activities and mobility. The operation of Strategic Development and Innovation Partnerships (see previous section, 3.2.1), especially SRIP Networks for the transition to a circular economy, were also taken into account.

The distinguishing feature of the Roadmap is the 'circular triangle', which emphasizes the importance of the systemic transition from a linear to a circular economic model, within which there is a strong interdependence between three elements - circular economy (business models), circular change (government policies) and circular culture (citizens). In its conclusion, the document also presents recommendations to the government on how to effectively approach the implementation of the circular transition and which opportunities and challenges were recognized in the process of creating the document. The document (Godina Košir et al. 2018) summarizes the strategic orientations and connections between various measures, especially the SRIP Action Plans, and highlights the transition to a circular economy as a horizontal priority, with priority areas of measures: sustainable management of resources (circular economy, waste as a resource, management of forest and wood); green economic growth (research and innovation for green growth), green products and services (green public procurement, energy efficiency and renovation of buildings, incentives for the use of green technologies), green budget reform, sustainable urban development, green public sector, training, and green practices in agriculture.

In the context of the circular and bioeconomy, the Roadmap highlights agriculture and food more explicitly in the context of "*green agricultural practices*", which include "*all stages of production, processing, transport, sale, consumption of food and the collection and processing of waste organic substances*" as well as links circular and bioeconomy and tourism. The document detects a gap in the handling of organic waste (eg. Discarded food from households 80 kg yearly per person). The Roadmap detects opportunities in the promotion of '*food self-sufficiency*', the '*zero mile*' and '*zero waste*' approach, the '*bioeconomy*' and invreased use of biomass in replacing fossil-based raw materials.

Another cross-sectional area highlighted by the Roadmap was the forest-wood chain. Wood has been recognised as "*one of the most circular materials*" with opportunities for innovation and the bioeconomy. As advantages on which to build, the document points out the good technological knowledge and equipment of enterprising operating in the sector, adding value by cascading use of wood, a favorable carbon footprint (the possibility of achieving the goal of CO2 neutrality) and good information support (databases managed by the Forestry Institute of Slovenia). Among the opportunities, the Roadmap highlights new forms of wooden construction, the furniture industry, green public procurement, connections with the paper industry, innovation, nanotechnologies, deepening the cascade and the use of waste wood as an energy source.

The Roadmap highlighted also some fundamental shortcomings at the level of public policies and suggestions for improvements. It pointed out a lack of coordinated actions between three ministries with the most pronounced (and budgetary supported) interest in the development of bioeconomy: Ministry for Education, Science and Sports, Ministry for Economic Development and Technology, and Ministry of Agriculture, Forestry and Food. Especially for the latter, the Roadmap the points out the need to strengthen the principle of circularity in its policies: "*MAFF must develop clear guidelines and conditions for the development of agriculture in the direction of circular models, take into account the opportunities brought by the bio-economy, and promote innovative approaches both in food production and in the management of forest value chains*". It also highlights the importance of directing research into the development of new bio-based materials. Among the activities that would contribute to a greater expansion of the circular organization of the bioeconomy, the Roadmap also mentions improved management of biomass and increased use of wood, the need for a more active and coordinated tax policy and green public procurement, and strengthening the use of recognized certificates based on appropriate analyses. The Roadmap 's proposal is that the SRIP Networks for the transition to a circular economy would assume the role of a connector with other SRIPs, which also relate to content from the field of bioeconomy. In this way, it would be possible to exchange knowledge, practices, address methodological gaps, as well as connections between individual SRIPs and their projects.

4.2.6 Comprehensive strategic project for the decarbonization of Slovenia

Slovenia is preparing a plan for the transition to a circular economy in accordance with the initiatives at the European level. This involves a comprehensive strategic decarbonisation project via the transition to a circular economy which is one of the key national projects that will bring positive effects to the economy's competitiveness, the environment, employment and other social aspects as well as a higher quality of life. The project is systemic and focuses in all areas that are key for the transition to a low-carbon circular economy.

The Comprehensive Strategic Project for Decarbonising Slovenia through the Transition to a Circular Economy has been under development since 2019. The project was developed with the participation of ministries with responsibilities in the areas that can contribute most to decarbonisation and the circular transition, i.e. the Ministry of Environment and Spatial Planning, the Ministry of Economic Development and Technology, the Ministry of Education, Science and Sport, the Slovenian Government Office for Development and European Cohesion Policy, the Ministry of Infrastructure, the Ministry of Agriculture, Forestry and Food, the Ministry of Public Administration, the Ministry of Foreign Affairs and the Ministry of Finance. The project is being prepared in partnership with the leading European institutions in this area: two Knowledge and Innovation Communities

(KICs) of the European Institute for Innovation and Technology (EIT), namely for climate (EIT Climate-KIC) and for raw materials (EIT Raw Materials), as well as the Joint Research Centre (JRC) of the European Commission.

The aim of the project is to contribute to the achievement of climate goals by introducing the principles of the circular economy and to support the decarbonisation of Slovenia in line with Slovenian strategic documents: the Slovenian Development Strategy 2030, the National Environmental Protection Programme for the period 2020-2030, the Slovenian Industrial Strategy 2021-2030, the Comprehensive National Energy and Climate Plan of the Republic of Slovenia, the Long-term Climate Strategy of Slovenia up to 2050, and agricultural and forestry policy documents. The implementation of the project will also support the achievement of the objectives and implementation of the activities foreseen in the Slovenian Recovery and Resilience Plan.

The overarching objective of the project is to lay the foundations for a systemic transition of Slovenia towards a low-carbon circular economy by transforming approaches to policy planning and implementation. The project is designed using the Systemic Transition Model, an innovative model for addressing complex challenges. In the case of the specific project, it relates to the transition to a circular economy or the introduction and implementation of circular economy principles in all relevant policies. The Comprehensive Strategic Project for Decarbonising Slovenia aims to establish that connections between already established solutions, their authors and introducers - companies, and science and policy makers in order to create new innovative solutions and findings that can be used at the system level, and consequently ensure an easier transition to a circular, regenerative economy.

The transition to a low-carbon economy and the European Green Deal will demand certain adjustments in various industries. Chemicals have a fundamental role in most industrial sectors and will become the builders of low-carbon and efficient technologies, materials and products. The new European strategy in chemicals for sustainability will promote the innovation and adaptations of the chemical industry (including the rubber, plastics and pharmaceutical industries) as well as all its consumers along the distribution chain. Increasing the investment and innovative capacity of the chemical industry in providing safe and sustainable chemicals, reducing pollution and the burden on health and the environment, and achieving the EU’s strategic autonomy and self-sufficiency in the supply of basic chemicals will be crucial for a successful green transition.

The project also includes support for establishing start-up companies that will work in low-carbon circular solutions and support innovation and the transition of SME to low-carbon circular business models. Systemic conditions for increasing the qualifications of various groups of stakeholders (primary and high schools, higher education institutions, companies, public administration) will be introduced at the same time to design and carry out the appropriate solutions necessary for a transition to a low-carbon circular economy. In this context, enhancing competences and the need for requalification and exploiting opportunities to create new green jobs is of key importance. Supporting decarbonisation in key value chains is also envisaged within the project: in processing industry, forest-wood chain, food chain, built environment and mobility.

After the period of scoping and preparation of the action plan of the Strategic Project for Decarbonising Slovenia (between 2019 and 2021), two phases of active implementation of the Deep Demonstration action plan follow in the period between 2022 and 2025. In these phases, systemic innovation will take place, a process in which a wide variety of stakeholders from all key target groups are actively involved: local communities, companies and policy makers. There will also be opportunities for acquiring and sharing new knowledge and training local experts for the transition to a circular, regenerative, low-carbon economy.

4.2.7 National Development Strategy of Agriculture and Food System

The agricultural policy in Slovenia also responds to the signals brought by the public debate, the preferences of stakeholders and, last but not least, the policy planners at the EU level. After a public consultation process, the National Assembly adopted the **Development Strategy of Agriculture and Food System** in January 2020. In the Strategy, formally titled *"Resolution on the national program on strategic directions for the development of Slovenian agriculture and food system - Our food, countryside and natural resources from 2021"*, the Ministry of Agriculture, Forestry and Food presents its vision of the strategic framework for the development of Slovenian agriculture, food processing and the countryside. The document tries to summarize and prioritize the key social demands related to agriculture, food, natural environment and rural development in Slovenia. It can also be seen as a response to the proposal of nine specific objectives of the CAP, which underpin European and thus Slovenian agricultural policy after 2021. In this sense, the Strategy can be seen as a **basis for the preparation of the National CAP Strategic Plan**.

Figure 28 presented below shows the strategic frame - focus areas, objectives and their interconnections. The strategic framework is designed in a way to reflect kay social requirements associated with agri-food system and rural areas, and includes concepts such as **food, natural resources and rural areas.** In the next layer, in response to social demands, **four specific objectives** are defined to address the needs and challenges pertaining the development of agri-food system and rural areas in the future:

A. Resilient and competitive food production and processing,
B. Sustainable management of natural resources and provision of public goods,
C. Improving the quality of life and strengthening economic activity in rural areas,
D. Horizontal objective: strengthening the formation and transfer of knowledge.

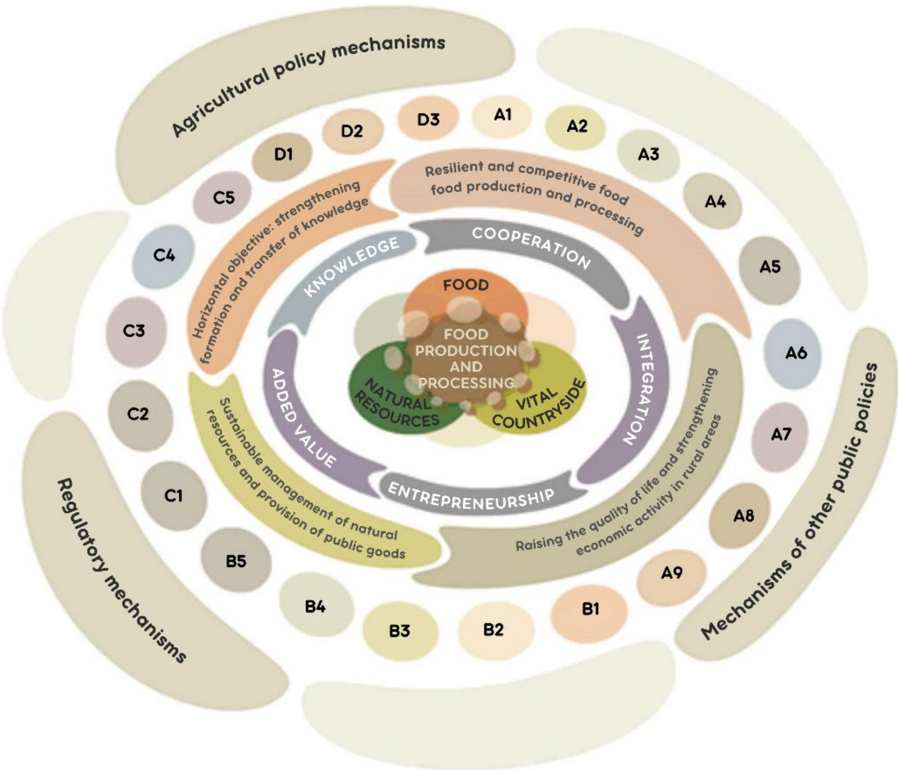

Figure 28: Strategic frame of the National Development Strategy of Agriculture and Food System

These objectives describe the key issues and requirements that define the conduct of rural stakeholders and actors involved in the food supply chain. These objectives also provide the cornerstones of agricultural and other policies related to agriculture and rural areas. The four specific goals resonate well also nine specific goals of the Common Agricultural Policy (hereinafter: CAP), which underpin European and thus Slovenian agricultural policy after 2023 and which Slovenia must also rely on when preparing its CAP strategic plan.

The strategy tackles the content of the bioeconomy significantly more ambitiously and systematically than previous program documents. Strategic objective A, **Resilient and competitive food production and processing**, refers entirely to the part of the bioeconomy that is directly related to agriculture and food systems. The following specific objectives are linked to it: A1. Ensuring high standards of safe and quality food; A2. Effective use and access to basic resources (agricultural land, capital, labor, knowledge); A3. Parity of agricultural incomes; A4. Income stability; A5. Strengthening agri-food chains and improving the position of the farmer in the chain; A6. Encouraging the production and consumption of food with higher added value; A7. Strengthening market orientation and entrepreneurship; A8. Encouraging generational renewal; A9. Preservation of production potential and extent of agricultural land.

