STAR-ProBio

Sustainability Transition Assessment and Research of Bio-based Products

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Deliverable D1.2
Mapping of Relevant Value chains and stakeholders

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Abstract

Bio-products and bio-based value chains have been identified as one of the most promising pathways to attaining resource-efficient circular economy. Such a system that valorises and transforms the available resources/ waste into high-value commodities incorporates a network of processes and actors, contributing to their socio-economic growth, environmental benefits and technological advances. To comprehend the complexities and the true potential of such systems, supply-chain visualisation, via mapping and analysis, is essential to determine their strengths, weaknesses, costs and benefits. Star-ProBio is dedicated to the development of a harmonised sustainability framework that will help analyse and highlight the environmental, techno-economic and social sustainability characteristics of any bio-based products.

D1.2 reports the selection and mapping of promising value chain that are significant to the EU plans for the bio-economy, and in particular, to visualise the boundaries of the diverse exemplary bio-based products that may be assessed along the course of this project. This study entails a systematic review of 12 bio-based value chains that are prevalent in the EU sourcing their starting material from biomass and bio-waste from agricultural produce, forestry and urban organic waste/ residue. A preliminary list of EU-based value chains are subjected to a systematised two-tier evaluation and selection approach. Value chains identified and selected in the first round, based on six selection criteria, are analysed further against a backdrop of EU-based bio-economy and sustainability initiatives, to ensure the selection of preferred value chains based on spatial feedstock relevance and technology maturity. The finalised list of eight value chains are mapped, with the collective effort of all the consortium members, at each "supply-chain" stage for visualisation of the system dynamics, interconnections, chain actors, employed conversion routes and existing/ potential end-of-life options.

Suggested citation

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Table of Contents

List of Figures

List of Tables

1 Introduction

Escalating environmental and economic pressure to consume responsibly has aided the identification of technology routes and the development of integrated biorefineries for value-addition in nearly every sector, at a global level. According to the EU Circular Economy Strategy, the aim of such systems thinking is to "*close the loop by becoming resource efficient through development and establishment of industrial symbiosis, to reduce the pressure on EU's natural capital*"[1].

The approach to attaining/creating a circular economy is cascading of material, which may be virgin raw materials, by-products or wastes resulting from any given sector. The concept of cascading and its significance to the establishment and growth of a resource/ energy efficient, green and low-carbon economy has been a recurring theme in EU policies since 2012, particularly in the EU Forest Strategy, EU Bioeconomy Strategy and EU Circular Economy package. In order to comprehend the potential for establishing a bioeconomy in the EU, a clear understanding of its biomass potential is essential. An elaborate mapping of the total biomass potential of EU-28, drawn from a previous FP7-funded project called "BioBoost", is presented in Figure 1 [2]. Further information and data on the total amount of biomass generated in the EU is detailed in the upcoming section. Nevertheless, long-term, innovative systems thinking, where major sources of organic waste/ residues from agriculture, animal husbandry, domestic, industrial and commercial industries are exploited is crucial to not only expand the boundaries of bioeconomy but also to enable a systematic and feasible transition to a bioeconomy.

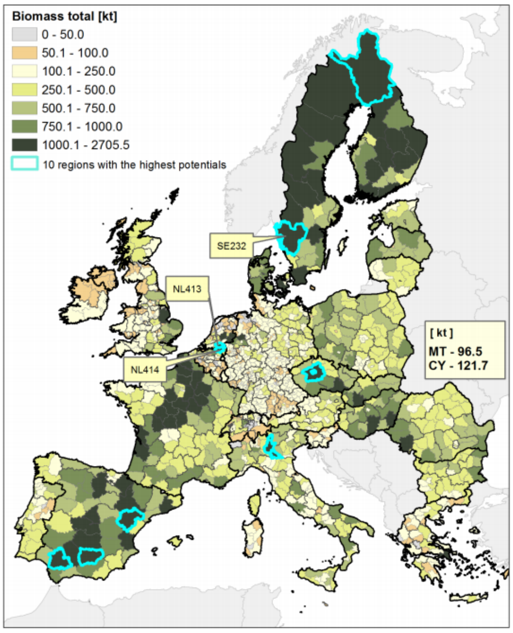

Figure 1: Biomass quantities generated in EU-28 (Source EU JRC) and the biomass potential of EU-member states (Source: Pudelko et al, 2015)

[1] European Commission, "Towards a Circular Economy", 2016. https://ec.europa.eu/commission/priorities/jobs-growth-and-investment/towards-circular-economy_en.

[2] Pudelko, R, M Borzecka-Walker, S Kühner, and E Pitzer, FP7 Biomass Based Energy Intermediates Boosting Biofuel Production (BioBoost): Feedstock, Potential, Supply and Logistic, Deliverable, Karlsruher Institut fuer Technologie (KIT), 2015. http://bioboost.eu/uploads/files/bioboost_d1.3_final_report_wp1_vers_1.0-final.pdf.

1.1 Biomass types

Biomass, based on their nature, may be classified as primary (e.g. starchy crops), secondary (e.g. straw and stover) and tertiary biomass (e.g. waste sludge and other organic-rich matter). These types of biomass may be sourced from a variety of sectors. However, based on their sectoral sources, they may be classified as follows:

- ***Agri-based feedstock*** includes biomass produced for food (e.g. cereals, starch-rich crops), feed (e.g. oil-crops, some varieties of straw) and waste/ residue (e.g. some low-feed value straw, plant material post-harvest, animal manure, residue from food and drink processing plants, slaughterhouse wastes).
- ***Forestry-based feedstock*** comprises biomass recovered from forest management activities, saw-mill residues and short rotation coppice (SRC) willow.
- ***Urban-based feedstock*** includes wastes generated from domestic set-ups (e.g. household food, garden waste and commercial set-up (food retailer waste and sludge).

Focussing on EU biomass supply, the vegetal and forestry feedstock within the EU constitutes 1.13 billion tonnes of dry biomass. According to Gurría et al [3], the biomass generated for food/feed, energy and bio-based material, for the year 2016 has been determined to be 62%, 19% and 19% respectively. The commercial significance and growth potential of transforming bio-waste/biomass into bio-based products (other than renewable energy), is evident from the progress of the bioeconomy reported by another study undertaken by DG (Directorate General) Research and Innovation, European Commission, 2014 [4].

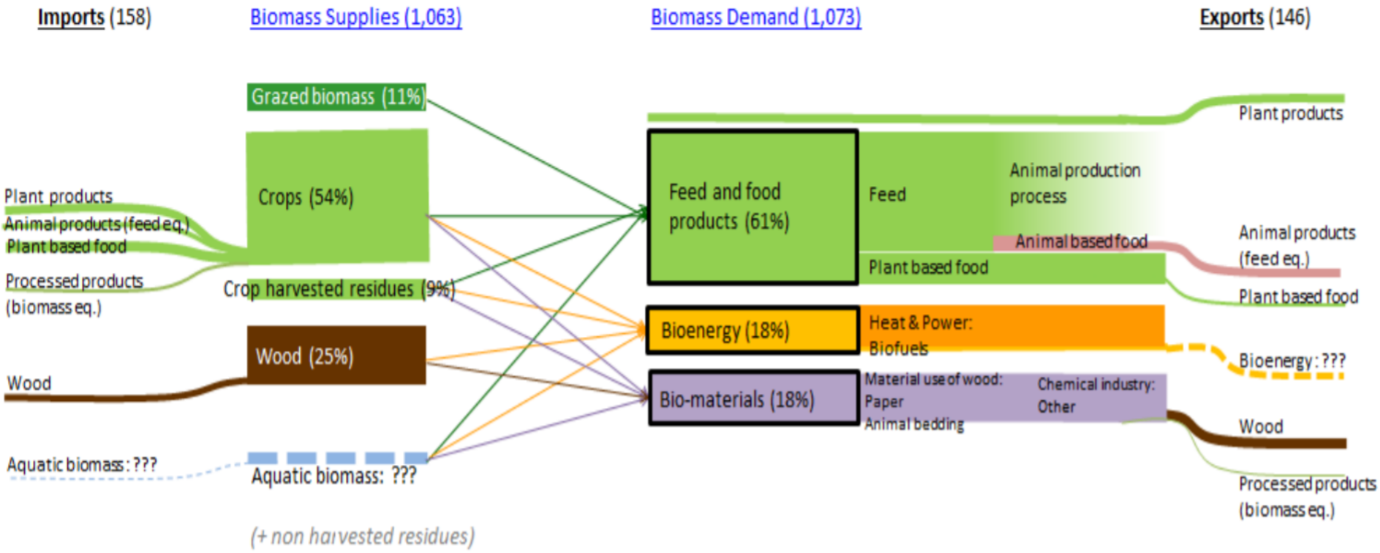

Figure 2: General biomass flow through the European value chains. (Source: Gurria et al, 2017)

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[3] Gurría, P, T Ronzon, S Tamosiunas, R López, S García Condado, J Guillén, NE Cazzaniga, et al., Biomass Flows in Thr European Union, Technical report, European Commission Joint Research Centre, Seville, Spain, 2017

[4] Spatial Foresight, SWECO, ÖIR, Nordregio, Berman Group, and Infyde, Bioeconomy Development in EU Regions. Mapping of EU Member States'/regions' Research and Innovation Plans & Strategies for Smart Specialisation (RIS3) on Bioeconomy for 2014-2020, Information, DG Research & Innovation, European Commission, Brussels, 2017. https://ec.europa.eu/research/bioeconomy/pdf/publications/bioeconomy_development_in_eu_regions.pdf.

According to this study, which draws data via engagement (interviews and survey questionnaire) with EU-based value chain actors, more than 40% of renewable material is invested into non-conventional industrial applications in EU-28. A breakdown of the flow of biomass (measured as 1000T of dry matter) emphasising the total biomass supply and demand within the EU-28, has been presented in Figure 2.

The European bio-based industrial sector will contribute with the development and market deployment of bio-based products to reduce Europe's reliance on fossil resources. Such a transition has been identified to benefit the economy through creation of SMEs and skilled employment opportunities, in addition to reaching EU's climate change mitigation targets. The benefits, challenges and strengths associated with the establishment of innovative value chains will be discussed further in the upcoming sections.

1.2 Bio-based value chains

A value-chain is defined as a set of interlinked activities that deliver products/ services by adding value to bulk material (feedstock). In a bio-based value chain, the feedstocks tend to be biomass drawn from an existing primary production route (e.g. agriculture, forestry and livestock), or of a novel (e.g. microalgae) or secondary origin (e.g. sludge, industrial wastewater and household organic waste). A generalised schematic for a bio-based value chain embedded with potential end of life options has been presented in Figure 3.