Strategic objective B, **Sustainable management of natural resources and provision of public goods**, addresses challenges in the bioeconomy that are related to sustainable management of ecosystems and agricultural use, as well as with the underlying ecosystem services. Coping with these challenges the strategy translates them into the following specific goals: B1. Reduction of negative impacts on water, soil and air; B2. Climate change mitigation and adaptation; B3. Biodiversity protection; B4. Preservation of the agricultural cultural landscape; B5. Ensuring higher standards of animal welfare. Within these objectives, the strategy highlights certain tasks, which clearly coincide with the challenges of the circular bioeconomy, such as: (i) economical and sustainable use of resources in line with the principles of circular economy; (ii) increasing the efficiency of water and energy use with an emphasis on renewable resources; (iv) use of by-products, waste, residues of organic origin and other non-food raw materials for bioeconomy purposes; (v) reducing emissions and reducing the amount of food waste; (vi) promotion of carbon sinks in agriculture, forestry and wood processing sector and (vii) use of sustainable materials in the product development process, taking into account product life cycle monitoring.

Elements of the development of the bioeconomy, especially those that extend beyond the agro-food value chain and the protection of natural resources, are covered in the strategic goal C - **Improving the quality of life and strengthening economic activity in rural areas**. It includes the following specific goals: C1. Promotion of on-farm diversification; C2. Strengthening local initiatives and inter-industry cooperation and strengthening tourism's connection to quality food from the local environment; C3. Development of the bioeconomy; C4. Social inclusion, rural women and care for vulnerable groups; C5. Reducing the gap in accessibility and quality of services in urban and rural environments.

Considering the focus of this strategic paper, we provide a more detailed insight will to the objective C3, which explicitly addresses the **development of the bioeconomy**.

The opportunity to transition to the bioeconomy is recognized as a new paradigm for the organization of business processes. By-products and residues thus become raw materials in existing optimized or new processes. Such organization of business processes brings many **economic, social and environmental benefits**. The National Strategy for the development of agri-food sector accentuates that primary producers in agriculture and forestry also receive direct benefits (income, employment). This is triggered through the increase in demand for primary products, as well as the growth in the market value of residues, as an affordable and technologically perspective raw materials. Positive impacts are also expected for various manufacturing sectors, where the transition to bio-based technologies means the potential for adding value to products and better utilization of raw materials of biological origin.

Bioeconomy value chains tend to take place at the local level, most often in rural areas, due to the low cost of transporting input raw materials. Therefore, the expansion of the bioeconomy brings opportunities to achieve **economic convergence between urban and rural areas**. The bioeconomy further contributes to the **circular economy** because it promotes the sustainable and efficient use of renewable resources in materially and energetically closed loops without waste.

To sum up, the new Strategy for the Development of the Slovenian agri-food sector and Rural areas certainly represents a great advance in the perception of the role of agriculture and agricultural policy in the accelerated transition of Slovenia to a circular bioeconomy. Nevertheless, the demonstrated ambitions yet need to be realized in the form of the appropriate set of measures of the Strategic Plan of the CAP for Slovenia 2023-2027, sufficient (public and private) resources intended for this and, as most importantly, long-term viable projects.

4.3 Instruments and measures supporting bioeconomy development in Slovenia

As we describe in detail in the previous chapter in Slovenia, contents related to bioeconomy development are only indirectly covered in national strategic and program documents. As a result, even at the implementation level of these documents, as a rule, we do not find instruments and measures that would explicitly support the development of bio-based value chains. Instruments and measures to support the bioeconomy can be divided into the following sections:

A. Sectoral structural measures, supporting endeavours of businesses in the bioeconomy sectors to improve their environmental sustainability, valorization of by-products and closing material/energy loops
B. Support for RDI and transfer of (bio-based) technological innovations in industrial production
C. Systemic measures to promote the transition to bio-based technology solutions
D. Targeted support for micro- and SMEs in the early stages of commercialization of (bio-based) innovations.

From the above, it is needless to say that there is currently no systemic programme, or underlying policy mechanism in Slovenia to tackle the development of bioeconomy explicitly. Furthermore, although bioeconomy is fairly strongly integrated in key national strategic documents (see section 3.2), dedicated measures and instruments, targeting bioeconomy development, are rare.

4.3.1 Implementation of support for Bioeconomy development from Rural development policy

With regard to the aggregate financial scope, as well as with regard to its sectoral focus and the total number of relevant policy instruments supporting bioeconomy, the main single public financial instrument is the European Agricultural Rural Development Fund, EAFRD. Relevant instruments and measures belong to the legal framework of the EU **Rural Development Policy**, which is currently (programming period 2023-2027) **integrated in the CAP strategic planning system**. But even in this case, one can notice a considerable gap between strategic commitments and the actual set of dedicated measures and amount of public funding. With respect to the sectoral structural measures (‘type A interventions) expectedly, the **majority** of measures and the funds allocated are earmarked **for structural interventions in primary agricultural and forestry production**, food processing and marketing and in the primary processing of wood sortiments. These measures (mainly designed as investment support) are also positioned highly in terms of the prioritization at the level of the National CAP strategic plan (CAP SP).

On the other hand, measures aimed at promoting the sustainable use of energy and the development of a **circular bioeconomy** (ie. valorising side streams in primary agricultural and forestry production, along with their respective value chains) are considered to be of medium importance, and **only partially addressed within the CAP SP**. In the chapter of the Strategic Plan that assesses the needs in this segment, the CAP SP highlights suboptimal biomass flows from the residues of primary agricultural production and the production and consumption of foodstuffs (e.g. whey, residues from the processing of cereals and oils, slaughterhouse residues, discarded food). Among the biomass flows with the highest unused potential, CAP SP outlines side products in arable production and horticulture, the potential of wood biomass and the almost unused energy potential of livestock manure are too poorly used. Improving energy efficiency and renewable energy sources are in fact the most strongly exposed eligible types of valorisation of side-products for support within CAP SP, amounting to about 10 million EUR of public financing (EAFRD + national budget) for the period 2023-2029. These operations are planned to be addressed as a part of the support for investments in increasing productivity and technological development, including the digitalization of agricultural holdings and the food processing industry, investments in the development and increase of competitiveness and market orientation of organic farms, collective investments in agriculture for the joint preparation of agricultural products for the market in, or for investments in the adaptation of agricultural holdings to the implementation of above-standard requirements in the field of farm animal welfare.

In order to promote the transition to a circular bioeconomy, the EAFRD will support non-agricultural supplementary activities on farms, as well as investments in agricultural production and food processing that contribute to the reduction of waste, the reduction of by-products and the use of the latter in an innovative way. Support is envisaged also for investments related to the reuse of by-products, residues and other non-food raw materials, investments in the reduction of water consumption and reuse of wastewater to reduce waste, investments in connection with recycling or composting, investments in renewable energy sources and efficient use of energy for the needs of the farm or agricultural holding, the introduction of biodegradable packaging and packaging made of recycled materials, investments in greater material efficiency of production processes. Further 9 million EUR of public financing (EAFRD + national budget) are earmarked for such investments for the period 2023-2029.

Provisions of the CAP SP reveal that EAFRD support is primarily intended for agricultural holdings and associated (food-, wood-) processing units. Establishment of technologically more advanced valorisation pathways goes beyond the scope of the CAP SP. For investment projects at the industrial scale that involve cascading use of biomass, sustainable use of energy or the development of the circular bioeconomy, CAP SP envisages *"support by other ESI funds"*.

Two types of public interventions should be pointed out with regard to their impact on the improvement of the mobilisation of **forest-wood biomass** and its economic performance (value-added, employment) along the forest-wood value chains. The first set of interventions derives from the EAFRD, and is thus subject to strategic planning within the CAP SP. The operation that corresponds most directly to the enhancement of the forest-wood bioeconomy is support for investment in the first-stage wood processing and digitalisation. About 9 million EUR of public financing (EAFRD + national budget) are earmarked for such investments for the period 2023-2029.

The second stream of public intervention in forest-wood bioeconomy will base upon the provisions of the updated Action Plan for increasing the competitiveness of the forest-wood chain in Slovenia (in preparation), which will be fully aligned with the relevant provisions of the Slovenian industrial strategy (see section 4.2.3), and the financial resources will be tied to ESIF (mainly ERDF). For the projects applying to the field of energy, technical-administrative support will be the responsibility of the Ecofund. Industrial investments in terms of the development of bio-based technologies and products will compete with generally designed measures and instruments to transfer innovations and strengthen the competitiveness of the economy (the public agency of the Republic of Slovenia for the Promotion of Entrepreneurship, Internationalization, Foreign investments and Technology SPIRIT, operating under the Ministry of Economic Development and Technology).

4.3.2 Implementation of support for bioeconomy development from Cohesion Policy

In the period 2021-2027, the EU cohesion policy in Slovenia is financed and implemented by four funds: the European Regional Development Fund, the Cohesion Fund, the European Social Fund and the Just Transition Fund. For the purposes of drawing European cohesion funds, Slovenia is divided into two cohesion regions - Eastern Slovenia and Western Slovenia. For Eastern Slovenia, the share of project co-financing is 85 percent, while in Western Slovenia this share is 40 percent.

In the programming period 2021-2027, a total of EUR 3.2 billion is available for cohesion policy measures across all funds, which are allocated to five priority areas: (1) Smarter Europe (innovative and smart economic transformation); (2) Greener, low-carbon Europe (including energy transition, circular economy, climate change adaptation and risk management); (3) More connected Europe (ICT mobility and connectivity); (4) More social Europe (European Pillar of Social Rights and support for healthcare); (5) Europe closer to citizens (sustainable development of urban, rural and coastal areas and local initiatives).

4.3.3 The role of Bioeconomy in national Recovery and Resilience Plan

Slovenia's Recovery and Resilience Plan (hereinafter: RRP), adopted in April 2021, responds to the urgent need of fostering a strong recovery and making Slovenia future-ready. The reforms and investments in the plan will help Slovenia become more sustainable, resilient and better prepared for the challenges and opportunities of the green and digital transitions. To this end, the plan consists of 55 investments and 33 reforms. They will be supported by 1.8 € billion in grants and 0.7 € billion in loans. 42% of the plan will support climate objectives and 21% of the plan will foster the digital transition.

The transformative impact of Slovenia's plan is the result of a strong combination of reforms and investments which address the specific challenges of Slovenia. The reforms address bottlenecks to lasting and sustainable growth, while investments are targeted to accelerate transition towards **four key development areas**: (1) green transition, (2) digital transformation, (3) smart, sustainable and inclusive growth, and (4) healthcare and social security.

Contents related to the development of the bioeconomy can best be placed in its first key development area, referring to **Green Transition**. Green transition plays a key role in speeding up the transition to a low-carbon circular economy, which is one of the goals of the Slovenian Development Strategy 2030 (see section 4.2.2) and one of the key factors in ensuring long-term productivity of economic entities and improving resilience of the society. Slovenia's RRP also contributes to achieving the goals of the Integrated National Energy and Climate Plan of the Republic of Slovenia (NEPN, see section **Error! Reference source not found.**) and the commitments to achieve climate neutrality by 2050 by supporting reforms and investments in the following areas: (i) energy efficiency, (ii) the use of renewable energy sources and sustainable mobility, (iii) transition to circular business models, (iv) adapting to the climate change and improving the quality of public services (water supply, wastewater treatment). Support, amounting to 624 million EUR is earmarked for the projects supporting Green transition from the Slovenian RRP.

While none of the identified projects is addressing bioeconomy development explicitly, related reforms and investments fit best to the **projects, designed to accelerate the transition to a circular economy**. Estimated value of public support for these projects is 48 million EUR. The supported projects are classified into two parts. The **Reform part** cosists of the following actions: (i) Establishing a strategic and legal framework for the transition to a circular economy; (ii) Establishing the conditions for more efficient financing of the transition to a low-carbon circular economy; (iii) Systemic approach: horizontal programs of the Comprehensive strategic project for the decarbonisation of Slovenia (see section 4.2.6). The Investment part involves: (i) A comprehensive strategic project of the decarbonisation of Slovenia through the transition to a circular economy (CSP KG): (ii) Support for circular start-ups; (iii) Support for circular innovations in SMEs; (v) Sector-specific support of selected (5) value chains, among which also industrial wood processing.

5 SETTING THE STRATEGY

5.1 OVERVIEW OF INTERNAL AND EXTERNAL FACTORS AFFECTING THE DEVELOPMENT OF BIOECONOMY IN SLOVENIA

The preceding chapters provide a structured description of the components, institutions and drivers that form the system of the national bioeconomy. Broadly speaking, two sets of information can be distinguished: the first one relates to the resource base, sectoral structure, innovation transfer and economic performance of bioeconomy, while the second one is concerned with the system governance. As the first step in setting the strategy, a conventional approach is applied by synthesizing and arranging the key findings into (internal) Strengths and Weaknesses, and (external) Opportunities and Threats.

The framing of the SWOT analysis is consistent with the overview of the factors affecting the development of the bioeconomy sectors, visualised and described in greater detail in section 3.1 of this paper. In this way, we attempt to ensure a systematic and consistent approach to the formulation of strategic propositions for the unlocking of the bioeconomy potentials in Slovenia.

The SWOT elements are presented in separate tables and grouped along the following factors affecting bioeconomy:

- **Biomass supply (BS)**, which describes the primary production of (agricultural, forest-based and aquaric) biomass, their interaction with related ecosystem services , as well as the infrastructural and logistic considerations;
- **Bioeconomy value chain (BVC)**, which describes the sectoral mix of bioeconomy, degree of inter-sectoral linkages and multiplier effects, the level of (technological and organisational) sophistication, as well as the status of enabling environment (ie. financial capital and other types of business support);
- R**esearch, development and innovation (RDI)**, which assesses the quality of bioeconomy-related research and development its integration in the development and transfer of industrial innovations;
- **Institutional and policy framework (IPF)**, which outlines the status of bioeconomy among the strategic development priorities of the national economy, its institutional setup and integration into policy planning, types, scope and mutual coordination of supporting instruments;
- **Competitive bioeconomy products (CBP)**, which outline the demand trends for biobased technologies and components in technology-intensive sectors, which accelerate (horizontal, vertical) integration along the extended bioeconomy value chains.

We start with the description of Strengths, which can be seen as the key internal factors shaping the growth of the bioeconomy in Slovenia (Table 6).

Table 6: Strengths of the bioeconomy in Slovenia

Code*	Description
S-BS1	Diverse and sustainably managed resources in agricultural and forestry production, associated with several ecosystem services, untapped potential for valorisation
S-BS2	High percentage of forest areas (58% of country area) and the consequent high production potential of Slovenian forests.
S-BS3	Under-exploited flows of residual biomass from (diversified) primary agricultural production and by-products of food production, well-organized organic waste management system.
S-BS4	Bioeconomy strongly represented in the manufacturing sector (conventional and novel bioeconomy sectors account for 28% of GVA at factor costs)

S-BVC1	Strong manufacturing industry and growing interest of companies to move towards bio-based technologies and to close energy- and resource-based flows, strongly driven on the demand side in the B2B supply segment
S-BVC2	Vibrant enabling environment for supporting start-ups (business incubators, startup accelerators), increasing emergence of bioeconomy-related spin-offs based on knowledge generated in (also public) R&D institutions.
S-RDI1	Internationally renowned applied research in various technologies of advanced bioeconomy capable of delivering hands-on solutions to industrial clients
S-RDI2	Established development networks and strategic partnerships linking R&D with the economy and development policy for transitioning into a circular bioeconomy.
S-RDI3	Participation of public research organisations in the projects of the leading European platforms and programmes, transferring good practices from the EU to the national level.
S-RDI4	Stable system of financing for applied research projects based on guidelines garnered from stakeholder initiatives on priority RDI topics.
S-RDI5	Growing small and medium-sized enterprise (SME) participation in Horizon 2020, EU networks and bioeconomy related R&D.
S-IPF1	Strong strategic commitments for systemic transition to a circular, regenerative, low-carbon economy in Slovenia, inter-ministerial coordination and international coaching (EIT Climate Deep Demonstration Project)
S-IPF2	Strong policy commitment towards bioeconomy development, reflected in particular in the national Smart specialization strategy, Rural Development policy, partly (support for forest-wood value chain) also in industrial policy.
S-IPF3	Networks and partnerships linking RDI with the industry, supported by development policy (Smart Specialisation Strategy - Circular Economy SRIP, PSiDL SRIP, Food SRIP Strategic RRI programmes)
S-IPF4	Green public procurement system with its direct and indirect impacts on the demand for biobased solutions (eg. Incorporation of biobased construction materials).
S-CBP1	Growing number of firms, developers and early adopters of innovation, with a presence in international markets and providing a good practice to others.

* BS (Biomass supply); BVC (Bioeconomy value chain); RDI (Research, development and innovation); IPF (Institutional and policy framework); CBP (Competitive bioeconomy products)

In setting the strategy for the future development of the bioeconomy in Slovenia, we need to take into account its characteristics, which should be considered as the weaknesses. They are outlined below (Table 7).

Table 7: Weaknesses of the bioeconomy in Slovenia

Code*	Description
W-BS1	Technology lag and productivity gap in primary bioeconomy sectors, in particular in agriculture.
W-BS1	Poor ability to enable industrially relevant quantities of biomass due to fragmented tenure structures in forestry and agriculture, lack of organisation, and efficient business models.
W-BS2	Low level of wood processing and consequently low added value (in 2018, 52% of unprocessed roundwood was exported abroad; softwood roundwood is mostly processed in sawmills (68%) and hardwood roundwood is mostly used for energy purposes (67%)).
W-BS3	Well organized monitoring of waste streams, but very limited or no systemic monitoring of by-products and side-streams of biomass in manufacturing sectors, consequently reduced potential for the cascading use of biomass side-streams
W-BVC1	Limited potential for developing scalable biobased value chains due to small-scale and fragmented plants for biomass processing.
W-BVC2	Low level of business integration in 'conventional' bioeconomy-related industries, making it harder to develop industrial-scale biorefineries, or leverage for the development of bioeconomy clusters.

W-BVC3	Succesful businesses in various bioeconomy sectors, but operating as individual firms on (usually niche) markets, lacking the capability, or willingness, to integrate into local/regional value chains.
W-BVC4	Weak financial leverage of companies in both conventional and 'new' bioeconomy sectors to make (investment-intensive and commercially risky) shifts to bio-based materials and technologies.
W-BVC5	Limited leverage of industrial and portfolio investors (e.g. venture capital), weak interest of financial service providers for higher-risk investments.
W-RDI1	Focus in public research institutions dedicated to basic research, rather than on new product and prototype development and demonstration.
W-RDI2	Insufficient feedback from the economy on RDI needs and applicability of results.
W-RDI3	Weak R&D infrastructure at the transition from laboratory to demonstration level (TRL 3-6) slows down innovation.
	Low activity in RDI in major bioeconomy industries (except manufacture of pharmaceuticals and chemicals) on one side and weak involvement of research institutions at high TRLs inhibits upscaling of pilot projects.
W-IPF1	No dedicated bioeconomy development strategy at the national level, leading to no systematic public support environment for the development of the bioeconomy.
W-IPF2	Low level of policy coordination, leading to scattered and often non-coordinated instruments and measures targeting particular sectors/aspects of bioeconomy.
W-IPF3	Lacking perception of bioeconomy as a strategic sector in public RDI funding and consequently inappropriate policies and lack of long-term funding.
W-IPF4	Fragmentation of resources in the R&D sector due to national funding being directed to small projects and groups; weak cooperation and integration of R&D.
W-IPF5	Administrative procedures and regulations inhibit development and commercialization through lengthy and uncertain implementation procedures.
W-CBP1	Difficulties faced by innovating companies to attract investments of sufficient critical mass as they are of moderate size and weakly integrated into regional clusters.

* BS (Biomass supply); BVC (Bioeconomy value chain); RDI (Research, development and innovation); IPF (Institutional and policy framework); CBP (Competitive bioeconomy products)

External trends that can positively affect the development, and performance of the bioeconomy in Slovenia are outlined in the Opportunities table below (Table 8).

Table 8: Opportunities for the bioeconomy in Slovenia

Code*	Description
O-BS1	Increased provision of forest-wood biomass – partly due to improved utilization of the reserves in the annual wood increment.
O-BVC1	Development of a robust enabling environment, providing investment, ensuring scale-up, reducing risk and enabling a faster transition to market.
O-BVC2	Adopting national strategic commitments to improve knowledge-intensity in bioeconomy sectors (e.g. development departments, clusters, networks).
O-BVC3	Macro-regional cooperation and business integration to make better use of the bioeconomy potential (e.g. BIOEAST).
O-BVC4	Closing local/regional loops of biomass use by setting up a network of small-scale modular biorefineries for the processing of different biomass sources (local2local principle)
O-RDI1	Technological and management know-how resulting from the strong presence of the wood and paper industries in the structure of manufacturing activities over the past decades.
O-RDI3	Better use of opportunities provided by the European Research Area to enhance bioeconomy related research excellence, international collaboration, openness and inclusiveness.
O-RDI4	Internationalization and participation of stakeholders in RDI strategic partnerships can ensure knowledge transfer to the national level and direct the supporting environment.

O-IPF1	Wider economic and social context (need for reduction of fossil resources and more efficient use of biomass by-products / waste streams).
O-IPF2	Growing awareness on the need for legislative changes towards environmental sustainability.
O-IPF3	The integration of bioeconomy content covered by the country's strategic development documents (four of the nine priority areas of the Smart Specialisation Strategies include bioeconomy content, the Slovenian Industry Strategy 2030 highlights the importance of a low-carbon circular economy and sustainable management of natural resources.
O-IPF4	Post-pandemic recovery developing the circular bioeconomy through appropriate investment, planning and inter-sectoral coordination.
O-CBP1	Increasing long-term demand for biobased technologies and products – partly due to poitive consumer perception for sustainable technologies, and partly due to the improving price-cost relationship of biobased products.
O-CBP2	Growing demand for bio-based products in some important export sectors of the Slovenian economy (e.g. wood, paper, chemicals, food additives and functional foods, automotive and electrical components).

* BS (Biomass supply); BVC (Bioeconomy value chain); RDI (Research, development and innovation); IPF (Institutional and policy framework); CBP (Competitive bioeconomy products)

Future development of the bioeconomy in Slovenia needs to take into account also the limiting external factors. They are outlined in Table 9.

Table 9: Threats for the bioeconomy in Slovenia

Code*	**Description**
T-BS1	(Un)availability of biomass (forest and agricultural) due to the impact of climate change.
T-BS2	Potential conflicts between alternative uses of biomass and the risk of over-exploitation of renewable carbon sources.
T-BVC1	Capital-intensive and technologically advanced competition for the purchase of (mainly woody) biomass in neighboring regions.
T-BVC2	The high capital cost of setting up efficient industrial operations for cascading use of biomass.
T-BVC3	Large investments in biorefinery capacity (demonstration development and industrial) in the wider EU region and limited access to new value chains.
T-BVC4	Inadequately sited biomass processing plants can disturb the price equilibrium, especially in the case of inappropriate subsidy policies (eg. negative past experience with the biogas installations).
T-RDI1	Lack of appropriate definition of priority areas and objectives of bioeconomy development may result in continued sporadic RDI work on individual projects.
T-RDI2	Loss of development and investment momentum at the transition to higher TRLs due to financial, technical, organisational challenges for commercialisation.
T-RDI3	Technology closedness: Many biomass processing technologies are protected by long-standing patents.
T-IPF1	Neglect of the bioeconomy in planning for post-pandemic recovery, reorientation of focus in public policies (eg. national security policy).
T-IPF1	Sporadic rather than systemic progress due to an uncoordinated legislative framework.
T-CBP1	Negative public opinion, linked in particular to the energy use of biomass and some poorly designed support policies in the past (e.g. support for the construction of oversized and technologically inadequate biogas plants).
T-CBP2	Unfavourable price-cost ratios of bio-based materials and technological solutions.
T-CBP3	Reduced public confidence in bioeconomy-related innovations: 'greenwashing' or promoting projects with a doubtful (environmental, material, economic) results.