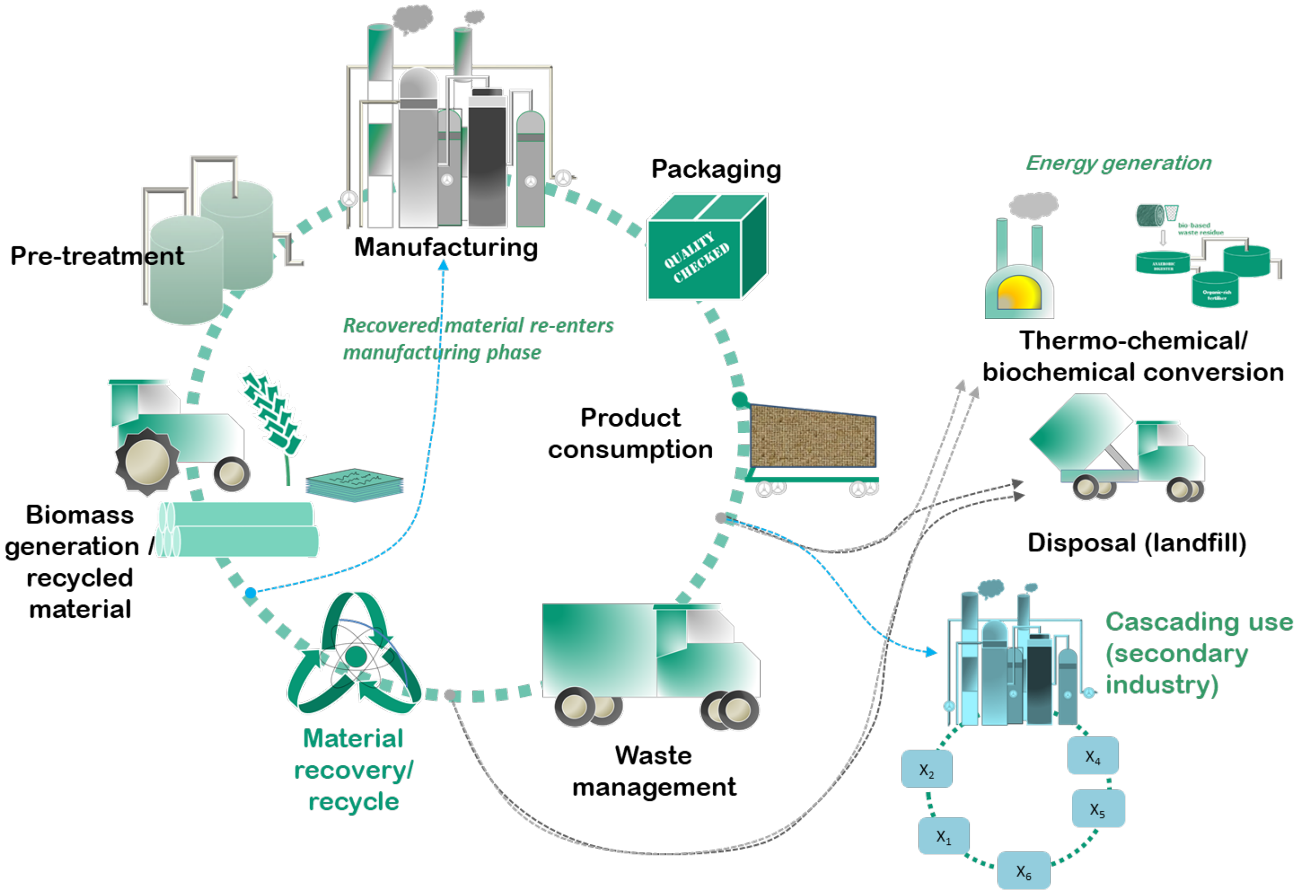

Figure 3: A generalised map of a bio-based value chain

Value chains, in particular those that valorise secondary resources are designed to turn available organic material into every possible valuable product, ranging from high-value chemicals to secondary-use by-products and renewable energy. Pathways that are capable of transforming waste/ secondary feedstock into an array of high value products are called integrated biorefineries. Integrated biorefineries contain a "pre-treatment plant" that prepares the feedstock for upcoming transformation and refining technologies within the supply chains, before packaging and distribution. From a techno-economic perspective, integrated biorefineries co-produce renewable energy, in addition to high value products. From the socio-economic perspective, creation of a multi-regional/ local value-chain, networks, growth of SME's and other employment opportunities, development of waste-management infrastructure (where lacking), local skill-forging and knowledge dissemination are some of the practical benefits of a fully-functional bio-based value chain[5].Recently, bio-based value chains that exploit waste/ residue from industrial sectors and organic residue from agro-food, forestry, municipal and commercial waste, have gained significant attention as next-generation value chains. A survey undertaken as a part of the study by the Bio-based Industries Consortium (BIC) and Nova institute (2017), is presented in Figure 4.

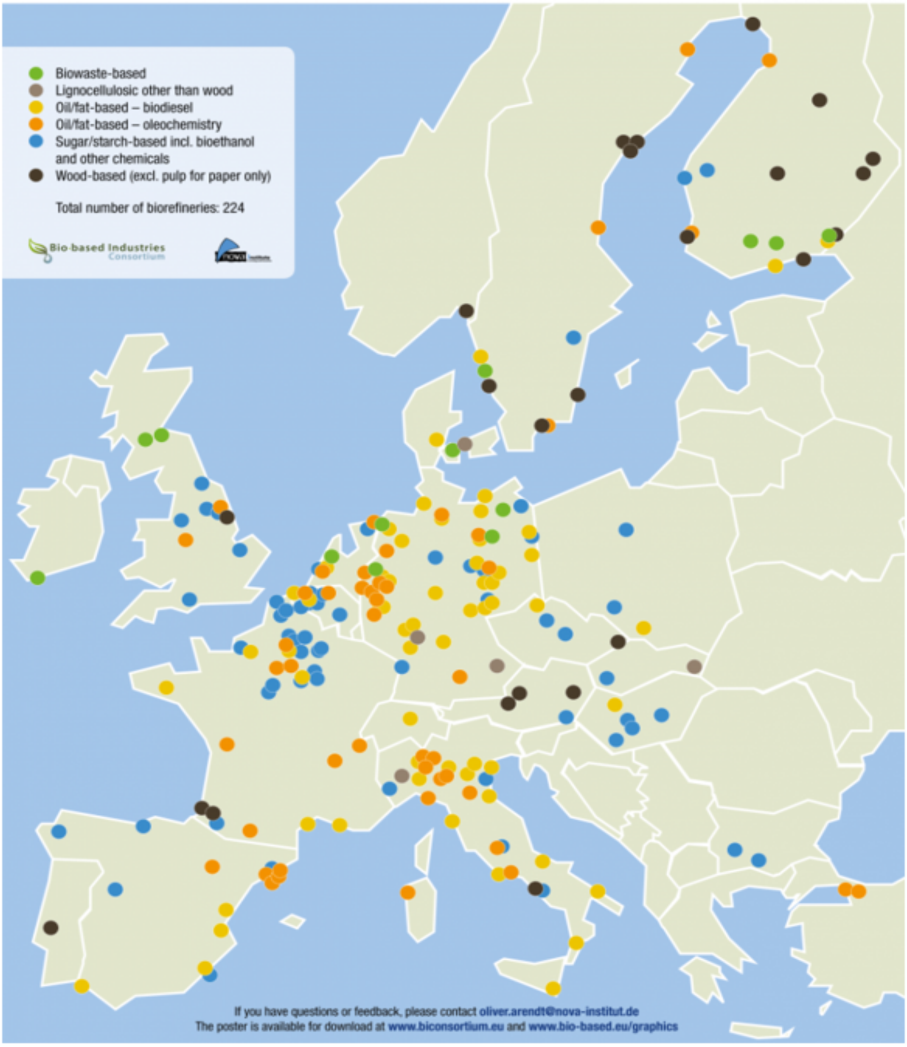

Figure 4: Biorefinery map in Europe (Source: Bio-based industries consortium, 2017[6])

[5] European Parliament, *Circular Economy Package: Four Legislative Proposals on Waste*, Briefing: EU legislation in progress, 2016.

[6] Bio-Based Industries Consortium, "Mapping European Biorefineries", 2017, http://biconsortium.eu/news/mapping-european-biorefineries.

According to a 2016 study undertaken by the Joint Research Centre (JRC), European Commission [7], EU-28 has been determined to be home to 133 bio-based industries, excluding the relevant industrial research and development (R&D) institutions. The EU-wide bioeconomy workforce, excluding those employed in the food/beverage and tobacco sector, has been determined to be 3.2 million. From a sectoral perspective, the EU biorefinery map (Figure 4) represents the prevalence of high numbers of oil and fat based biorefineries dedicated to the production of biofuel and oleochemical products. The maturity of the conversion routes for processing oil-crops (e.g. bio-based lubricants and other transformer fluids) are, attributable to the abundant oil crop plantations established across the EU towards the renewable energy consumption targets, Energy strategy 2030 [8]. Similarly the technology for the development of bio-based products from starch-rich crops (e.g. cereals, tubers), primarily fermentation, is quite a mature-level conversion process to synthesise bulk and fine chemicals, in-spite of its usage of potential food crops as feedstock. Additionally, the biorefinery map also demonstrates the presence of integrated bio-refineries that cascade agricultural lignocellulosic waste and forestry residue towards the synthesis of similar bio-based products. The presence (and potential growth) of such integrated bio refineries demonstrates the evolution of bio-based value chains that practice cascading and other forms of waste valorisation routes. However, the progress of such value chains is dependent on the geographical specifications, local/ national economic activity, the advances in processing technology and global product preferences. The impact of these factors on the commercial development, uptake and success of any bio-based value chains has been captured in the "methodology" section.

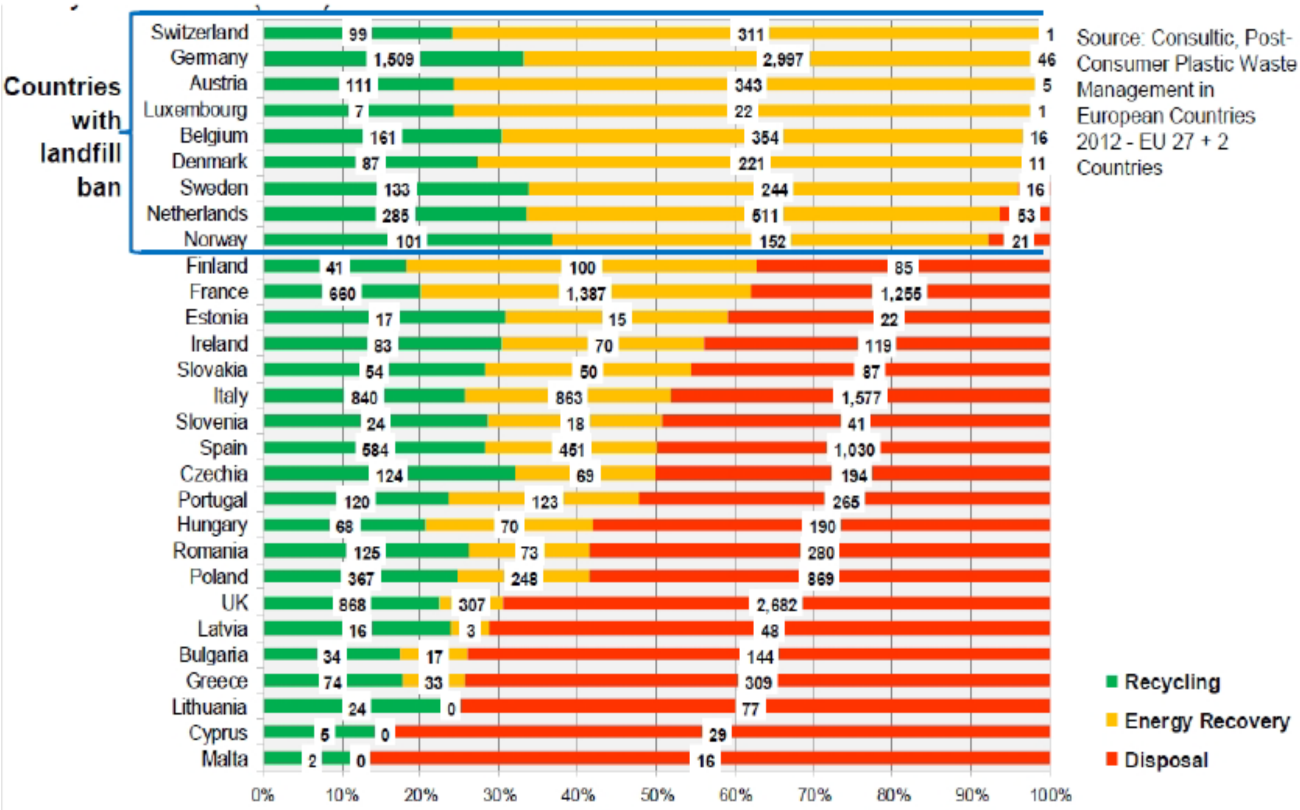

Figure 5: EU-28 Countries with and without systematic plastic waste management.

[7] Parisi, C, and T Ronzon, A Global View of Bio-Based Industries: Benchmarking and Monitoring Their Economic Importance and Future Developments, Information, JRC Technical reports, European Commission, January 1, 2016.
[8] European Commission, "2030 Energy Strategy - Energy - European Commission", Energy, n.d. /energy/en/topics/energy-strategy-and-energy-union/2030-energy-strategy.