* BS (Biomass supply); BVC (Bioeconomy value chain); RDI (Research, development and innovation); IPF (Institutional and policy framework); CBP (Competitive bioeconomy products)

5.2 Strategic propositions as derived from the SWOT analysis

5.2.1 Setting up the strategy: the need for context-based solutions

The idealized model of circular bioeconomy is based on continuous and cost-effective access to industrially relevant quantities of biomass of homogeneous composition, its gradual decomposition in large integrated biorefineries into simpler (chemical, material) building blocks, which are then integrated a wide range of biobased products. The process is following the cascading use principles – starting with high value-added products and finishing with the energy use. Economic entities interact in the development of new technologies and processes (bioeconomic clusters) and in the exchange of material and energy flows (industrial symbiosis). The transition towards circular bioeconomy and its growth depends also on the wider supporting environment. It consists of a business supporting system supporting the early-stage companies, capable venture capital market to meet the firms' growth potentials, and the state with stable business environment, responsive legal framework, and consistent policy support.

In reality, the utilization of the development potential of the bioeconomy is context-based. The development of circular business models in the context of the Slovenian bioeconomy differs from the idealized model described above in practically all elements. It starts already with a small scale and fragmented production structure in primary sectors. Starting from this, it is clear that in the design of circular business models suitable for the conditions of the Slovenian bioeconomy, we will have to resort to innovative and context-adapted solutions. On the other hand, the primary sectors of the bioeconomy (agriculture, forestry) and the resulting value chains show characteristics typical of countries participating in the BIOEAST initiative: a low level of productivity in primary production with a relatively high share of employees in these industries, the unused potential of residues and by-products in production, processing and consumption, the absence of biorefinery capacities and the low level of awareness of opportunities for circular technological solutions and business models. The latter is present both on the side of industry, and on the side of public development policies. In this context, it is expedient to cooperate with the countries of the BIOEAST macro-region, which are facing similar challenges, in developing appropriate solutions.

The context-specific strategic propositions, as derived from the SWOT analysis in the previous section are framed in the same manner, ie. along the the factors affecting the development of the bioeconomy sectors (see section 3.1 of this paper).

5.2.2 Biomass supply

First and foremost, in order to address the opportunities associated with favorable long-term trends on the demand-side (O-CBP1, O-CBP2), actions are needed to **overcome the technology lag and productivity gap** in the primary sectors of the bioeconomy, particularly in agriculture (W-BS1), and to better valorize the associated ecosystem services (S-BS1). Due to the small-scale and fragmented structural conditions associated with agricultural and forestry production (W-BS2, W-BVC1), further actions are needed in terms of the **integration of primary producers into producer organizations.** This would not only strengthen their bargaining position in the value chain, but would bring potentials for **improved logistical flows** for residual biomass (S-BS3) eg. by storage, or partial processing of biomass to improve the cost efficiency of transport, and its durability.

Mobilisation of industrially relevant quantities of biomass to address the growing demand (O-CBP1, O-CBP2) is particularly relevant in the forestry sector with the relatively high and growing (S-BS2), but poorly utilized production potential (W-BS3). The changing species composition of forests and faster growth (O-BS1) associated with climate change (T-BS1) offer an opportunity for bioeconomy growth, although this will require a long-term reorientation of the associated manufacturing sectors (growth opportunities especially for the novel bioeconomy sectors). This would be needed also in order to improve the sectors' position in the competition with the capital-intensive and technologically advanced competition in neighboring regions (T-BVC2).

For a better mobilization of biomass side-streams, **improvements are also needed in the monitoring system**, (W-BS4) which would enable better data availability about the available quantities and technologically relevant characteristics of biomass for further processing along the cascading principles.

5.2.3 Bioeconomy value chain

Unlocking bioeconomy potentials along the bioeconomy value chains in Slovenia (O-CBP1, O-CBP2) should take place in two directions. Similarly to the primary bioeconomy sectors, the reserves of the conventional manufacturing sectors of bioeconomy in Slovenia (food production, wood processing) lie in **boosting the sectors' productivity and value added** (S-BS4), partly also in the **closing the material and energy loops** within their operations. The **second trajectory is more demand-driven**. Its forerunners are firms, which are integrated into international value chains (S-BVC1) and include some of the **key national manufacturing** (eg. chemical, automotive, electrical) and other sectors (eg. construction), where the demands and needs for the transition to bio-based materials and technological solutions is increasing (S-CBP1). **Increased demand for biobased final products** from these sectors (O-CBP2) creates opportunities for growth along its upstream (technology developers) and downstream (primary and conventional manufacturing) sectors.

In order to unlock the potentials for a more integrated and sustainable bioeconomy in Slovenia, three sets of challenges and opportunities have been pointed out in the SWOT analysis. First, Slovenia faces a **significant, but suboptimally utilized raw material potential of agricultural and forest-wood biomass**. The structure of practically all activities dealing with the processing of agricultural and forest-wood biomass is fragmented (W-BS2) and produces large amounts of side streams and residues, whose current mobilisation is currently limited mostly on energy use (W-BS2). The added value of side-streams and residues in primary production and conventional processing sectors is therefore relatively low and poorly diversified.

Another challenge lies in a **low level of horizontal and vertical integration along the bioeconomy value chains** (W-BVC2, W-BVC3). This should not be misinterpreted by the general absence of technologically advanced and competitive firms in sectors operating along these chains. On the contrary, their number and significance is increasing (S-BVC1). What is lacking however is the low level of their integration, or at least cooperation. As a result, most of the firms in bioeconomy sectors are operating at the SME scale. Consequently, a large percentage of primary products in agriculture and forestry is valorised outside the national economy, and the conditions for biorefining of biomass side-streams at industrial scale is hardly attainable. Setting up a **network of small-scale modular biorefineries** (O-BVC4), combined with **macro-regional cooperation and business integration** (O-BVC3) would significantly improve the potentials for sustainable valorisation of biomass and economic performance (value added, employment) of the bioeconomy sectors witin the national economy.

Better valorization of biomass sidestreams through the installation of biorefining capacities and business integration will require development of a **robust enabling environment, providing investment, ensuring scale-up, reducing risk and enabling a faster transition to market** (O-BVC1). A vibrant generic business enabling environment (S-BVC2) provides a good groundwork, whereas **improvements are needed in the financial leverage** for (investment-intensive and commercially risky) innovative approaches towards biomass valorisation (W-BVC4, W-BVC5). Improvements are required also in terms of **increased knowledge-intensity in bioeconomy**

sectors by strengthening industrial RDI through clusters and networks (O-BVC2). Internationalization and participation of industrial partners (O-RDI4) in international RDI strategic effort (eg. through their participation in CBE JU projects) can ensure accelerate innovation transfer. This can also control for the threat of being left out from the industrial innovation community (T-RDI3).

5.2.4 Research, development and innovation (RDI)

The SWOT analysis, reveals a vibrant research community engaged in RDI work in applied life sciences and other relevant science disciplines for bioeconomy, able to deliver hands-on solutions to industrial clients (S-RDI1, S-RDI2). Research institutions and teams are well integrated into international RDI effort (S-RDI3). Investments in research and development and publications in this area are constantly increasing. The system of revolving (national) financing of research programmes (S-RDI4) brings the stability needed for a long-term applied research work. Increased involvement of end-users in research effort (S-RDI5) can also be seen as an asset on which we can start to **improve innovation adoption in the bioeconomy-related manufacturing sectors**, which is currently assessed as weak (W-RDI3, W-RDI4). Another asset to improve the innovation adoption is also a **vigorous startup community** and many of their business ideas are inspired by biobased innovations (S-BVC2). Although these firms are operating at the niche scale and in the early stages of the business cycle, they can be seen as the harbingers of the entrepreneurial transition to the bioeconomy.

Despite the obvious progress, there are still potentials for improvements in **bringing research closer to the commercially viable outputs** by new product and prototype development, or demonstration activities. To achieve this, refocusing of their operation is needed on both sides: (mostly public) research institutions should adopt applied research and innovation more ambitiously (W-RDI1), whereas the industry should also take a more proactive role in commissioning applied research and in providing feedback on the current research results (W-RDI2). Technological and management know-how resulting from the strong presence of the 'conventional' biobased industries in the structure of national manufacturing sector (S-BS4, O-RDI1) is an asset on which we can **strengthen knowledge intensity** through applied research and integration of RDI and industrial partners. This is one of the prerequisites for the improvement of bioeconomy performance in terms of innovation adoption. Additional funding of research excellence and international **collaboration through the European Research area and dedicated public-private partnerships (eg. CBE JU)** would further stimulate these processes.

5.2.5 Institutional and policy framework

Despite the proven long-term political commitment in Slovenia to the generic strategic development goals that comfortably accommodate the ambition of making better use of the bioeconomy potentials towards sustainable, more integrated and better performing bioeconomy (S-IPF1), **institutional status and strategic significance of bioeconomy is unclear**. This is reflected also in the fact that **Slovenia is one of the seven EU Member States without a dedicated national bioeconomy strategy** (W-IPF1).

Furthermore, extensive review of national strategic documents and bioeconomy-related policies carried out in Section 4 of this Concept Paper reveals that **bioeconomy is not explicitly identified among the national strategic priorities in Slovenia**. It needs to be accentuated though, that **inter-ministerial coordination on various issues related with bioeconomy development is operating**. Elements of (circular) bioeconomy have been **integrated into various strategic documents and policy instruments** (S-IPF1, S-IPF2). Bioeconomy-related themes are relatively strongly represented in the key strategy documents, such as Slovenian sustainable smart specialization strategy (S5), Slovenian industrial strategy 2030, Comprehensive national Energy and climate plan 2030, and the Comprehensive strategic project for the decarbonization of Slovenia.

At the level of the implementation of instruments and measures, the coordination between various ministry portfolios and funds is largely lacking (W-IPF2). From the point of view of final beneficiaries, especially in the case of large, integrated multi-sectoral projects, the **lack of coordination** (eg. different criteria for selection of operations, different financial rules, overlaps of eligible operations between different funds on one side, uncovered areas of support on the other) may **bring confusion and reduce the motivation of eligible beneficiaries to participate in supported actions**.

For effective public support to a circular bioeconomy, it will be necessary to **adjust and coordinate several government portfolios related to bioeconomy** (ie. environoment, agriculture, industry and technology, research and innovation, education, employment). **Setting a National bioeconomy strategy with the related Action plan** would be a step in this direction. If this is not deemed appropriate due to the opacity and a number of (already adopted) strategy documents, it would however still be beneficial to prepare an informal document to promote inter-ministerial coordination and to strengthen the role of the bioeconomy in the context of the future strategic planning.

Apart from the strategic planning, **stronger inter-ministerial coordination** is required in particular in the planning and implementation of supporting **instruments and measures**. As an illustration, we can take the example of investment support in the forest-wood value chain; coordination of instruments from two related funds (EARDF funding intended for forestry and primary processing of wood sortiments, and ERDF funding intended for products/process improvements in the manufacturing sectors) may stimulate intensified cooperation of firms along the value chain, bringing benefits both, in resource use sustainability, and in overall economic performance. Coordinated policy instruments are required also to encourage the **development of biorefinery capacities**, which represent a bridge between conventional and new bioeconomy products and technologies and represent a key link in the formation of comprehensive multi-sectoral value chains.

On the long-run, systematic and coordinated approach towards the the development of supporting instruments and measures would lead to more ambitious forms of cooperation between economic entities (eg. industrial symbiosis) and cross-sectoral cooperation fetween manufacturing firms and other relevant actors (eg. R&D institutions) in areas of mutual interest (RDI, closing the loops) within bioeconomy clusters.

Public policies can have an impact on the **demand side of the market for biobased technological solutions and materials.** The most straightforward tool for this is the system of public procurements which - apart from the direct market effect with the institutional purchase – brings positive demonstration effects for private (corporate and individual) buyers. Positive experiences from the established system of **Green public procurements** in Slovenia (S-IPF4), which reflect in increased demand for local food supply, organic food and use of biobased materials in construction, can serve as an incentive to upgrade the instrument to other relevant biobased commodity markets (eg. packaging materials, cleaning agents, stationery etc.).

Often overlooked aspect that has a strong impact on market introduction of biobased technologies and products, relates to the **regulatory issues, such as certification, product standards and product authorisation procedures**. SWOT analysis current situation characterizes the current situation in Slovenia as unfavourable. Lengthy and bureaucratically cumbersome authorisation procedures with uncertain outcomes are seen as a weakness (W-IPF5) that needs a serious overhaul.