In addition to the above mentioned, it is also essential for the industries and local municipalities involved in bio-based business model development to cooperate and create linkages to ensure the establishment of a robust waste management infrastructure to circularise value chains. Top-down approaches via market based mechanisms such as landfill tax and pay as you throw (PAYT) schemes and "bottom-up" approaches like national/ international public engagement and awareness programmes may complement and encourage the growth of a bio-based market. Figure 5 demonstrates the effectiveness of plastic waste management infrastructure in EU-28 countries with and without market based mechanisms. Such waste management mechanisms have also been identified to pave the way for innovative bioeconomy initiatives, which has been elaborated onSection 3.

1.3 Challenges to Bioeconomy transition

In addition to understanding the significance of a bio-based economy, key factors that challenge its progress must be identified and addressed through development of robust dependable sustainability initiatives. The identification of these factors could help chain actors foresee barriers and devise strategies/ pathways to be implemented to overcome such barriers These potential barriers are as follows

- use of agro-food based biomass as the starting feedstock invites "food vs. bio-products" conflict, undermining the "sustainability characteristics of a bio-based value chain;
- lack of local, large reliable source of biomaterial, sufficient to set-up a large local biorefinery;
- techno-economic hurdles to the development of EU-wide bio-based value chains due to requirement of relatively larger financial investments;
- societal perception of bio-based products: limited supply, excessive costs and uncertianties on product functionality;
- penetration into well-established non bio-based value chains (existing fossil-based chains);
- development and policy-level improvisation of the "push" mechanisms including standards, certification and other regulatory tools (such as defining clear thresholds, quantified risks and benefits etc).

Nevertheless, a number of national and European Commission (EC) initiatives dedicated to overcoming these barriers are currently in existence. Waste utilisation, transformation to bio-based products and national-level knowledge transfer strategies are some of the many approaches adopted to overcome these barriers. However, waste valorisation is a techno-economically multifarious concept with a variety of feasibility issues and difficult trade-off requirements, in spite of success stories[9]. Such issues in particular stem from the method of product synthesis and product functionality. The practicality of this concept depends upon the functionality and the current technological advances in processing the starting material. The technical complexities of bio-product synthesis, restrictions in its functionalities and application, and subsequent difficulties associated with their end-of life management (except for biodegradable products) have been the reality for most bio-based products. SMEs and larger companies, therefore, invest heavily into research and development of simpler, repairable and re-usable products, as opposed to the conventional linear model of consumption.

[9] Fehrenback, H, S Köppen, B Kauertz, A Detzel, F Wellenreuther, E Brietmayer, R Essel, et al., Biomass Cascades: Increasing Resource Efficiency by Cascading Use of Biomass- from Theory to Practice, Summary, German Envrionmental Agency, Heidelberg, Germany, 2017. https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2017-06-13_texte_53-2017_biokaskaden_summary.pdf.

It is essential to acknowledge that such products (due to design-level complexities) may not be economically feasible in the current time frame. The feasibility issues stem from the cost of raw material transformed and the specialist technology employed in synthesising the product. Use of agricultural and forestry residue or industrial residue as a starting material is likely to overcome such techno-economic limitations. It is essential to assess some commercially successful and novel bio-based value chains to be able to comprehend the techno-economic environmental and social performance of bio-based industries. The aim of Task 1.3 is to identify a range of innovative and most promising bio-based value chains, prevalent in the EU. The selected value chains will contribute to the techno-economic environmental and social evaluation of chosen exemplary case studies, which are to be identified within Task1.4: Identification of case studies and stakeholders. The selection criteria for the screening and identification of EU-specific bio-based value chains have been presented in Section 3.

2 Literature review

2.1 Bio-based value chains in Europe

This study began with a review of current European certification initiatives, sustainability schemes and any relevant literature available in the open domain. This review was undertaken, as part of Task 1.1 and Task 1.2, to examine the state of the current bio-product sustainability assessment framework and to identify inherent gaps and limitations. Based on the analysis of the strategies and established policy trajectory for resource efficiency, the vast forestry/ agricultural resources available in the EU have been identified as a valuable feedstock for more than just a renewable energy source[10]. The biomass potential (primary and waste biomass) of EU-28, presented in Figure 1, qualitatively highlight the biomass production capacity of EU.

A study was undertaken by the DG Research and Innovation, European Commission (2016)[11], where a survey was conducted to assess the trajectory of all the bioeconomy strategies in EU-27. The outcome was presented as % of total number of strategies planned/ established in the EU (Figure 6).

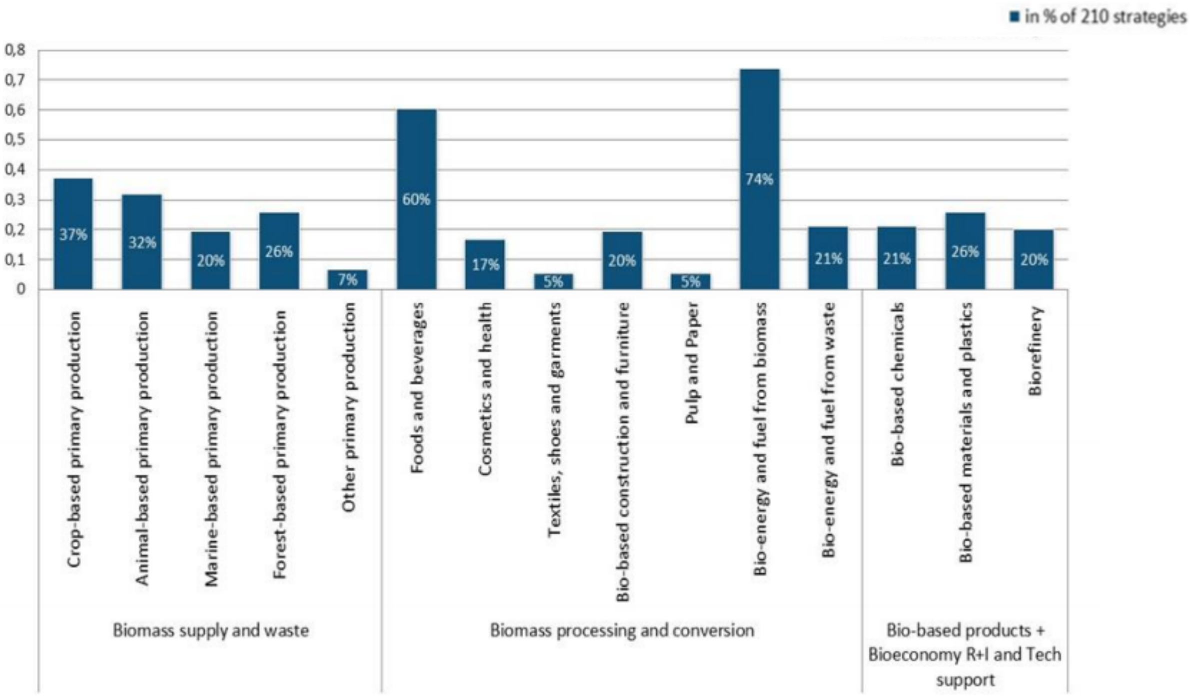

Figure 6: Indication of specific value chain approaches within the member state bioeconomy strategies (Source: Spatial foresight and group, 2017)

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10 Majer, S, D Moosman, S Wurster, and L Ladu, Report on Identified Environmental, Social and Economic Criteria/indicators/ Requirements and related "Gap Analysis", Deliverable 1.1, December 11, 2017.

11 Spatial Foresight, SWECO, ÖIR, Nordregio, Berman Group, and Infyde, Bioeconomy Development in EU Regions. Mapping of EU Member States'/regions' Research and Innovation Plans & Strategies for Smart Specialisation (RIS3) on Bioeconomy for 2014-2020, Information, DG Research & Innovation, European Commission, Brussels, 2017. https://ec.europa.eu/research/bioeconomy/pdf/publications/bioeconomy_development_in_eu_regions.pdf.

From a value chain and bio-product perspective, a majority of current bioeconomy strategies are dedicated to bioenergy and biofuel-based value chains, followed by food and beverage chains (Figure 6). Prevalence of many such value chains may be attributed to the EU's race towards renewable energy consumption targets set in the Energy Strategy for 2030. However, a surge in integrated biorefineries that synthesise bio-based products other than biofuels is evident from the most recent report compiled and analysed from a stakeholder engagement approach undertaken by the Bio-based Industrial Consortium (BIC) and Nova Institute (Figure 4). The growth of biomass-cascading biorefineries is also supplemented by the keenness of European bio-based industries to valorise organic-rich bio-waste (mainly agricultural residue and sludge). Besides, capturing an opportunity to synthesise value-added products from low-cost feedstock, an unhindered supply of feedstock (one of the key barriers to bio-product synthesis), seems a promising start towards waste-utilising value chains. According to a study undertaken by Meyer-Kohlstock et al (2015)[12], the supply of biomass and waste for consumption within other value chains was predominantly sourced from the agri-food and livestock sector. Figure 7 represents the utilisation of bio-waste by other sectors and availability of sludge waste across EU-28.

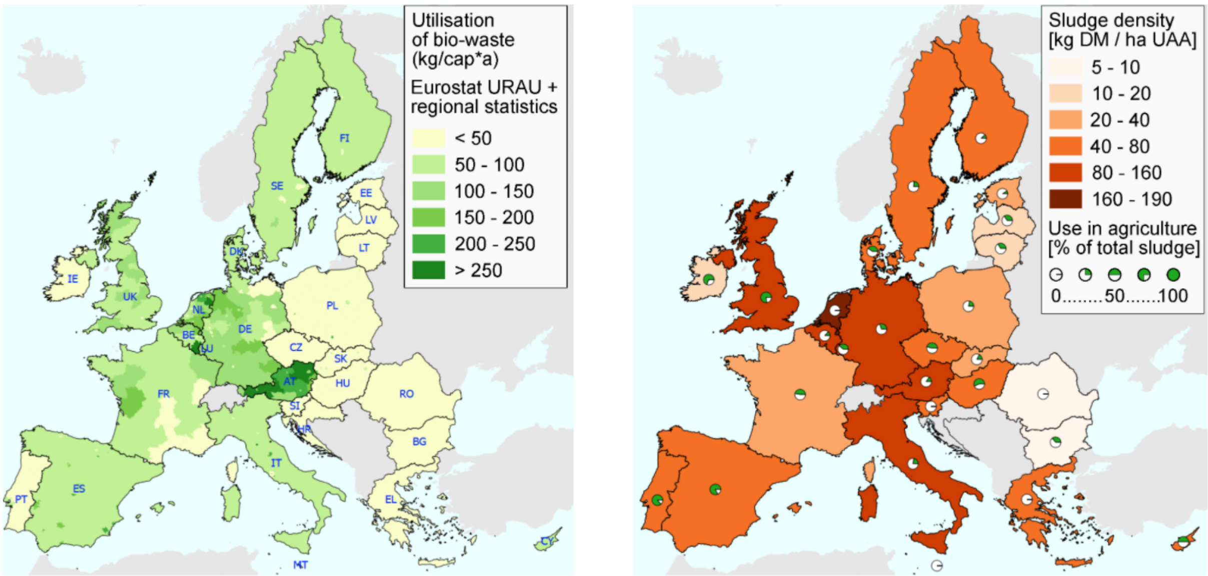

Figure 7: Fraction of bio-waste (kg per capita per year) and sludge utilisation (kg dry matter per hectare agricultural area utilised) in EU-28 within the agricultural and other sectors (Source: Meyer- Kohlstock et al, 2015).

Though bio-based value chains create opportunities to circularise value chains, some chain-level dynamics influence the environmental, commercial and social practicability of the same by different degrees. These dynamic factors include biomass supply logistics, feedstock costs (influenced by whether the feedstock is primary or secondary), feedstock treatment requirements and ethical compliance requirements. When developing a bio-based business model or mapping and analysing a potential bio-based value chain, it is essential to consider and model the influence of these dynamics on the overall performance of the chain. We aim to capture and shed light on these dynamics as a part of this study, during the value-chain mapping exercise.

2.2 Previous research and gaps

[12] Meyer-Kohlstock, Daniel, Tonia Schmitz, and Eckhard Kraft, "Organic Waste for Compost and Biochar in the EU: Mobilizing the Potential", Resources, Vol. 4, No. 3, June 25, 2015, pp. 457–475.

A number of projects initiated prior to STAR-ProBio, aiming to develop harmonised sustainability assessment schemes for investigation and approval of bio-based products, were identified and reviewed.

The aim of this review is to develop an insight into the environmental, economic and social parameters considered, methodologies adopted and accomplishments made, and identify perceived gaps and limitations. The findings of this review are presented in the upcoming section. Task 1.3 is dedicated to bridging these gaps and overcoming the identified limitations via appropriate use of methodologies for the selection and mapping of promising value chains, thereby, contributing to the final development of a harmonised framework for sustainability assessment.

2.2.1 Knowledge Based Bio-based Products' Pre-Standardization (KBBPPS)

KBBPPS is an EU-funded FP7 project, co-ordinated by the NEN Standardization Institute [13], that was undertaken (2012-2015) to support policy development initiatives for the design and development of sustainability test methods and 'labels' for bio-based products. The outcomes of this assessment fed directly into the CEN standardisation protocols. The test methodologies were designed and developed to be able to be applied to diverse bio-based products, irrespective of the product's functionality.

This project was initiated with the identification of market drivers and hurdles associated with a selected list of bio-based products. A stakeholder workshop contributed to the identification of a list of commercially-preferred European bio-based products, via a multi-criteria-based selection questionnaire, including the purpose/nature of demanded feedstock, position within the value chain, application sector, market demand, growth potential, bio-based content, bio-degradability, product functionality, product state (e.g. solid, liquid or gas) and product mix (100% natural or mixed with fossil-based product). From stakeholder interaction, it was observed that for the success of bio-based products, it is essential that they enter the commercial market as a replacement for existing fossil-derived products. Otherwise, in a 'business as usual' scenario, only bio-based products that satisfy niche demands were able to achieve commercial uptake. Other key market barriers identified from this review were industrial/ end-user perspectives, acceptance and, more importantly, the lack of a local waste management infrastructure. This research also identified that any local/ national/ international certification and sustainability schemes either lacked or failed to provide any level of visibility of the benefits and issues of adopting bio-based products via a systematised environmental, economic and social impact assessment (i.e. employing life cycle assessment or other scoped sustainability assessment). Among the various methods proposed by this study (including biodegradability, recyclability, toxicity and bio-based carbon content), the CEN standardisation panel adopted the criteria for measured biomass based carbon and bio-based content as one of the measures of sustainability assessment, towards "CEN/TC/411: Bio-based products". Nevertheless, there is a need to address the sustainability characteristics, particularly the cascading capabilities embedded in the various stages of bio-based value chains.

2.2.2 Opening bio-based markets via standards, labelling and procurement (OpenBio)

[13] 30. Costenoble, O. KBBPPS: Knowledge Based Bio-Based Product's Pre-Standardization, Deliverable, Netherlands Standardisation Institute, Delft, The Netherlands, 2015, http://www.biobasedeconomy.eu/projects/kbbpps-knowledge-based-bio-based-products-pre-standardization/.

OpenBio is an FP-7 funded follow-on project (2013-2016) to KBBPPS, co-ordinated by the NEN Standardization Institute[14] that aimed at addressing the drivers and hurdles for bio-based products in the commercial market. This project was dedicated to creating strategies that generate a market pull for bio-products via standardisation, labelling and procurement.

Key strategies involved increasing the approval speed of standards, labels and creation of a harmonised method of disseminating (via labels) product information for bio-based products in Europe. The activities involved selection of bio-based products, investigation and measurement of their sustainability criteria including product biomass-content (%), biomass carbon content (%), biomass type and origin (feedstock), environmental impact, product functionality, and EoL characteristics of the bio-product: biodegradability/ recyclability/ compostability (according to REACH guidelines). Open-Bio adopted qualitative approaches (Delphi method) for this evaluation undertaking surveys and interviews of industrial and domestic consumers from the EU's mixed socio-economic states, including Czech Republic, Germany, Denmark and Italy to learn their perception of bio-based products. It was observed that from among many, some key factors that present a positive image for bio-based products in the commercial market include:

- the product's functional effectiveness;
- costs/ savings to the consumers;
- independence from fossil-based feedstocks;
- availability of an established managed (diverse EoL characteristics) waste management; infrastructure for the consumer's convenience;
- lessened human-health impact from product use.

2.2.3 STAR4BBI

STAR4BBI is an EU-H2020 and Bio-based Industries (BBI) funded project (2016-2019), co-ordinated by the Netherlands Standardization Institute (NEN)[15], which aims to develop a well-coordinated and harmonised regulatory framework for a cutting edge bio-based economy, supporting the development of new value chains dependent on forestry, agriculture and organic waste streams. This project has opted for a similar approach to understanding the current EU-bioeconomy landscape in addition to the analysis, identification and mapping of existing and novel bio-based value chains, comparable to STAR-ProBio. Owing to the confidential nature of the contents captured within STAR4BBI, we are unable to present further details in this section. However, some gaps were identified in their approaches to selection and mapping of value chains. Bio-based value chains were identified purely based on the feedstocks and related factors such as feedstock characteristics, location and production quantity. Limited specificity on the target market of these value chains and lack of emphasis on potential circular characteristics of these value chains were also identified as major gaps in their approaches.

[14] Costenoble, O, C Bolck, M Behrens, and M Meusen, "Open-Bio – Opening Bio-Based Markets via Standards, Labelling and Procurement - Final Report", Impact, Vol. 2017, No. 3, March 10, 2017, pp. 36–38, http://www.biobasedeconomy.eu/projects/open-bio/.

[15] van der Zee, M, "STAR4BBI, Standards and Regulations for the Bio-Based Industry", Wageningen University and Research, January 1, 2017. https://www.wur.nl/nl/project/STAR4BBI-Standards-and-Regulations-for-the-Bio-based-Industry.htm

3 Value-chain selection criteria

A robust sustainability assessment framework will investigate the entire bio-based value chain covering every material and energy flow across the system addressing the techno-economic, environmental and social characteristics, in addition to highlighting the chain's strengths, weaknesses, opportunities and issues. The aim of Task 1.3 is to identify, select and map promising value chains, in preparation for the upcoming cross-disciplinary sustainability evaluation (undertaken within WP2-7) towards the final development of a harmonised sustainability assessment framework for bio-based products. This report will select value chains drawing information from the findings of D1.1, which encompasses a review of the existing sustainability and certification schemes prevalent in the EU. The outcomes of this assessment, in combination with the outcomes of Task 1.4, enables the identification of exemplary bio-based products and stakeholders, which will be used to test the effectiveness of the methodologies and sustainability criteria, developed in the upcoming work packages.

A variety of bio-based value chains have been identified within the EU and are presented in Table 1. This list of preliminary value chains was drawn from the outcomes of Task 1.1 and Task 1.2 focussing on bio-based value chains/products covered by the EU certification schemes and market demand, in addition to those drawn from literature review of previous projects captured in Section 2.2. The list comprises bio-based value chains with diverse characteristics covering:

- From virgin food-based feedstock to bio-waste cascading;
- 100% bio-based to partially bio-based, value chains;
- Those with a fully-functional waste management infrastructure to those that lack one;
- Diverse product functionality.

Table 1: List of EU-based value chains considered for selection, analysis and mapping exercise

Sector	Value chain
Chemicals	Cellulose to bio solvents
Disposable food packaging	Starch to bioplastic food packaging
Agriculture	Starch to bio-based mulch films
Fabrication	Starch to bioplastics for fabrication
Automotive	Vegetable fats to bio lubricants
Agriculture/waste management	Solid biomass to fine chemicals
Textiles	Cellulose to fabric
Food packaging	Cellulose to plastic paper cups
Construction	Waste biomass to insulation material
Construction	Waste biomass to wood-plastic composites
Agriculture	Polysaccharides to crop health inducers
Animal husbandry	Plant-based chemicals to fine chemicals

For systematic identification of promising value chains, a multi-criteria selection approach was used. Use of value chain-relevant selection criteria will help this study weigh the potential and resilience of these candidates in the commercial market, against the backdrop of the EU's bioeconomy policies. The selection criteria chosen for the first-round assessment of bio-based value chains are presented in Figure 8.

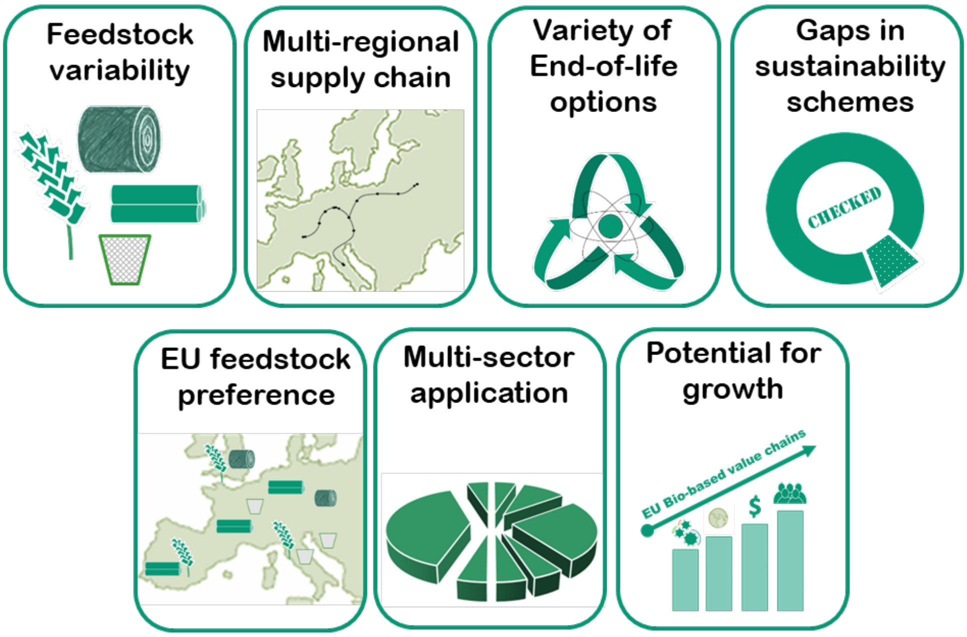

Figure 8: Selection criteria for EU Bio-based value chains.

3.1.1 Feedstock variability

The "high-priced" nature of bio-based products, in general, stems either from the cost of the starting material or the complexities of the technology route. The greater the specificity of a product to a feedstock, the greater is the demand for that particular feedstock. Such competition for specific starting material will eventually increase the market price for that feedstock. Technology routes that facilitate the use of organic residues and waste have since been the most preferred pathway for production of value-added products. A bio-based value chain that relies on an unfailing supply of low-cost, low-value starting material, from an economic perspective, also promises an effective "return on investment" model [16]. Biomass-cascading, one of the key strategies for a circular economy in recent years, is simply defined as an efficient use of biomass. Biomass cascading is more applicable to use of agricultural and industrial residue i.e. utilising left-over residues (wheat straw, corn stover, forest residue) for conversion to value-added products, rather than starch-based (potato, corn and wheat). Nevertheless, use of peels of potato, orange and other organic waste from the commercial food and drink sector create an opportunity for biomass waste valorisation. However, unhindered supply of feedstock for the synthesis of bio-based products (in a fully functional bio-based value chain) may be affected by other external (and uncontrollable) factors such as crop failure from climate change impacts, geo-political instabilities and other value-chain instabilities.

Feedstock variability was adopted as one of the selection criteria to identify potential value chains that can cope with sourcing multiple feedstocks. Variable feedstock- value chains are capable of overcoming barriers from fluctuations in the feedstock cost and supply. This creates a levelised biomass-supply landscape where bio-based business models have a set "threshold" for potential feedstock costs.

[16] Fehrenback, H, S Köppen, B Kauertz, A Detzel, F Wellenreuther, E Brietmayer, R Essel, et al., Biomass Cascades: Increasing Resource Efficiency by Cascading Use of Biomass- from Theory to Practice, Summary, German Envrionmental Agency, Heidelberg, Germany, 2017. https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2017-06-13_texte_53-2017_biokaskaden_summary.pdf.