The policy of **project incentives**, which currently represents the backbone of public policies supporting bioeconomy development in Slovenia, needs to be integrated and **coordinated with regulatory frameworks** (climate fund, waste, energy strategy), tax policy, public procurement, in order to ensure appropriate synergies that are necessary for the long-term development of the chain and the survival of links beyond individual public funding sources.

Public policies can also provide effective indirect support for market mobilisation of biomass side-streams by establishing a monitoring system. Most likely this would require legal tightening in the direction of mandatory reporting. Although this is an unpopular measure, the long-term gains in terms of the availability of market information and consequently, commoditising and the establishment of market exchange with biomass side-streams and by-products would overcome the costs and initial dissatisfaction.

5.2.6 Competitive bioeconomy products

For a serious qualitative leap towards (resilient, circular, sustainable) bioeconomy, all actors operating in the bioeconomy sectors or directing the development of bioeconomy in Slovenia, need to significantly strengthen their effort. This involves reaching a **wide public consensus on the strategic importance and institutional consolidation** of the bioeconomy.

Establishment of the National Bioeconomy Hub could be seen as a step in this direction. The hub would serve as a platform for mutual exchange of information, the dissemination and exchange of expertise, and the creation of business opportunities through cooperation. Industry associations and/or the chamber of commerce should be encouraged to draw up their own vision document on the bioeconomy. It makes sense to institutionalise a public-private partnership in the form of a bioeconomy hub or centre, linking knowledge institutions with industry, and to involve knowledge institutions and industry. Institutionally, it would be expedient to assign the role of a hub to an already operating platform with similar tasks. With the implementation of the Smart Specialization Strategy, the coordinating role is attributed to Strategic development innovation partnerships (SRIPs). SRIP Networks for the transition to a circular economy, with the Focus Area Biomass and alternative raw materials seems as the most appropriate candidate for this task.

Another action to overcome the identified untapped potential for business integration (W-CBP1) is to **identify national industrial leaders in bioeconomy** and motivate them to act as integrators of regional bioeconomy value chains. Actions leading towards the support of their investment decisions (eg. financial and equity input in the form of public-private partnerships) should be undertaken to motivate such actions.

6 INDICATIVE CASE STUDIES / NICHES FOR THE VALORISATION OF RESIDUAL BIOMASS

In contrast with the previous strategic chapter, this chapter of the concept paper is taking a more practical approach. Deriving from the analysis of the current state of the bioeconomy in Slovenia (section 2), we outline four indicative sectors, or niches, that could serve as the starting basis for development of a more sustainable, integrated, and better performing bioeconomy in Slovenia. Two criteria (biomass source, scale/availability) and two attributes were applied in the choice of market niches:

1) Agriculture, mainstream, low value-added: Transforming animal waste and agricultural residuals into energy and nutrients
2) Agriculture, niche, high value added: Encapsulation of plant extractives
3) Forestry, mainstream, low value added: Network of small-scale modular lignocellulosic biorefineries
4) Forestry, niche, high value added: Nanocellulose applications

The selection of raw materials and the development of the technological concept for the circular use **of crop residues and by-products** are based on two principles. Firstly, that the proposed solutions and business models provide for a pattern and scale of use that **does not jeopardise the soil organic matter balance**. Secondly, that the design of the business models takes account of the structural characteristics of primary production, where the limitations of quantities and technological characteristics (in particular heterogeneity) make it necessary to look for **modular solutions** to organise logistics flows and to target the bio-based product proposals in **niche categories**.

Before we turn to the market niches however, the chapter provides a systematic outline of the biorefinery concept, as the bridging technology between the biomass (side-)streams generated in primary bioeconomy production, manufacturing, or consumption, and its further application in various (novel) sectors of bioeconomy.

6.1 BIOREFINERY CONCEPT: HOW FEEDSTOCKS ARE CONVERTED TO PRODUCTS VIA PLATFORMS AND CONVERSION PROCESSES

6.1.1 BIOREFINERIES – BASIC PRINCIPLES AND CLASSIFICATION

One of the technical and organizational innovations in the transition to a bioeconomy is the emergence of biorefineries, which 'sustainably process biomass into a spectrum of marketable bio-based products, such as food/feed ingredients, chemicals, materials, and bioenergy (power, heat, fuels)' (the IEA Bioenergy Task 42). To facilitate understanding of complex arrangements of technological processes for converting different types of biomasses to generate bioenergy and a variety of marketable bio-based products, the '**Biorefinery Classification System'** was developed by the IEA Bioenergy Task 42 and updated by the EU Biorefinery Outlook to 2030. This classification system consists of four categories:

1) **Feedstocks**
   a. Primary biomass (aquatic biomass, lignocellulosic biomass from wood/forestry, lignocellulosic biomass from croplands and grasslands, oil, starch, sugar crops, and other[11])
   b. Secondary biomass (microbial biomass, residues from agriculture, aquatic biomass, forestry and forest-based industry, nature and landscape management, recycled bio-based products, and other)

[11] Term 'Other' is used to include new concepts, technologies, and products (subgroups are proposed to enable NACE classification).

2) **Conversion processes**
    a. Biochemical (aerobic conversion, anaerobic digestion, enzymatic process, fermentation, insect-based bioconversion, and other)
    b. Chemical (catalytic, esterification, hydrogenation, hydrolysis, methanation, chemical pulping, steam reforming, water electrolysis, water gas shift, and other)
    c. Mechanical and thermomechanical (blending, extraction, mechanical and thermomechanical disruption and fractionation, mechanical pulping, separation processes, and other)
    d. Thermochemical (combustion, gasification, hydrothermal liquefaction, pyrolysis, supercritical conversion, torrefaction and carbonization, and other)
3) **Platforms** (biochar, bio-coal, bio-crude, biogas, bio-oils, bio-hydrogen, bio-naphta, C5/C6 sugars, CO_2, lignin, oils, organic fibres, organic juice, protein, pyrolytic liquid, starch, syngas, and other)
4) **Products**
    a. Chemicals (additives, agrochemicals, building blocks, catalysts and enzymes, colorants, cosmeceuticals. flavours and fragrances, lubricants, nutraceuticals, paints and coatings. pharmaceuticals, solvents, surfactants, and other)
    b. Materials (composites, fibres (textile, paper and board, carbon/speciality), organic fertilizers, polymers, resins, and other)
    c. Food
    d. Animal feed
    e. Energy (cooling agents, fuels, heat, power, and other)

To distinguish between different types of biorefineries and provide more specific information to different stakeholders, eleven '**Biorefinery Conversion Pathways'** were established by the EU Biorefinery Outlook project and describe how the feedstocks are converted to products via platforms (intermediates) and conversion processes. These conversion pathways (described in greater detail in Annex 8.2) are listed as follows:

A. One platform (C6 sugars) biorefinery using sugar crops
B. One platform (starch) biorefinery using starch crops
C. One platform (oil) biorefinery using oil crops, wastes and residues
D. Two-platform (pulp and spent liquor) biorefinery using wood
E. Three-platform (C5 sugars, C6 sugars and lignin) biorefinery using lignocellulosic biomass
F. Two-platform (organic fibres and organic juice) biorefinery using green biomass
G. Two-platform (oil and biogas) biorefinery using aquatic biomass
H. Two-platform (organic fibres and oil) biorefinery using natural fibres
I. One platform (syngas) biorefinery using lignocellulosic biomass and municipal solid waste
J. Two platform (pyrolytic liquid and biochar) biorefinery using lignocellulosic biomass
K. One platform (bio-crude) biorefinery using lignocellulosic biomass, aquatic biomass and organic residues

Based on the scale of operations, biorefineries are divided into three categories (EU Biorefinery Outlook project):

1) **Small-scale biorefineries:**
    a. suitable for wet biomass (such as grass), agricultural and food processing residues and aquatic biomass
    b. production facilities located in rural areas using local biomass
    c. using modular mobile units
2) **Large-scale biorefineries:**
    a. capital-intensive processing such as thermo-chemical conversion (e.g., gasification)
    b. for production of large volumes (biofuels, bulk chemicals)
    c. potential integration in existing (petro)chemical complexes at harbour areas

3) **Integrated decentralized small-scale processing with centralized large-scale upgrading:**
   a. small-scale primary refining (biomass pretreatment and conditioning) to increase biomass density (in case of pyrolysis or torrefaction) and potentially the quality (deashing, demineralization)
   b. separate nutrients close to source and recycle closing the loop
   c. efficient transport
   d. efficient secondary refining.

6.1.2 Deployment status of biorefineries in Slovenia

Currently, there are no biorefineries in Slovenia that would provide the most technologically, economically and environmentally perspective model of biomass utilization. There are some processing units dedicated to the energy use of biomass (Task 42 Biorefinery Atlas Portal: http://webgis.brindisi.enea.it/bioenergy/maps.php), which are unpromising in terms of adding value to the biomass-derived feedstock.

The strong existing chemical industry (at least 25% of the top 20 companies in terms of revenues or number of employees) and the great industrial interest in fostering innovation, together with the growth of the market for bio-based products in Slovenia, promote the idea of developing biorefineries based on cascade and sustainable conversion of biomass into high-value bio-based materials. However, the question arises as to how large a biomass biorefinery is optimal for placement in Slovenian territory in the long term. Considering the dispersion of resources, the associated high costs and price-cost risks, the concept of a network of modular and spatially dispersed biorefineries makes more sense, however a larger integrated biorefinery would enable exploiting industrial symbiosis concepts and provide efficiency gains, as well as specialized manufacturing of diverse materials and products at a regional scale.

6.2 Forest-wood bioeconomy: Network of small-scale modular lignocelulosic biorefineries (possible Pathways D,E,I,J,K)

Among the promising sources of lignocellulosic biomass in Slovenia, wood of poorer quality is definitely the leading one, while residues from wood processing and papermaking are also a promising source of raw material. Other sources of lignocellulosic biomass include harvest residues, wood residues from permanent crops and horticulture, and potentially also mowing of extensive grasslands and municipal cuttings.

The key challenges are efficient logistics (and the associated cost of biomass collection) and substrate heterogeneity (composition and quality). This, together with the relatively small volume, which does not ensure the achievement of economies of scale, represents a significant obstacle to the organization of an economically sustainable biorefinery plant. An important part of the solutions should therefore be sought on the revenue side, i.e. the production of bio-based products with a sufficiently high added value to justify the cost of the investment in biorefining processes. A public-private partnership to establish biorefinery capacity is an alternative worth considering in our context, where there are no major industrial processing plants interested in such independent investments. This is of course assuming that such ventures involve economic operators that are technologically capable and commercially interested in taking on the role of catalysts for integration into bio-based value chains.

Slovenia's main advantages in the possible establishment of pilot biorefineries of this type are the vast biomass resources (forest biomass, wood and agricultural biomass waste), the open possibilities for improvements in lignocellulosic biomass processing and, last but not least, the willingness of existing industrial partners to cooperate. When planning the transition towards sustainable production of bio-based products in the context of biorefineries, it is important to be aware of the risk of potential low competitiveness of biorefinery products, or of the added value of the resulting products and services. At the same time, weaknesses such as the missing midvalue chain of biomaterials or bio-chemicals on the Slovenian market and the very highly developed CAPEX technologies should be highlighted. On the other hand, the implementation of a pilot biorefinery for the material recovery of biomass is a tremendous opportunity for companies with a strong interest in bio-based products, such as the production of state-of-the-art chemicals and materials. In national economic terms, the installation of biorefinery capacity is also essential if our manufacturing activities, which are the engine of our small, open and export-oriented economy, are to keep pace with demand trends in more technologically sophisticated downstream markets.

The most widespread interest is expressed in advanced biorefining products, i. e. mainly cellulose, hemicellulose and lignin, which should use processes that ensure the best technological carbon management, i. e. organosolv instead of traditional paper kraft fractionation process. Considering the ratio between energy consumption, integrated feedstock utilisation, the possible applications of a wide range of lignocellulosic specialties and the simultaneous high quality of the digested main components of the lignocellulosic biomass, the organosolv process seems to be a very suitable digestion method. In particular, the quality of the individual fraction obtained is crucial, as it allows the subsequent conversion of cellulose into bioethanol or levulinic and glucaric acids, of hemicellulose into furfural and xylitol, and of lignin into vanillin and eugenol, i. e. high value-added products. In addition, the process itself is economically viable and ecologically acceptable due to the availability and easy recycling of solvents for reuse in the process and the mild reaction conditions, which also contribute to the safety of the process itself.