Nevertheless, a biorefinery's capacity to handle diverse feedstock introduces a techno-economic toll. For example, the techno-economic modelling of a value chain must cater to the varying processing (pre-treatment and conversion route) needs of the various feedstock. A preliminary assessment of the bio-based value chain could provide an opportunity to identify the trade-offs in the selected value chain, i.e. predict if this techno-economic toll has significant economic repercussions compared to a single-feedstock market. A value chain mapping process appropriately visualises the performance potential of a multi-functional value chain. Please refer to the "Results and Discussion" section for mapped value chains.

3.1.2 Multi-regional supply chain

The bio-based economy, in general, is made of multi-regional supply chains with the feedstock generated in one or multiple regions and the product being consumed in other regions. A multi-regional value chain, besides creating value from a given feedstock, contributes to economic growth of dependent communities via creation of jobs, development of skills and knowledge pool of the local communities leading to improved community wellbeing and social equity. This multi-regional value chain also provides an opportunity for EU states with transition economies to establish bio-economy models, with the needed investment from national funding initiatives.

3.1.3 Variety of end of life options

The importance of end-of-life waste management has been realised in every sector influencing the global economy, to the extent, that it has been identified to be one of the key drivers to enable the uptake of bio-based products in the commercial market. Strategic management and utilisation of waste is capable of delivering three-fold benefit: environmentally through reduction of waste for treatment and disposal; economically by enabling resource efficiency and through transformation of waste (as low-cost raw material for a secondary industry) and; socially through creation of jobs, new value chains and social equity. The EU Waste Framework Directive's most preferred option of waste management is waste reduction, thereby supporting the growth of waste valorising value-chains. A bio-based value chain fits within the scope of the EU Waste Framework Directive's goal and consideration of their "end-of-life" (EoL) options is at the heart of this project. EU waste management hierarchy provides guidance on "best" to "worst" waste management options and though, there is less clarity on some of the strategies suggested (like "other recovery options"), this hierarchy contributes to systems thinking[17]. According to this 2008 Directive, waste reduction is followed by reuse, recycle and recovery and finally by "disposal to landfill", which is the least preferred option. In the current situation, biodegradable products and those that are capable of being recovered via a producer or local authority organised waste management infrastructure is much preferred for commercial uptake[18]. To be able to catch up with the 2014 EU Landfill Directive [19] (which aims to phase out landfilling recyclable waste, e.g. bioplastics, paper, glass and bio-waste), we need to identify candidate value chains that generate products that can potentially circularise the value chain. Selection of value chains based on the capabilities of the products to demonstrate a variety of end-of life characteristics would be valuable to report via this study.

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[17] European Commission, "Directive 2008/98/EC on Waste (Waste Framework Directive) - Environment - European Commission", n.d. http://ec.europa.eu/environment/waste/framework/.

[18] Costenoble, O, C Bolck, M Behrens, and M Meusen, "Open-Bio – Opening Bio-Based Markets via Standards, Labelling and Procurement - Final Report", Impact, Vol. 2017, No. 3, March 10, 2017, pp. 36–38.

[19] European Commission, "Landfill Waste - Environment - European Commission", n.d. http://ec.europa.eu/environment/waste/landfill_index.htm.

3.1.4 Gaps in sustainability assessment

The bio-based industrial sector (except the bioenergy value chain), within the EU, is currently in its infancy. There are a number of sustainability schemes in place to ensure the introduction, encouragement and sustainable scale-up of the various elements in the bio-based value chain (e.g. feedstock supply, type and processing methods). For example, the EU 2003 Forest Law Enforcement, Governance and Trade (FLEGT) Action Plan [20] ensures that no illegally harvester timber enters the EU market which led to the adoption of the EU Forest strategy in 2013.

From assessing the outcomes of Task 1.1 and Task 1.2[21], it is evident that sustainability schemes for bio-based products (e.g. bioplastics, bio-solvents, bio-based adhesives and binders, enzymes and cosmetics, etc but not bioenergy) are either still in their infancy or have variable levels of maturity with major sustainability related gaps to cover. For example, for the CEN standards for bioplastics (CEN/TC/249), some of the sustainability criteria such as the determination, declaration and reporting of the bio-based carbon content (between year 2011-2012) are required via the following standards:

- CEN/TS 16137:2011: Plastics - Determination of bio-based carbon content[22]
- CEN/TS 16295:2012: Plastics - Declaration of the bio-based carbon content[23]
- CEN/TS 16398:2012: Plastics - Template for reporting and communication of bio-based carbon content and recovery options of biopolymers and bioplastics - Data sheet[24]

However, these standards do not direct the economic operator to take further responsibility to address/ quantify the sustainability criteria associated with bioplastics including production derived emissions to air,water and soil or economic and social impacts. A discrete set of standards is under development by the technical committee (CEN/TC/411) for bio-based products to report the sustainability aspects of bio-based products. These standards are responsible for the determination, declaration and reporting of environmental impact assessment exists (e.g. EN16751: Bio-based products: sustainability criteria). The scope of EN16751 in particular, despite providing guidance on undertaking impact assessment and reporting on bio-based products, covers the stages from feedstock acquisition up to the feedstock "pre-processing" phase. Lack of guidance on assessment and reporting of environmental burden resulting from "manufacturing" to "end-of-life" phases, and lack of assessment methodologies and thresholds are some of the major gaps and limitations in these standards. Further information on the work and outcomes of this technical committee have been elaborated in Deliverable 1.1 report on "gap analysis". A scheme under the Single Market for Green Products called Product Environmental Footprint (SMFP-PEF) is dedicated to capturing the environmental impact of any given product via modelling and quantitative analysis from a "Cradle to EoL" perspective, however, this plan is currently under a "test" phase.

[20] European Forest Institute, "What Is the EU FLEGT Action Plan? | EU FLEGT Facility", Information, EU FLEGT Facility, 2017. http://www.euflegt.efi.int/flegt-action-plan.

[21] Majer, S, D Moosman, S Wurster, and L Ladu, Report on Identified Environmental, Social and Economic Criteria/indicators/ Requirements and related "Gap Analysis", Deliverable 1.1, December 11, 2017.

[22] CEN, CEN/TS 16137:2011: Plastics. Determination of Bio-Based Carbon Content, Standard, CEN, 2011.

[23] CEN European Committee for Standardization, "PD CEN/TS 16398:2012: Plastics. Template for Reporting and Communication of Biobased Carbon Content and Recovery Options of Biopolymers and Bioplastics. Data Sheet", CEN, November 2012.

[24] CEN European Committee for Standardization, "PD CEN/TS 16398:2012: Plastics. Template for Reporting and Communication of Biobased Carbon Content and Recovery Options of Biopolymers and Bioplastics. Data Sheet", CEN, November 2012.

Identification of promising value chains (except bioenergy) with potential gaps in sustainability schemes would provide an opportunity to not only expand the coverage of these standards and sustainability schemes, but also to assess and identify the innovative value chains, promote sector-level competition and encourage investment and growth of such novel value chains to establish a full-fledged bio-economy.

3.1.5 Preferred feedstock within the EU

Consistency in raw material supply and chain-productivity is essential for the successful uptake of bio-based products and their associated value chains. The guarantee of a promising flow of feedstock to the facilities can only be ensured through the choice of "locally sourced" feedstock. "Locally-sourced" feedstocks generally have established logistics and reporting procedures, which can communicate their point of origin to the economic operator. This may not be the case with some "cross-border" feedstocks. The uncertainties associated with "cross-border" feedstock supply have already been associated with instability from climate change impacts and geopolitical sensitivities. In addition to that, such feedstocks, in a majority of cases, tend to carry the environmental burden of international freightage and a high chance of inviting the "food/ feed vs chemical" conflict undermining the sustainability of the value chains. In addition, the scope of STAR-ProBio covers only the EU borders, and therefore, value chains that have a preferred feedstock sourced from within the EU was identified as one of the key criteria for value chain selection.

3.1.6 Multi-sector application

Ability of a bio-based product and its value chain to cover a range of applications (in different industrial sectors) was identified as an important criterion for value chain selection. The goal and scope of this project is to develop extended sustainability indicators and thresholds via life cycle assessment (LCA). Undertaking this task for value chains with products that serve a rather smaller demand/ specialised demand could make this study highly specific, deviating from the aim to create a harmonised sustainability framework for horizontal sector application. Therefore, focus is placed on value chains and bio-based products that have the potential to be applied in a variety of sectors (e.g. Bio-based mulch film caters to agricultural/horticulture industries and other industries like landscaping industry; versatile fine chemicals that find application as solvents in paints and coating, adhesives and binders, fuel additives and agrochemicals).

Similar to the CEN's aim to develop standards for horizontal application, this project aims to select value chains that cover multiple sectors, rather than those catering to a niche market.

3.2 Procedure for Value chain selection

3.2.1 First round of Assessment

Owing to the prevalence of diverse value chains in the EU and the lack of resources and time led to the consortium's preference to initiate the development of a sustainability framework with the selection of promising EU-based value chains, particularly those that cascade residual biomass. Initially, a preliminary list of value chains was developed. This preliminary list was drawn partially from literature review and from the initial review of the value chain coverage by the sustainability and certification schemes, drawn from the analysis in T1.1 and T1.2. The preliminary list of value chains have been considered for selection and analysis towards T1.4: Identification of case studies and stakeholders. This list of value chains has been presented in Table 1, in section 0.

STAR-ProBio consortium partners were allocated to specific selection criteria based on their expertise to provide their recommendation (*yes/maybe/no*) for a given value chain and provide sufficient information to support their decision. These recommendations were subjected to further analysis via the approach presented as follows:

1. The rationale for the recommendations were reviewed in detail and finalised;
2. The selection of value chains were decided to be undertaken by "weighting" the selection factors;
3. Each of the selection criteria were allotted weighting factors based on their relevance and significance to bio-based value chains and growth of the bio-economy. (These weightings were decided upon review, analysis and identification of the above mentioned literature to determine the significance of these selection criteria to bio-based value chains. The weighting factors are presented in Table 2.

Table 2: Distribution of weighting to the "value-chain selection" criteria

Selection criteria	Weighting
Feedstock variability	0.2
Gaps in certification/ sustainability schemes	0.2
Multi-sector application	0.15
Variety in End-of-life options	0.2
Multi-regional supply chain	0.15
Preference within EU member states	0.1

The criteria that have been allocated a weighting of 0.2 are those that directly contribute to innovative or under-represented but resource efficiency value chains and subsequently, encourage the establishment of a circular economy. Criteria with a weighting of 0.1 (preference within EU member states) has been covered further with an elaborate evaluation under second round assessment (see section 3.2.2). The recommendations allocated to the different bio-based value chains taken into account with the weighting of the selection criteria supported value-chain ranking. The value chains selected via first round assessment, to progress to a second round of assessment are presented in the Results Section.

3.2.2 Second round of assessment

The second round assessment initiated with the collation of information, analysis and identification of national policies, bio-economy initiatives and growth plans established by individual EU member states. This review provides an insight into the bioeconomy strategy adopted by individual states based on their strengths (natural bio-resources) and capabilities (technology) and maturity level. Such information was expected to help identify the most promising value chains in circular economy landscape, against a backdrop of EU's circular economy goals. A list of initiatives and action plans associated with each of the EU member states is presented in the Supplementary Annex Section, 7. Upon collation, analysis and categorisation of these initiatives, information was drawn on the preference of these member states over the choice of feedstock, biorefining technology, current and desired products/ sector development and techno-economic or social optimisation routes. This information was used to calculate scores to specific value chains based on the preference demonstrated by the EU-wide bioeconomy strategies, the scores (as a % of total number of strategies), which have been presented in Table 3. A screenshot of the information collated and analysed as a part of the second round assessment is presented in Figure 9. The outcomes of this assessment are presented under Results and Discussion.

Table 3: EU value-chain preference scores as a function of strategy type and nature (as a % of total number of EU-bio-economy strategies)

Value chains targeted by the strategies	Strategy type	EU chain preference scores
Bio energy and fuel production	Renewable energy	0.74
Food and beverage production	Primary food production	0.6
Crop based primary production	using waste and residue	0.37
Animal based primary products	using waste and residue	0.32
Forest based primary production	using waste and residue	0.26
Bio-based material and plastics	Products/ Technology and research	0.26
Marine based primary production	Primary food production	0.2
Bio-based chemicals	Products/ Technology and research	0.21
Bio-based construction and furniture	Common conversion	0.2
Biorefinery	Products/ Technology and research	0.2
Cosmetics and health	Biomass conversion	0.17

STAR PRoBio T1.3: EU and member states initiatives towards Bioeconomy/ circular economy

Member state	Scheme	Year	Emphasis	Nature of initiative	Activities (description)	Other details
Italy	Italian Bioeconomcy strategy	2014-2020	Policy framework to prioritise funding	Policy	Ultimately lay down a policy framework to enable prioritisation of funding for research and innovation development in bio-based industry and agrifood initiatives (a part of the National Smart Specialisation strategy)	
EU	Marine Strategy Framework Directive	2015-2020	Fisheries	Policy	Achieve good environmental status (GES) through protection of the EU marine resource base (from pollution, contamination and over-explaoitation) on which the social and economic activities are embedded.	
EU	Circular Economy Package	2015-2020	Industrial manufacture	Implementation	Reduce pressure on natural resources by closing the loop for a product and inducing industrial symbiosis, where one industries waste turns into another industry's feedstock	
EU	Climate change strategy	2015-2030	Energy	Implementation	Increase share of renewable, clean energy while reducing overall energy footprint. Develop adaptive capacity to the effects of climate change	
Italy	Environmental Annex to the Stability Law	2014	Circular Economy via Green Public Procurement (GPP)	Policy	Use of GPP to implement a "environmental minimum" criteria through labelling and certification (Eco-label; Emas, Made gree in Italy) ; Monitor the impact of public policies on the natural resources; Creation of a natural capital committee to monitor natural biomass consumption Incentivise purchase of post-consumption materials to manufacture products; Incentives for self management of specific waste fraction; Incentives for increasing thier share of collected waste; Establishement of a system of payment to the eco-system and environmental services; Catalogue on Environmentally useful and harmful subsidies.	EU Commission Environment: Europe's public autho major consumers. By using their purchasing power t environmentally friendly goods, services and works, make an important contribution to sustainable consu and production - what we call Green Public Procuren (GPP) or green purchasing
Italy	Environmental minimum criteria - Green public procurement National Action Paln	2016	GPP	Policy	Companies and service providers to the public authority are required to adopt this to apply for public tenders	
Italy	National programe for waste reduction	2016	GPP	Potential measure	50% share of "green purchases"; valourisation of agri-sector by-products;	Green purchases - procurement of product services which upon consumption have a r impact on human health and environmenta compared to competitors products which se same purpose
Germany	New Products: made from nature	2012	Industrial manufacture	Information	Inform business community of the significance and opportunities of bio-based products (sourced from natural renewable material)	
Germany	National research strategy: bioeconomy 2030	2013	Overall	Policy		
Germany	Quality check- Stustainability standard project	2013	Manufacturers	Labelling / information	Product labelling on product's sustainability performance	
Germany	National Action plan for substance recovery from renewable raw material	2009-2010	Industrial manufacturers	Information/ research strategy	Research and development of techniques to recover useful material from biomass and application	
Germany	Biorefineries road map	2012	Information	Information	Development of an awareness on the present and future biorefining technologies	
					To facilitate dialogues between public and private sector to learn about thier perception of bioeconomy ;To coordinate programmes to facilitate the exchange	

Figure 9: A screenshot of information on the various national policies and bio-economy strategies undertaken by the EU member states and relevant bodies.

4 Results and discussion

A preliminary list of value chains was drawn from an assessment undertaken in Task 1.1 and Task 1.2, to enable the selection of four to five most promising value chains. The aim of this value chain selection is as follows:

- To identify the different types of value chains that are prevalent and have promising prospects in the EU member states, based on the individual member states preference for technology development targets and material utilisation.
- To identify, comprehend and map the dynamics of value chains, material flows and chain-actors;

The purpose of this assessment is to utilise the selected value chains setting a trajectory for the techno-economic, environmental and socio-economic evaluation of potential case studies (or an exemplary bio-based product) which will be identified as part of Task 1.4. These exemplary case studies will help develop a methodology for the multi-disciplinary product evaluation framework. This methodology is expected to provide a guiding framework for sustainability assessment of competitive bio-based products to qualify and create market-pull. A two-tier bio-based value-chain analysis was undertaken via a “weighting” to be able to identify and select the most promising value chains for further assessment and the outcome of the first round of assessment is presented in Table 4.

4.1 First round assessment

Table 4: Selection of bio-based value chains from first round "multi-criteria" assessment

Sector	Value chain	Score	Rank	Status
Chemical	Cellulose to bio-based solvents	7.44	1	Selected
Food Packaging	Starch to bio-plastics	7.25	2	Selected
Agriculture	Starch to bio-based mulch films	6.62	3	Selected
Fabrication	Starch to bioplastic framing material	6.09	4	Selected
Multiple sectors	Vegetable fats/ plant lipids to bio-based lubricants	5.50	5	Selected
Textile	Cellulose to fabric	5.50	6	Selected
Chemical	Solid biomass to fine chemicals	5.20	7	Selected
Construction	Waste agri. biomass to insulation material	4.78	8	Selected
Food packaging	Wood/ cellulose to plastic paper cups	4.37	9	-
Food packaging	Straw to food packaging	4.31	10	-
Construction	Solid biomass to wood-plastic composite	4.00	11	-
Agriculture	Algal polysaccharides to phytoprotectives	3.91	12	-

The most preferred bio-based value chains within the EU based on the previously identified criteria of Feedstock Variability, Supply Chain Boundaries, Variety in End-of-Life options, Gaps in Sustainability Schemes and Multi-sector application has been presented in Table 4. Bio-plastics, bio-based solvents, bio-lubricants, fabrics and fine chemicals followed by bio-based insulation material were chosen to progress to a second round of assessment. The top eight value chains were selected to account for the recurrence of bioplastics as the 2nd, 3rd, and 4th qualifying candidates in the selection, coupled with the goal of this task to ensure coverage of diverse bio-based value chains under this assessment.

4.2 Second round of assessment

Within the second round assessment, the eight bio-based value chains selected from the earlier analysis are subjected to a similar weighted scoring. This scoring is primarily based on the target-feedstock and technology preferences of the bio-economy initiatives and other relevant sustainability schemes established/ planned with an active interest to transform from a linear economy to circular bio-based economy.

In terms of feedstock preference, EU member states seemed to possess a clear strategy on utilising feedstock generated locally or nationally within minimalistic logistics complexities and not demanding an additional stream (land-conversion)/ infrastructure for feedstock generation (in other words, use excess and residual biomass). As a result, a majority of the initiatives indicated of their feedstock preference in the following order: agricultural (63%), forestry (35%), waste stream (organic waste from domestic and commercial waste) (25%). In terms of initiative, there are initiatives that either focus on pursuing innovative technology routes or prefer a combined approach to utilising biomass with innovative biomass transformation technologies. Preference of bio-based value chains based on the nature and goal of the initiatives assessed as a part of this study have been identified and ranked in Table 5.

Table 5: Selection of value chain from a second round of "initiatives-based preference" assessment

Sector	Value chain	EU chain preference scores	Final score	Rank
Food Packaging	Starch to bio-plastics	0.63	4.57	1
Agriculture	Starch to bio mulch films	0.63	4.17	2
Fabrication	Starch to frame material	0.63	3.84	3
Chemicals	Cellulose to bio-based solvents	0.47	3.50	4
Multiple sectors	Vegetable fats/ plant lipids to bio-based lubricants	0.58	3.19	5
Chemical	Solid biomass to fine chemicals	0.58	3.02	6
Construction	Waste agri. biomass to insulation material	0.57	2.72	7
Textile	Cellulose to fabric	0.31	1.71	8

It is evident that there is a greater emphasis on development and exploitation of bio-based solvents and plastics, in the conceived bioeconomy agenda and existing bio-based infrastructure. This is owing to their promising potential to create social, economic and environmental value, coupled with the current damage to the health and well-being of human/ global biodiversity presented by the petro-derived commercial counterparts, particularly from soil and marine pollution.

4.3 Mapping of bio-based value chains

Value chain maps are a valuable tool in analysing the scope and performance potential of a bio-based business model by breaking down the various process dynamics into logistics, sectors of application and embedded stakeholders. The strengths, weaknesses, costs and competition from other value chains in the production of specific commodities can be visualised via value chain maps, which is complemented by the flexibility and convenience of their development.

In this study, the purpose of an initial "cradle-to-grave" value chain mapping is to provide a generalised yet visual schematic of the dynamics including the resource flow and actors integrated within bio-based value-chains that have been chosen via the assessments above. The value chains have been divided into the following life-stages

1. Feedstock Production (or procurement);
2. Pre-treatment/ pre-processing;
3. Manufacturing – Conversion, refining and formulation;
4. Packaging;
5. Product consumption;
6. End-of life management.

For the selected bio-based value chains, the following chain characteristics have been deemed relevant to the above life stages. The characteristics are:

- Material/energy inputs and outputs , including potential products, co-products, waste and emissions;
- Sector-level contributions;
- Technology/ conversion routes;
- Chain-actors or stakeholders
- End-of life (variable) characteristics emphasising the fate of the outputs from each of the life cycle stages.

The outcomes of this task will pave the way for the selection of specific, process mapped case studies covered in Task 1.4, which will be used to test the effectiveness of the sustainability framework that is to be developed through WP2-WP8. A brief description of each of the value chain stages with further elaboration of the above-presented characteristics, is presented below for each of the selected value chain.

Feedstock production / procurement: Feedstock production/procurement stage depends on the nature of feedstock generated. For cultivated biomass (e.g. oilseeds, starch-rich feedstock), this stage will entail land preparation/conditioning and protection, seeding, maintenance and cultivation, harvest, clearing of the field to prepare the land for the next batch of crops, coupled with harvested biomass storage and handling. With forestry residue or organic agricultural waste (e.g. logs, remaining plant matter and straw), this stage would be termed "feedstock procurement" where the biomass is collected from its source point and stored before transport to the pre-treatment facility.

Before the discovery of fossil fuel, however, waste animal fat (whale oil) was used for bio-based lubricant synthesis. Currently bio-based lubricants are synthesised from oilseeds (e.g. Rapeseed, Camelina or sometimes, oil-rich microalgae) and other oil crops (e.g. Jatropha, Palm and Coconut). For algal biomass, the cultivation may occur either in open air ponds or closed algal bioreactors. Each have their own techno-economic benefits and issues.

Lignocellulosic biomass is the preferred choice of feedstock for bio-based fibres and chemicals. The cellulose and hemi cellulosic components provide the needed sugars for fermentation, leading to the synthesis of a huge array of commodity chemicals. On the other hand, natural wood fibre insulation boards, and other bio-based fibres can also be generated from such feedstock, in addition to their current utilisation in the paper and pulp industry.

Pre-treatment/ pre-processing: At this stage, the biomass (cultivated or residual) is subjected to a single-stage or multiple processes which may vary between simple (e.g. physical) to hybridised processes (e.g. thermochemical- microwave). The purpose of this stage is to prepare the biomass for the next stage of manufacturing, by breaking down the complex structure, exposing or re-arranging its components. Such a pre-treatment stage boosts biomass conversion rates and the rates of desired product formation (also reducing the amount of unreacted waste generated). This stage is significant, in particular, to the lignocellulosic feedstock (e.g. straw and forestry biomass) due to their complex structure and for the removal of lignin, which, if intact, affects the rate of conversion. This is of significance to their conversion to either basic or commodity chemicals. However these pre-treatment stages vary with the choice of desired product. Pre-treatment, in the case of production of insulation material or bio-textiles production, mainly involves separation of fibres via retting and decortication of raw biomass, followed by physical or chemical processes such as steam explosion in preparation of following phases.

For bio-based lubricants, this stage involves extraction of the bio-crude (raw bio-oil) from the oilseeds and potentially algal biomass. The process for extraction of oil from algal biomass is complex and depends on the type of the method employed (e.g. dry or wet).