Many domestic manufacturing companies in the chemicals sector, the export pillar of our economy, are seeing growing demand for renewable materials, both due to increased pressure from customers and supply chain problems. In the absence of domestic biorefineries, raw materials are mainly sourced from abroad, which is again problematic due to the poor carbon footprint, reliability, as well as rising prices, which again raises the need for more large-scale biorefining at home. In addition to bio-based polymers, there is a significant demand for bio-based compounds, especially in coatings and adhesives.

6.3 AGRICULTURE—BASED BIOECONOMY: TRANSFORMING ANIMAL WASTE AND AGRICULTURAL RESIDUALS INTO ENERGY AND NUTRIENTS (POSSIBLE PATHWAYS G, I, J, K)

Livestock waste, totaling (2017 data) 621,300 tonnes of dry matter in various forms (slurry, poultry manure, and livestock manure), represents the most important quantitative raw material flow in Slovenian agriculture. Livestock waste is important in agriculture because it is used as organic fertiliser; it is important for the growth and development of plants or crops, and it improves soil quality. In the current context (exponential growth and uncertain supply of mineral fertilisers), the importance of livestock manure as a source of nutrients for crop production is even more important. The environmental challenges of GHG emissions and groundwater contamination are also linked to the current use of livestock manure, in particular when stored or applied inappropriately. In our research, we will assess the technological options and feasibility of several ways to improve current practices. Among them, we highlight (i) energy use (biogas) and application of digestate as plant fertiliser; (ii) use of livestock excreta as substrate for cultivation of algal biomass for further use in agricultural production (bio-protectants, growth promoters); (iii) N2 treatment of slurry (N fixation from the air and application to the slurry - stabilisation of methane and ammonia, and addition of N in reactive, fertilization form into slurry), which improves the nutritional value of livestock manure and drastically reduces environmental burdens.

Improvement of slurry or biogas digestate with low-energy plasma technology (LEPT): Improved utilisation of organic waste for fertiliser has significant economic and ecological potential, which the use of plasma can help unlock. Organic wastes that can be used as fertiliser include animal excreta (manure and urine) and/or biogas digestate, potentially also human sewage, food waste. Air-plasma treatment of aqueous organic fertiliser solutions (plasma-activated organic fertiliser) is a promising new technology that splits airborne nitrogen using low-energy plasma electricity to form nitrogen oxides (e.g. NO_2^-, NO_3^-) in solution, which combine with ammonium in liquid livestock fertilisers to form ammonium nitrate. In this way, the slurry is enriched with nitrogen from the air, the pH of the slurry is reduced to neutral, thus virtually eliminating the gaseous losses of ammonia (NH_3) and also reducing or eliminating the atmospheric emissions of volatile organic carbon (VOC) compounds (odour-causing agents) and methane (CH_4). We envisage that the LEPT process would improve the commercial value of organic fertilisers and reduce their environmental footprint. The commercial viability of LEPT depends on a number of factors, the most important of which are the energy efficiency and capital costs associated with the plasma process and associated processing equipment, the cost of electricity, and the nature and extent of regulations relating to pollution from organic waste and all types of fertilisers.

Example of (potential) application: Installation of LEPT would be a technologically feasible strategy for (in context of Slovenian agriculture) large farms in Slovenia engaging in livestock production. This technology can be applied within farm operations of approximate size 100 to 200 Livestock Units and their own source of renevable electricity (e.g. PV). In such a case filtering the slurry (solid and liquid separation) is required to meet the specifications of the plasma LEPT unit. The slurry buffer tank should cover a processing period of a couple of days or longer if possible. This makes the size needed around 10 to 45 m3. Running at full capacity one 50 kilowatts unit can cater between 2,000 and 4,000 m3 of a standard slurry per year (= capacity for ca. 100 – 200 adult cows). It is also possible to run multiple units in parallel. During production, the LEPT process creates excess heat, which can be utilised for improving total energy balance of the farm. This heat can be captured as hot water with a temperature up to 60 °C.

Incorporation of suitably processed lignocellulosic residues (e.g. biochar) into the material stream of livestock fertilisers to prevent/reduce nutrient losses from livestock fertilisers and development of a prototype biostimulant fertiliser for regenerative agriculture. Properly biologically activated biochar has been shown to stimulate plant growth, especially when bound in organic-mineral complexes with micro-organisms and nutrients. Many agricultural holdings manage significant areas of forest. Lower-quality wood (damaged wood, branches) is currently the least exploited resource and is best used for thermal energy production. The idea is to use this wood (and other lignocellulosic agricultural residues such as hulls) as a source for biochar production by means of technological adaptations. Many scientific studies show the positive effect of properly prepared biochar on carbon sequestration (removal of CO_2 from the atmosphere) and on improving soil quality. In this thesis, we will therefore make a proposal for the introduction/adoption of national quality standards for biochar that should be used in agriculture. We will investigate possible scenarios of mass balances of carbon sequestration in soil through pyrolysis of wood (lignocellulosic) residues to biochar for Slovenia. We will examine the technological, environmental, and economic parameters for the siting of agricultural pyrolysis plants, which would provide farms with an additional source of income and a renewable source of heat, while permanently sequestering/sequestering CO_2 through biochar production. Prototyping of soil improvers based on biochar and livestock manures will be explored. Farmers could combine biochar production with organic fertiliser production (slurry conditioning) on farm or in a group of farms. The use of a bio-stimulating organic-mineral fertiliser based on biochar can improve soil conditions for sustainable, conservation agriculture: (1) binding and increasing soil organic carbon content, (2) binding nutrients and micro-organisms to the active surface of the biochar for better nutrient and water use, (3) creating biologically active, probiotic soils with a high organic matter content.

Example of (potential) application: Installation of agricultural pyrolysis devices appears a feasible upgrading strategy for farms with modern biomass (eg. wood chips) heating devices as it would provide them saving on the purchase of fertilizers, potential additional source of income and a renewable source of heat, while at the same time permanently binding/sequestering CO2. Small agricultural pyrolysis device has a capacity consumption of wood dry mass 20 to 120 kg/h and production of 5 to 26 kg biochar/h and 20-160 kW heat output.

Production of biostimulants based on microalgae grown on suitably conditioned liquid livestock manure or biogas digestates. The production of microalgae represents a potential for a new, innovative agricultural production of high protein foods (for either human or animal nutrition) of plant origin based on algae, using suitably formulated livestock manure as the growing substrate. Besides, algae exhibit biostimulative effects on plants. Biostimulants from various strains of (micro)algae contain a wide range of bioactive compounds which are usually able to improve the nutrient use efficiency of the plant and enhance tolerance to biotic and abiotic stresses. In vegetables, the application of biostimulants allowed a reduction in fertilizers without affecting yield and quality. In leafy vegetables susceptible to nitrate accumulation, such as rocket, biostimulants have been able to improve the quality. In leafy vegetables, biostimulants increase leaf pigments (chlorophyll and carotenoids) and plant growth by stimulating root growth and enhancing the antioxidant potential of plants.

Example of (potential) application: Adapted organic seaweed cultivation system could act as a complementary activity for typical Slovenian livestock farms. Small-scale production units would supply small-scale processing plants that transform seaweed into various applications (organic fertilisers, biostimulants or biopesticides).

6.4 High value-added application 1: encapsulation of plant-based extractives (Pathway F)

6.4.1 Key opportunities and challenges

In Slovenia, the potential for value added products arising from residual biomass flows of agricultural production and food supply chain remains untapped. Due to a high diversity of agrifood activities, particularly in plant food production, the many residues in offer a diverse bioeconomic potential, even when taking in account the "food -first" principle, as well as the priority principles in food supply biomass and waste alleviation, where surplus food should be prevented or intended for human consumption, and where non- or ex-foods should be first used for animal feed, and there for other processes in the bioeconomy.

Furthermore, in the food industry, where production systems are notoriously linear, the opportunities of transition to circular bioeconomic routes lie in (i) the need for better by-product utilisation, (ii) valorisation of non-edible parts of food and (iii) using alternative and renewable energy sources.

Residues in the food processing industry are, in material terms, biomass with an extremely diverse composition, produced in the production and processing of meat, milk, fruit, vegetables, bakery and confectionery products, as well as alcoholic and non-alcoholic beverages. A feature common to most such residues is their high water content and consequently short shelf life, so that for their effective continued use they must either be used quickly or various measures to prolong stability must be implemented. At the same time, some side streams provide a very good source of antioxidants with antibacterial and antifungal activity, and could be used to stabilize others. Furthermore, inedible fraction separated from edible food parts in processing, such as fractions of outer layers of fruit and vegetables e.g., husks, peels and shells can contain high contents of bioactive compounds as these protect the plant parts from various external damaging factors. Such biomass is typically discarded in processing; however, we can use it in our advantage in e.g., prolonging shelf life or other types of food and/or technical additives.

These diverse agro-industrial residues should there be firstly fully exploited in their original form or using their original containing compounds, as the end processes in biomass valorisation following biorefining, biodegradation or energy production can destroy many of these intrinsically available valuable components.

Likewise, many of these agro-industrial streams are rich in fibers and are suitable for raw feedstocks for biobased material production. Following the principles of cascading use after the recovery of containing bioactive substances or special biopolymers / polymer building blocks the remaining residues are therefore highly useful for subsequent fibre utilisation.

Due to the sensitive nature of the bioactives, the recovered bioactive compounds (e.g. polyphenols and vitamins) often require encapsulation techniques for compound protection and/or incorporation into food matrices. These can also be provided from natural polymers arising from the same or other residues of food production.

The discovery process should be focused on components:
- with a high biological activity,
- enabling simple/feasible isolation,
- with a high concentration within the waste stream.

In the field of bioactive compound discovery, recovery and protection, mostly the information gap is the bottleneck for systematic market-wide exploitation of agroindustrial streams. Improved knowledge on the availability of homogeneous, quality and stable individual agro-industrial streams is required and their respective properties and composition, to further identify the classes of bioactives that are most promising for recovery as well as for the substitution of their existing synthetic counterparts. Furthermore, development of a legislation that enables implementation of novel products on the market (e.g. encapsulation carriers and packaging materials) as well as safe but practical end-of-waste criteria are also required.

6.4.2 Technological and organizational assumptions

When considering actual available amounts it is important to understand that in the Slovenian agrifood activities, generate roughly 90.000 tonnes of biodegradable waste (a third of these come from the food processing) and 140.000 tonnes of food waste (40% edible fraction) per year (SISTAT, 2022). Furthermore, even though the exact amounts of the by-products produced in the food industry are unknown, it is clear that these amounts are considerable, surpassing waste amounts, and thus representing important and prospective inputs for bioeconomy.

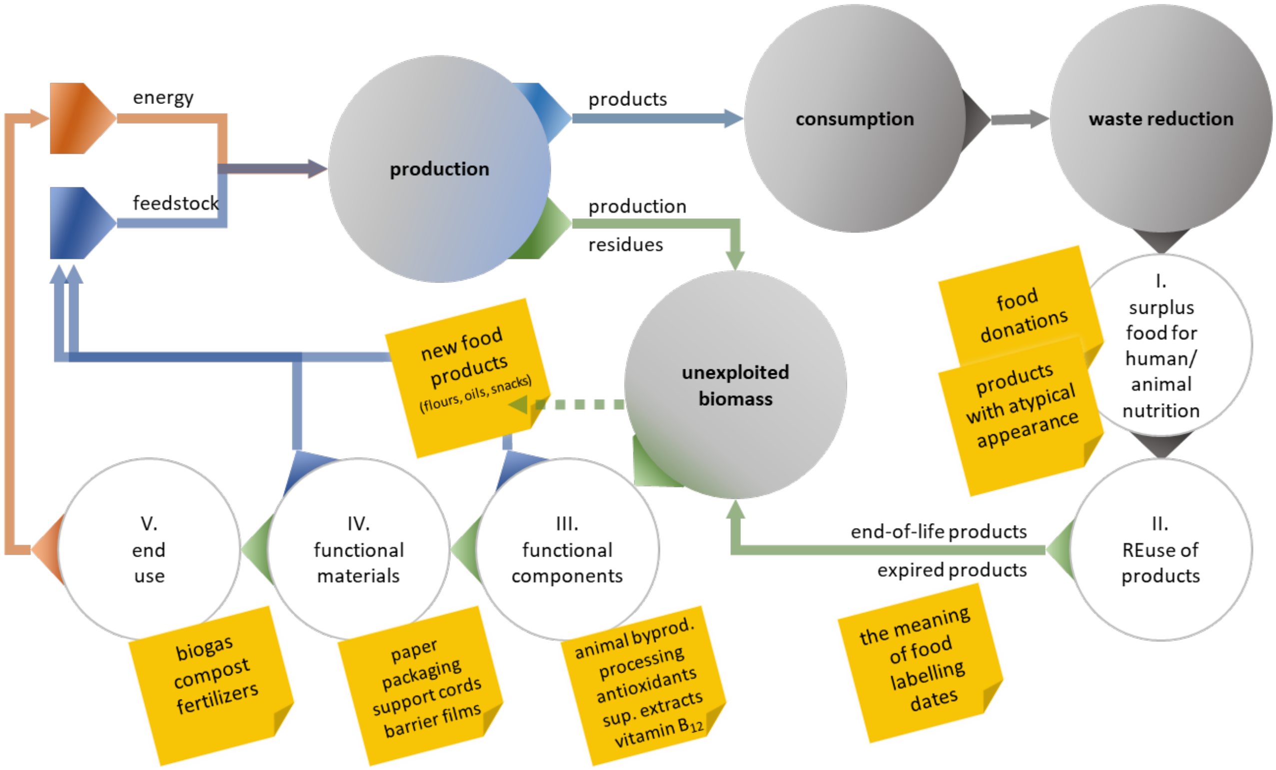

Figure 29: Priority order of waste prevention (I. to II.) and cascading use approaches (III. to V.) in the food supply chain / food industry including existing bioeconomy models in Slovenia (shown on yellow squares).