Manufacturing - Conversion and formulation: This is the phase where the key transformation of biomass or biomass drawn platform molecules to the desired product (either intermediate or end-product) occurs. The associated technology route, at this stage, varies with the product synthesised. The rate of conversion efficiency improves with technological maturity and innovation over time. The refining stage involves extraction of the desired product compounds from mixed medium (e.g. via filtration) though the requirement for this stage, again, varies with the product under study.

Packaging: The desired product is packaged using material based on the nature of the product synthesised.

Consumption: At this stage, it is essential to take into account which market the value chain is dedicated to. For instance, end-products will be utilised by domestic consumers, industrial and commercial consumers. For intermediate products, there will be a secondary industry which may utilise platform chemicals to synthesise a secondary product, thereby introducing a second manufacturing stage. Intermediate products include value-added products like purified anhydrous sugars, pigments, dyes and surfactants. End-chemical products may include adhesives, advanced polymers, industrial detergents and personal care preparations.

End-of life management: This stage is of immense significance to any circular economy strategy. It is crucial to acknowledge that the end-of-life options and their techno-economic environmental impact must be accounted for not only at the end of the value-chain. All life cycle stages have an output waste stream the fate of which must be accounted for via "end-of life" analysis. The key end-of-life characteristics that are considered in the bio-based value chains presented in this section, have been presented in Figure 10.

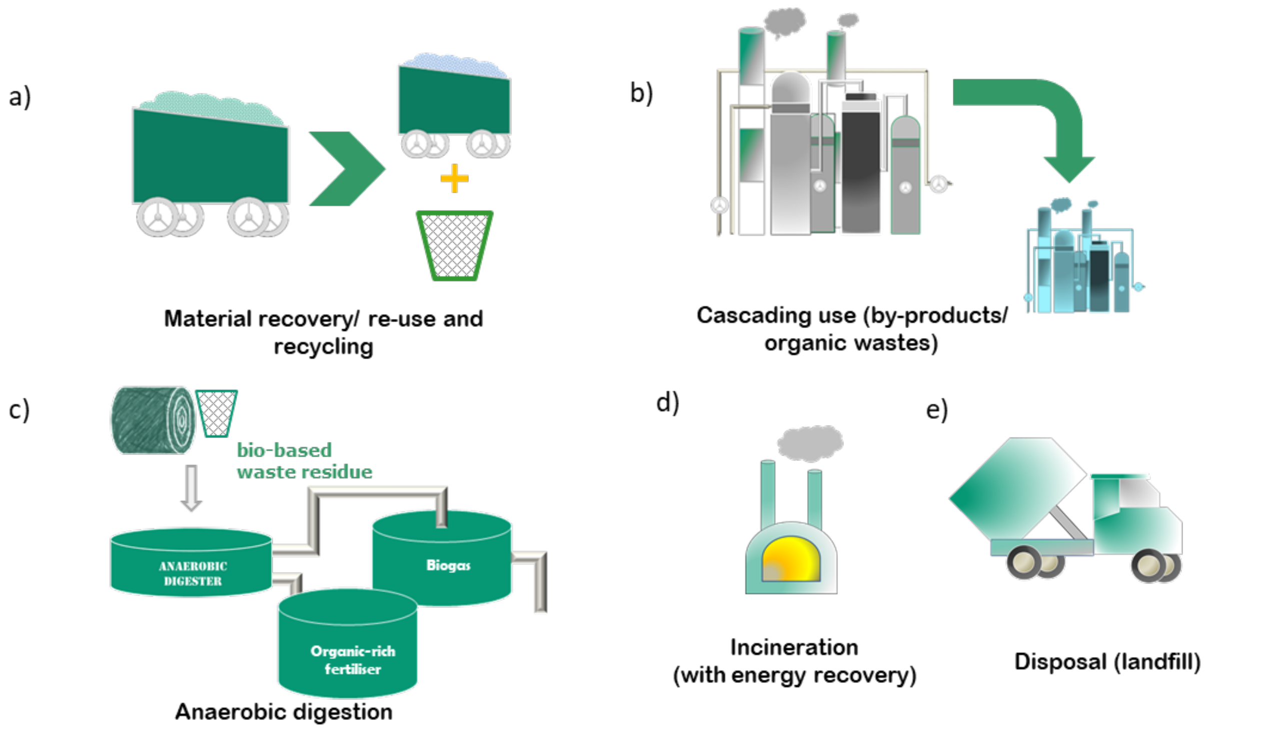

Figure 10: Potential product "End of life" management for circularising value chains.

According to the EU waste hierarchy, the most preferred option is to prevent waste followed by the potential to recover and re-use, recycling, other means of recovery (e.g. anaerobic digestion and incineration) and finally disposal (landfill), the least preferred option. Waste derived value-added products contribute to overall waste reduction/ prevention. However, the output stream from each of these value chain stages is likely to have some amount of waste. Among the waste generated, the reusable fraction is recovered, and this fraction, may re-enter the value chain, to be transformed into the new product. Alternatively this fraction may be utilised in secondary industries to be transformed into a completely different bio-based product, which is also called cascading use. Agricultural residue, livestock waste, urban wastewater and other anaerobically biodegradable components of the products after conversion can be subjected to anaerobic digestion, leading to the generation of biogas (an energy carrier). The digestate from the process can be used as manure for crop cultivation. Alternatively, used hazardous bio-based products (e.g. healthcare waste), irrecoverable and useable products may be incinerated which also contributes to energy recovery.

In the case of bio-plastics, non-biodegradable candidates may be recycled and reproduced. In most cases, the manufacturing companies may have a waste management infrastructure, contractors or work in collaboration with the local authorities for waste collection, recovery and re-use.

The selected bio-based value chains have been mapped to acquire full (general) coverage of the resource flows, technology/ conversion routes employed the various stakeholders and the fate of the products or the other waste streams that may result from the value chain. These schematics have been presented in Figure 11-Figure 14.

4.3.1 Bio-based chemicals

The market for bio-based chemicals in general is worth $6 billion and at a projected annual growth rate of 16.16%, the market is expected to reach $27 billion by 2025 [25]. Bio-based chemicals include a broad spectrum of products, which may be classified as commodity chemicals, intermediate chemicals and speciality chemicals, based on their application. Commodity chemicals refer to the "high volume-low value" products, sourced from biomass (but not restricted to), such as fatty acids, methyl esters and alcohols. Intermediate products refer to the refined sugar complexes, basic (building block) polymers, pigments/ dyes, plant oils and other types of starches. Speciality chemicals, synthesised either independently from plant or prepared from intermediate chemicals includes bio-based chemicals such as advanced polymers solvents and other preparations for final formulation in personal care products, pharmaceuticals, paint coatings, additives, domestic/ industrial detergents and other applications.

In particular, bio-solvents are broadly classified into plant based alcohols, diols, organic acids, glycols and many more. From an economic perspective, according to the above mentioned report (Research Zion, 2017), the global bio-based solvent market was worth roughly 6 billion USD in Dec 2016 and it is currently projected to grow at a CAGR of 7.8% reaching 9 billion by 2024 . The versatility of bio-based chemicals, particularly bio-based solvents (for example, in pharmaceutical, cosmetics, agriculture, cleaning, printing inks and adhesive applications), and demand/room for innovation and product development, coupled with stringent regulations on hazardous pollutants released from use of conventional chemicals have fostered increased research interests and financial investments via national programmes and government support. Moreover, the feedstock variety that can be used to generate a myriad of bio-based chemicals makes these value chains innovative and techno-economically viable, in addition to their improved environmental performance.

[25] Research, Zion Market, "Global Bio-Solvents Market Will Reach USD 9.43 Billion by 2022: Zion Market Research", GlobeNewswire News Room, September 22, 2017. http://globenewswire.com/news-release/2017/09/22/1131467/0/en/Global-Bio-Solvents-Market-Will-Reach-USD-9-43-Billion-by-2022-Zion-Market-Research.html.

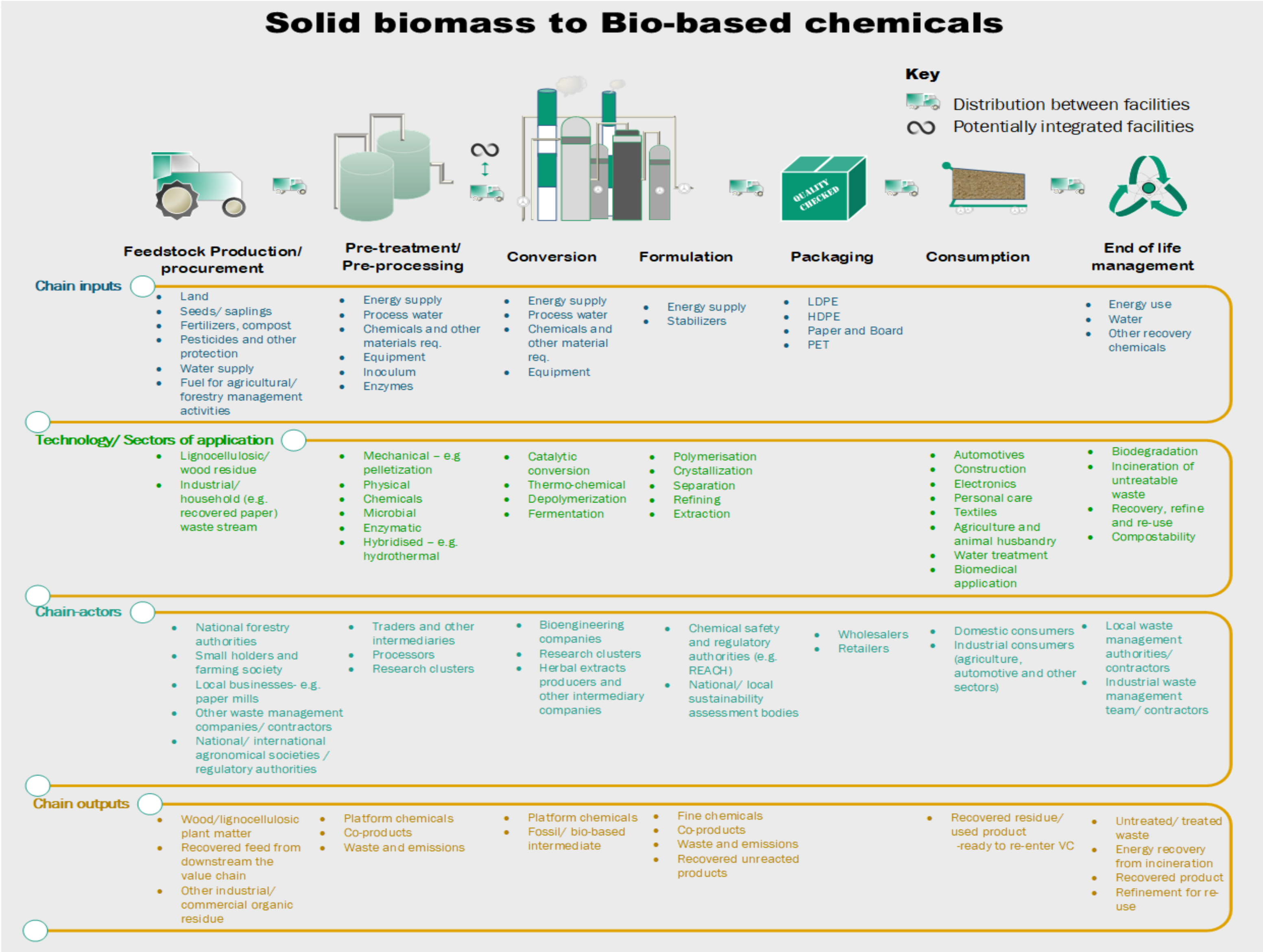

Figure 11: Value chains for solid biomass to bio-based chemicals, mapped for material flow, technology routes and stakeholders

4.3.1 Bioplastics

EU-preference to develop a manageable and multifunctional bioplastic category for the commercial market stems from the rapid and unsustainable consumption of conventional plastics for a variety of purposes, at a global level [26]. In addition, the discovery of alarming levels of micro plastics in our food sourced from soil, water and sea, led to the awareness of the interactions between the plastic degradation and environment (bioaccumulation)[27]. It is evident from a number of initiatives, listed in the supplementary annex, that all target at withdrawal from fossil-based resources over the next decade with particular focus on energy and plastic consumption. Unlike a decade ago, modern bioplastics are catching up with bio-based solvents in terms of multi-sectoral application (including packaging, agriculture, cosmetics, electronics, construction and automotive)[28]. Evidence of encouragement of bio-based product development and growth can be seen from a plenary meeting of the European parliament that voted in favour of "biodegradable mulch films" during the revision of EU Fertiliser Regulation [29] and a recent increase in "big-brands" adopting bio-plastics to appeal to their prominent (high spending power coupled with relatively high environmental awareness) consumer base [30].