Cascading use based on initial small molecules recovery and subsequent fibrous use offers thorough utilization options for many agro-industrial by-products and residues. Following the waste hierarchy principles within the food supply chain (Figure 29), current state-of-the art approaches include recovery of bioactives as food, animal feed or technical additive ingredients in the first stage and in the second phase of cascading use, subsequent use of remaining fibers for functional materials (paper or other types of packaging or packaging additives). For these, cascading technological processes include applications described in the sections below.

6.4.3 Discovery (chemical profiling) and recovery (green extraction procedures) of bioactives

Agro-industrial waste of plant origin is typically particularly rich in bioactive compounds and lignocellulose content. The bioactive contents of agro-industrial residues, and especially the phenolic compounds in fruit and vegetable waste, are gaining attention in the food industry. As it has been extensively demonstrated for Slovenian plant production and processing residues (e.g. Terpinc et al., 2012; Abram et al., 2015; Cifà et al., 2018; Osojnik Črnivec et al., 2021), these parts can be used as a natural, cheap and easily accessible source of antioxidants for food fortification.

Further unexploited potential in bioactives and/or extract utilization are the production of technical additives (e.g. paper binders, barrier films and antimicrobial additives for packaging) or further chemical/ biotechnological transformation of extracted compounds to even higher added products.

6.4.4 Protection (encapsulation) of bioactives

Food and other products integration of bioactives must be integrated protection procedures in food ingredient development and food product prototyping. These range from conceptualisation to product validation including process, stability and shelf life. includes Protection of bioactive compounds as well as their targeted application in new/innovative or reformulated food products is required in order to improve (i) the compatibility of the extracts and contained compounds with food matrices (especially for insoluble compounds), (ii) the stability of the extracts during processing, storage or ingestion, and (iii) to improve the nutritional function (e.g. delivery or absorption) of the compounds. In this context, high level RR capacity exists at the University of Ljubljana and many pilot testing facilities exist in the field either in academia or through development companies, including for ice-cream production, confectionaries, bakery products, non-alcoholic beverages, dairy and meat products.

6.4.5 Use of the remaining fibrous fraction in the production of packaging

Long term growth of the packaging industry is driven by the development of high-performance renewable materials. Recent consumer market trends in Europe have shifted toward sustainable packaging solutions (i.e. packaging made from recyclables, re-usable packaging, reducing material use through lightweighting, and bio-based polymers) (Parker, 2008). Environmental policies encourage the creation of natural fiber-based products as well as the reuse of as much material as possible (Kozlowski & Mackiewitz Talarczyk, 2020). Developing packaging materials from renewable and bio-based sources has become critical, not only to address and prudently valorize waste disposal issues, but also to reduce stubble burning and save timber resources. Valorization and conversion of renewable agro-waste to biodegradable composites has proven to be a significant breakthrough in the packaging area (Bhardwaj et al., 2020). There has been an certain extent to which the packaging materials, in particularly paper production for e.g. packaging of fruit and vegetables has been already demonstrated in Slovenia, however additional uses, e.g. using fibrous fractions for production of fillers, absorbents, etc., including transformation of natural fibers into alternative polymers (PLA, TPS etc.) is however still required at the market level.

6.4.6 Prospective final uses and their advantages

Many agricultural wastes, together with their bioactive compounds, can be used in food and feed products, as well as active and intelligent food packaging. Both classes of applications have developed strongly in the last decade as they have sought to meet the need for long-lasting processed food in addition to antioxidant/antimicrobial ingredients in packaging materials. These components are designed to release the desired substances into the food in a controlled manner. These growing trends have been reflected in the field of food packaging by the use of extracted and plant-derived chemicals in active packaging formulations.

The potential of residues from the production or primary processing of agricultural biomass for the extraction of bioactive compounds can be illustrated by the examples of onion peels (rich in the phenolic compound quercetin) and hops (rich in the phenolic compound xanthohumol). According to data from 2016, Slovenia produced a total of about 100,000 tonnes of dry waste biomass from vegetable and fruit production. Hops, vegetable residues and root crops account for another 100,000 tonnes of dry biomass waste, and green cuttings from vines and fruit plants account for another 30,000 tonnes of dry biomass waste per year. Furthermore, looking at similar agro-industrial biomass streams, the production of fruit and vegetable juices generates high amounts of residues (ranging from ~50% for citrus fruits, ~30% for apples and carrots and ~20% for beetroots), while a large Slovenian apple juice factory can generate ~ 300 tonnes of apple pomace/year. Similarly, in beer brewing spent grain is produced that represents ~20% of the weight of the final product, and a typical large Slovenian brewery can generate around 30-40.000 tonnes of spent grain and around 5.000 tonnes of excess yeast per year.

Taking into account the content of antioxidant phenolic compounds in agro-industrial waste, and the availability and quality of the available residual biomass, we estimate that between 5% to 10% of the dry agro-industrial residues in Slovenia have the potential for this kind of circular bioeconomy use in the form of bioactive phenolic compounds recovery, followed by fibrous materials production.

Different types of **lignocellulosic biomass** contain different levels of each structural component. Cellulose is usually predominant, with a content of 25 to 55 %, hemicellulose 25 to 50 % and lignin 15 to 40 % by dry weight. The composition and chemical properties of each type of biomass dictate its potential usefulness, it being noted that all three components are technologically useful. Furthermore, some horticultural residues can contain high amounts of cellulose and hemicellulose, and at the same time less than 5% of lignin (Osojnik Črnivec et al., 2021), therefore providing a feedstock that does not require delignification, as this is frequently required in further processing of fibres (e.g., in papermaking).

The development of packaging materials produced from renewable and bio-based sources has become critical not only for solving and analysing waste disposal problems, but also for reducing stubble burning and saving wood resources. In the packaging sector, the valorisation and conversion of renewable agricultural waste into biodegradable composites is gaining ground.

The prospective stakeholders for these applications are on one side producers of biomass residues (primary producers, food processors), that have the RRI capacity to reformulate their own products and develop novel products and also have the need/ know-how to produce their own packaging/ sell the fraction to other companies. Furthermore, the highest potential should target manufacturers of functional ingredients, such as natural extracts/ naturally sourced aromas, flavours and additives. These are the producers that are focusing on functional ingredients obtained by green extraction procedures and sustainable food production are seeking on-demand new food products design incorporating nutrient protection and natural principles for shelf-life prolongation and can couple bioactives and fibrous streams within a common business model.

In this sector, looking at the PRODCOM data for 20.53.10.75 (essential oils) NACE code, high product values arise in the range 20-45 €/unit, and high consumption of 40-70 mil units/year is reported just for the market in Belgium, Germany, Netherlands and Denmark. The integration of protection (encapsulation) of bioactives has the potential to grow this market significantly, as it enables integration of compounds to a wider scale of end products, including, food, feed, cosmetics, papermaking, packaging and other sectors.

Example of (potential) application: Onion peels are a promising biomass source for valorization due to its quantity (one of the major horticulture products) and due to its chemical/technological properties. Various applications for onion skin in food processing/ nutrition were demonstrated. The extract of yellow onion skin can be used as a stabilisation additive (eg. prolonging the shelf-life of olive oil). Onion skin also contains a high proportion of cellulose, making it particulary interesting for paper production. The resulting paper exhibited good mechanical properties and also provided characteristics that can improve the appearance and feel, which are particulary valuable in the product range of special papers (Osojnik Črnivec et. al., 2021).

6.5 High value-added application 2: Nanocellulose applications, Wood and bark extractives (Possible pathways D, E)

Wood and other lignocellulosic biomass are typically composed of three main building blocs which are cellulose, lignin and hemicelluloses. Cellulose is considered as one of the most aboundat natural polymers in the biosphere and it is assumed that approximately 1011 – 1012 tons of cellulose is sinthetisezed annually. Cellulose is main component of every plant cell. Wood contains 40-50% of cellulose, bark slightly less (aprox. 30 %), whereas cotton hairs contain up to 95% of cellulose. Wood remains most important feedstock for cellulose pulp production, which is traditionally processed in paper and board, chemical and textile industry to mention only some of them, where mostly derivatives of cellulose are used. In last two decads, cellulose based value chains has expanded thanks to development of biorefining technologies and procceses, as reported above. One of the advanced products is nanocellulose.

Nanocellulose is the term describing two types of cellulose nanoobjects, which are cellulose nanofibrils and cellulose nanocrystals. Both objects have dimeter form 5-60 nm, length of cellulose nanofibrils is tipicaly < 1 µm, whereas cellulose nanocrystals are 100-250-600 nm long. Crystalinity of cellulose nanofibrills is 50-70%, and even higher in cellulose nanocrystals. Nanocellulose has exceptionally good properties; its is renewable, sustainable and envionmentaly friendly material, biodegradable, has high modulus of elasticity and high axial tensile strength, low density, good thermal stability and favourable relation between diameter and length. It is hydrophilic and is usually supplied as water suspension where dry matter represents up to 2%. It is rich with -OH groups and therefore prone for chemical modification, which is opening the application in the matrices with hydrophobic charater.

Nanocellulose is prime candidate for improving properties of existing polymers and for development of completelly new bio-nanocomposites. Nanocellulose materials/composites are class of inovative biomaterials with versatile industrial potential for replacing fossil derived materials. Compound annual growth rate for nanocellulose global market is assessed to 19,9 %. Increasing concern regarding global climatic change, plastic waste, strengthening of bio-based oriented consumer awareness is fostering the application of nanocellulose in paper and packaging, food products, filter materials, cosmetics, composites, textiles and others.

Nanocellulose is usually produced form chemical pulp, mostly Kraft pulp, which has been frequentlly considered as bottleneck for prodocution od nanocellulose in domestic bio-based sector. Research and devolepment in the past ten years has demonstrated that Slovenia posses capacity for production of different types of nanocellulose. Cellulose nanofibrilis are produced at laborotory and pilot scale at University of Ljubljana, Biotechnical faculty, at Pulp and Paper Institute, whereas celulose naocrystals production runs at industrial scale at company Navitas. Production of nanocellulose fibrills and crystals are somewhat diferent, as are the properties and application potentials of these two nanocellulose objects. In brief, production of cellulose nanofibrils demands purification of the feedstock, bleaching, mechanical pretreatment, biological or chemical pretreatment, defibrilation processes and postrteatment. Acid hydrolisis is usually, but not exclusivelly, applied as main processing step in case of cellulose nacrystal production.

Application of nanocellulose remains at low TRL in Slovenia, however, numerous prototypes of nanocelulose based materials were successfully deveoped. For instance, surface barrier, mechanical and printing properties of paper were improved, new bio-based composites were produced based on PLA and PHB polymer matrices, hydrogels with tunable propertes for medical applications as well as aerogels were produced.

Commercialisation example: Production of Nanocrystacell Aqueous suspension by the company Navitas d.o.o. is a case of industrial production of cellulose nanocrystals in Slovenia. The product is supplied as water suspension, particles are 10-15 nm in diameter and up to 300 nm long, their crystallinity is 90.3 %. The applications of this type of nanocellulose are foreseen in glues, paper, cement, plastic materials and composites, paints and coatings, electronics, personal and health care. Production of cellulose nanofibrils is currently restricted by the absence of chemical cellulose pulping in Slovenia, although production technology is ready for upscaling. Implementation of organosolv process even in small scale biorefinery will unlock this production direction.

Woody biomass contains low molecular compounds. In addition to structural polymers, cellulose, hemicelluloses and lignin, tree`s biomass contains low molecular compounds which are usually named extractives. Content and phytochemical profile of extractives differs by tree species and individual parts of the tree, but factors like growth site, time of the season, geographical origin and general tree condition additionally influence content of extractives. Variability in content of extractives in different parts of the tree is illustrated by the data for Pinus sylvestris; sapwood contains 3,1 %. heartwood 5 %, knots 25 % bark 26 % and needles 40 % of extractives. Trees biomass contains lipophilic extractives, which are soluble in nonpolar solvents, and are represented by terpenes (resin acids, fatty acids ad fats, fatty alcohols) and compounds soluble in polar solvents, which represents fraction of hydrophilic extractives. Some examples of these are sugars, phenolic compounds, alkaloids. Trees are considered as one of the richest sources of phenolic compounds. Bark usually contains tannins and flavonoids, knots are rich in stilbenes and lignans, whereas heartwood of some species may contain large amounts of tannins.

Recovery of extractives is usually extraction in different facilities, where water or organic solvents were used under increased temperature or pressure or both. Extractives of wood and bark are bioactive compounds and are interesting as food and feed additives, and even as bio based protecting agents, fungicides, insecticides biocides, glues and adhesives, tanning agents, emulsifiers, thickeners etc.

Commercialisation example: Tanin Sevnica d.o.o. is one of the largest producers of tannin from oak and chestnut biomass in Europe. The firm initially produced tannin mainly for textile and leather industry, whereas nowadays they are oriented globally toward solutions for modern animal breeding, oenology and green chemicals. Another successes story is company Ars pharmae d.o.o., which is producing silver fir bark extractives, patented as Abigenol, for food applications. Extractive-based value chain could receive additional boost with implementation of modular extraction biorefineries in rural areas in Slovenia.

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8 ANNEXES

8.1 Research, Development and Innovation projects in the field of bio-based products and biorefining in Slovenia

Financing Partner in Slovenia	Acronym – Title	Duration
H2020 & BBI JU RIA **InnoRenew CoE**	OLEAF4VALUE – Olive leaf multi-product cascade based biorefinery: from an under-used biomass in the primary sector to tailormade solutions for high added value international market applications	2021-07-01 - 2024-06-30
H2020 & BBI JU RIA **National Institute of Chemistry**	BioSPRINT – Improve biorefinery operations through process intensification and new end products	2020-06-01 - 2024-05-31
H2020 RIA **Skupina Fabrika**	Heat-To-Fuel – Biorefinery combining HTL and FT to convert wet and solid organic, industrial wastes into 2nd generation biofuels with highest efficiency	2017-09-01 - 2021-08-31
H2020 and BBI JU IA Demo **GIZ Grozd Plasttehnika**	AgriMax – Agri and food waste valorisation co-ops based on flexible multi-feedstocks biorefinery processing technologies for new high added value applications	2016-10-01 - 2020-09-30
HEU RIA **National Institute of Chemistry**	ESTELLA – DESign of bio-based Thermoset polymer with rEcycLing capabiLity by dynAmic bonds for bio-composite manufacturing	2022-06-01 – 2025-11-30
HEU AG **National institute of Chemistry**	CARBIOW – Carbon Negative Biofuels from Organic Waste	2022-10-01 – 2026-03-31

HEU RIA **Educell**	Triple-A-COAT - Sustainable Development of a Safe and Bio-based Antimicrobial, Antifungal and Antiviral Nanocoating Platform	2022-09-01 – 2026-08-31	
HEU RIA **InnoRenew CoE**	NewWave – Building a sustainable & circular economy through innovative, bio-based manufacturing lines	2022-04-01 – 2026-03-31	
H2020 and BBI JU IA Demo **INFINITA**	B-FERST – Bio-based FERtilising products as the best practice for agricultural management SusTainability	2019-05-01 – 2024-04-30	
H2020 and BBI JU IA **Acies Bio**	SUSFERT – Sustainable multifunctional fertilizer – combining bio-coatings, probiotics and struvite for phosphorus and iron supply	2018-05-01 – 2023-10-31	
H2020 and BBI JU IA **Acies Bio**	BIOVEXO – Biocontrol of *Xylella* and its vector in olive trees for integrated pest management	2020-05-01 – 2025-04-30	
H2020 and BBI JU RIA **InnoRenew CoE**	Pro-Enrich – Development of novel functional proteins and bioactive ingredients from rapeseed, olive, tomato and citrus fruit side streams for applications in food, cosmetics, pet food and adhesives	2018-05-01 – 2021-10-31	
H2020 and BBI JU IA **Aquafil, Circular Change**	EFFECTIVE – Advanced Eco-designed Fibres and Films for large consumer products from bio-based polyamides and polyesters in a circular EConomy perspecTIVE	2018-06-01 – 2023-02-28	
ERA-NET ForestValue **InnoRenew CoE**	BarkBuild – Tree bark as a renewable source of wood protection materials for building applications	2022-07-01 – 2025-06-30	
ERA-NET Marine Biotechnology **National Institute of Chemistry**	Mar3Bio – Biorefinery and biotechnological exploitation of marine biomasses	2016-2018	
ERA-NET CoBioTech	RhodoLive – Biovalorization of olive mill wastewater to microbial lipids and other products via *Rhodotorula glutinis* fermentation	2018-2021	

National Institute of Chemistry, CO BIK, Acies Bio		
ERA-NET CoBioTech **University of Ljubljana**	WooBAdh – Environmentally-friendly bioadhesives from renewable resources	2018-2020
ERA-NET CoBioTech **Acies Bio**	SyCoLim – Synthetic microbial communities for the production of limonene derived products	2020-2023
ERA-NET CoBioTech **Institute Jožef Stefan**	Cell4Chem – Engineering microbial communities for the conversion of lignocellulose into medium-chain carboxylates	2021-2024
ERA-NET CoBioTech **Acies Bio**	MCM4SB – Replacing food competing feedstocks with Methanol, CO2 and Methylamine for a Sustainable Bioeconomy	2021-2024
ERA-NET CoBioTech **University of Ljubljana, Institute Jožef Stefan**	OleoFerm – Sustainable oleochemicals bioproduction from carboxylates via oleaginous fermentation	2021-2024
Interreg ITA-SLO **National Institute of Chemistry**	BioApp – A trans-regional platform for the transfer of technological biopolymers from the research sector to the market	2017-10-01 – 2020-03-31
EU ESRR program	Cel.Krog – Potential of biomass for development of advanced materials and bio-based products	2016-2020
LIFE **Arhel, University of Ljubljana**	LIFE for Acid Whey – Reuse of waste acid whey for extraction of high added value bioactive proteins	2017-07-03 – 2021-06-30
H2020 MSCA IF **InnoRenew CoE**	Pack-NIN – Modified lignin nanoparticles for composite and bio-based/Cu packaging applications	2021-04-01 – 2023-03-31

HEU MSCA PF **InnoRenew CoE**	MULTI-WOOD – Multi-functionalization of wood with bio-based approach	2023-09-01 - 2025-08-31
HEU MSCA PF **National Institute of Chemistry**	Lig2BTX – Catalytic hydrotreatment of Kraft lignin to aromatics	2023-09-01 – 2025-08-31

8.2 Biorefinery Conversion Pathways (as described in the Biorefinery Outlook project, 2021)

		NAME	FEEDSTOCKS	CONVERSION PROCESSES	PLATFORMS	PRODUCTS	TRL
Bottom-up approach (extension/upgrade of existing biomass processing facility)	A	One platform (C6 sugars) biorefinery using sugar crops	Sugar crops	Extraction, fermentation, (chemical conversion)	C6 sugars	Chemicals, polymers, food, animal feed, ethanol (building block or fuel), CO_2, power and heat	9
	B	One platform (starch) biorefinery using starch crops	Starch crops	Extraction, fermentation, (hydrolysis, chemical conversions)	Starch	Chemical, (modified) starches, polymers, food, animal feed, ethanol (building block or fuel) and CO_2	9
	C	One platform (oil) biorefinery using oil crops, wastes and residues	Oil crops, waste/residue fats, oil and greases[12]	Pressing, transesterification, (hydrolysis, chemical conversions)	Oil	Chemicals (fatty acids, fatty alcohols, glycerol), food, animal feed, fuels (biodiesel and renewable diesel)	9
	D	Two-platform (pulp and spent liquor) biorefinery using wood	Lignocellulosic wood/forestry	Mechanical processing, pulping, combustion, papermaking, (separation, extraction, chemical conversions, gasification)	Pulp, spent liquor	Materials (pulp and paper, specialty fibres), chemicals (turpentine, tall oil, acetic acid, furfural, ethanol, methanol, vanillin), lignin, power and heat	9-7
Top-down approach (new industrial value chains, integrated systems)	E	Three-platform (C5 sugars, C6 sugars and lignin) biorefinery using lignocellulosic biomass	Lignocellulosic crop, wood/forestry, residues from agriculture and forestry	Pretreatment, hydrolysis, fermentation, combustion, (thermo-/chemical conversions)	C5 sugars, C6 sugars, lignin	Chemicals, lignin products (materials, aromatics, pyrolytic liquid, syngas) ethanol (building block or fuel), power and heat	8-7
	F	Two-platform (organic fibres and organic juice) biorefinery using green biomass	Green wet biomass[13]	Pressing, fibre separation, anaerobic digestion, combustion, (upgrading, separation)	Organic fibres, organic juice	Materials, chemicals (lactic acid, amino acid), animal feed, organic fertiliser, fuels (biomethane, ethanol), power and heat	5-7
	G	Two-platform (oil and biogas) biorefinery using aquatic biomass	Aquatic biomass	Extraction, hydrolysis, anaerobic digestion, combustion, transesterification, (separation, hydrolysis, chemical conversions)	Oil, biogas	Chemicals (fatty acids, fatty alcohols, glycerol), nutraceuticals, food, organic fertiliser, biodiesel, power and heat	5-6

[12] Waste/residue fats, oils and greases belong to category "Other organic residues"

[13] Green biomass and Natural fibres belong to category "Lignocellulosic from croplands and grasslands"

	H	Two-platform (organic fibres and oil) biorefinery using natural fibres	Natural plant fibres (e.g., hemp, flax), leaf, stalk	Fibre separation, extraction, physical processing, (chemical conversions)	Organic fibres and oil	Materials, chemicals (fatty acids, fatty alcohols, glycerol), nutraceuticals, cannabinoids, food and biodiesel	4
	I	One platform (syngas) biorefinery using lignocellulosic biomass and municipal solid waste	Lignocellulosic crops, wood/forestry biomass, forestry residues, agricultural residues and municipal solid waste	Pre-treatment, gasification, gas cleaning and conditioning, chemical conversions	Syngas	Chemicals (methanol, hydrogen, olefins), waxes and fuels (F-T biofuels, gasoline, LNG, mixed alcohols)	7-8
	J	Two platform (pyrolytic liquid and biochar) biorefinery using lignocellulosic biomass[14]	Lignocellulosic crop, wood/forestry, residues from agriculture and forestry	Fast-pyrolysis, separation, combustion, (gasification, cracking, extraction)	Pyrolytic liquid, biochar, (syngas)	Pyrolysis oil (for materials, chemicals, food flavourings, syngas, biofuels), biochar, power and heat	4-5
	K	One platform (bio-crude) biorefinery using lignocellulosic biomass, aquatic biomass and organic residues	Lignocellulosic crop, wood/forestry, residues from agriculture and forestry, aquatic biomass and organic residues and wastes	Hydrothermal liquefaction, upgrading	Bio-crude	Chemicals and fuels	4

For each biorefinery pathway, several process variants exist due to the secondary refining process, and the way co-products and residuals are processed.

[14] Lignocellulosic biomass includes Lignocellulosic from croplands, wood/forestry and residues from agriculture.