[26] Greene, Joseph P., "Biobased and Biodegradable Polymers", Sustainable Plastics, John Wiley & Sons, Inc., 2014, pp. 71–106. http://dx.doi.org/10.1002/9781118899595.ch4.
[27] Carrington, D, "Plastic Fibres Found in Tap Water around the World, Study Reveals", The Guardian, September 5, 2017, sec. Environment. http://www.theguardian.com/environment/2017/sep/06/plastic-fibres-found-tap-water-around-world-study-reveals.
[28] Greene, Joseph P., "Sustainable Plastic Products", Sustainable Plastics, John Wiley & Sons, Inc., 2014, pp. 145–186. http://dx.doi.org/10.1002/9781118899595.ch7.
[29] Schwede K, "European Parliament Supports Use of Biodegradable Mulch Films", European Bioplastics e.V., n.d. http://www.european-bioplastics.org/european-parliament-supports-use-of-biodegradable-mulch-films/.
[30] European Bioplastics.org, Bioplastics : Facts and Figures, Berlin, Germany, 2016. http://docs.european-bioplastics.org/publications/EUBP_Facts_and_figures.pdf.

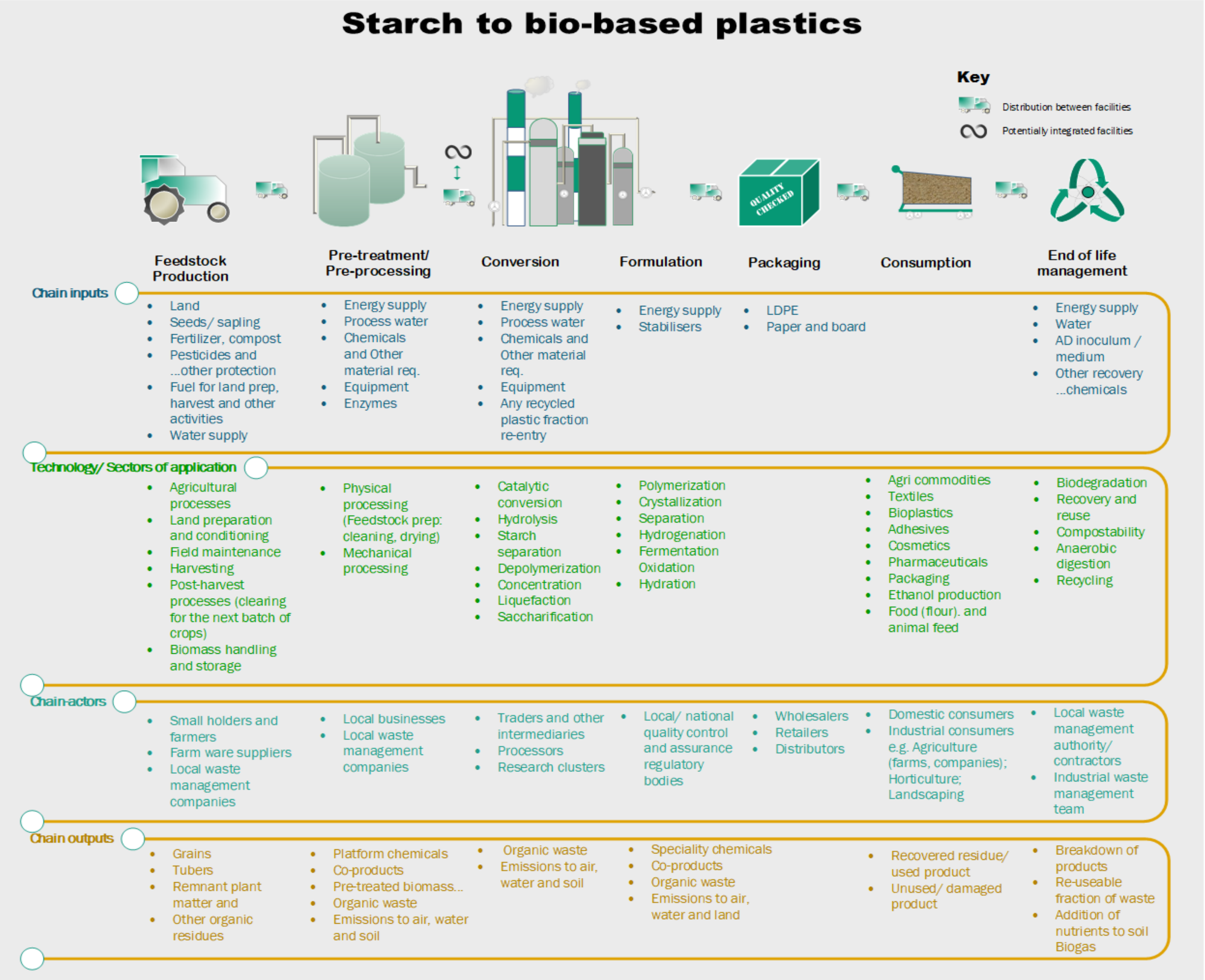

Figure 12: Value chains for starch to bio-based plastics, mapped for material flow, technology routes and stakeholders

4.3.1 Other bio-based products

Bio-lubricants, predominantly synthesised from oil crops, find application in the domestic, industrial, automotive and aviation industry. Among the 220 EU-28 biorefineries assessed as a part of the study undertaken by the Bio-based industries consortium and Nova institute (Figure 4), 20% are dedicated to the manufacture of oleochemicals from plant-derived fats. Environmental concerns and strict standards for management of leakage, maintenance and disposal of unused fossil-derived lubricants provides evidence for the growth and development of this sector. A EU-H2020 funded project entitled FIRST2RUN [31], is dedicated to the identification and development of integrated bio refineries that utilise low-input, under-utilised oil crops, grown in marginal lands to synthesise bio-lubricants and bioplastics from vegetable oil. Besides valorisation of marginal lands and low-input biomass, this project envisages the capability of such a value chain to create a skilled labour pool, generate other bio-based products and energy (composting unused parts of the plants), thereby revitalising the local economy.

Agricultural waste transformed into green, low-environmental impact insulation material was the conventional technology until the discovery of fossil resources, which gave rise to relatively inexpensive polymers and materials (e.g. polyurethane, mineral wool). However, some environmental and human health concerns are associated with these insulation materials (from long-term release of aerosols and vapour) such as respiratory issues and eye and skin irritation, particularly in the case of foam insulations. Natural fibre insulation such as cotton wool and wood fibre boards have been identified to perform similarly to their petroderived counterparts and are particularly advantageous with regards to complying with any environmental building certification schemes [32]. Bio-based binders and other additives, such as Polylactic acids (PLA) and Polyhydroxyalkanoates (PHA) generated from other starch-based value chains, may be utilised in the preparation of these insulation materials. Dry lignocellulosic biomass can also be processed into compressed fibres for dashboard panels, geotextiles and animal bedding[33].

[31] Bio-based Industries Consortium, "FIRST2RUN | Bio-Based Industries Consortium", 2017. http://biconsortium.eu/library/case-studies/first2run.

[32] Carus, M, A Eder, L Dammer, K Korte, L Scholz, R Essel, E Breitmayer, and M Barth, "WPC/NFC Market Study 2014; Wood-Plastic Composites (WPC) and Natural Fibre Composites (NFC)", Nova Institute, 2014. https://compositesuk.co.uk/system/files/documents/WPC-NFC-Market-Study-Short-Verson%202015.pdf.

[33] Alkhagen, M, A Samuelsson, F Aldaeus, M Gimaker, E Ostmark, and A Swerin, "Roadmap 2015-2025: Textile Material Form Cellulose", RISE Research Institute of Sweden, 2015.

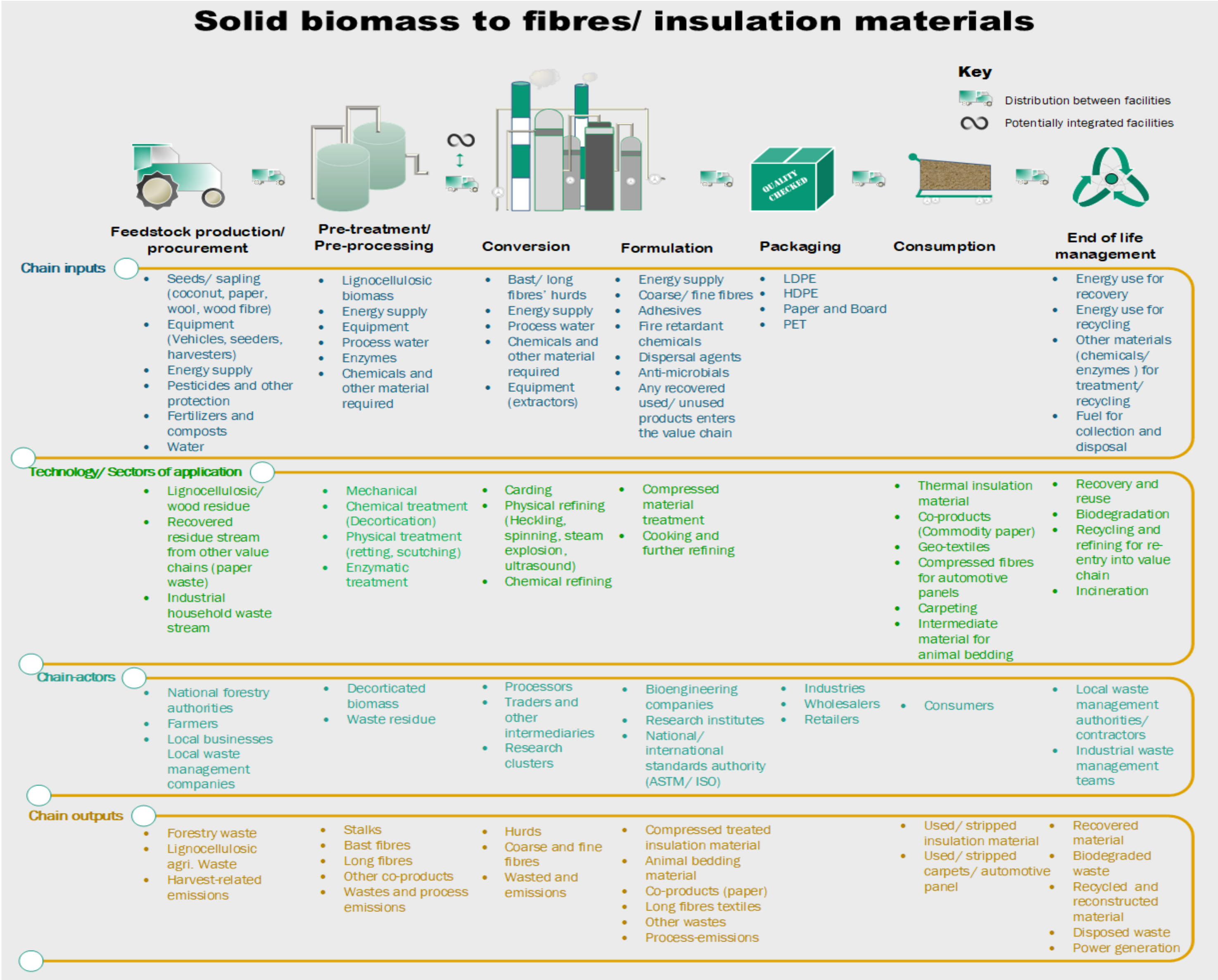

Figure 13: Value chains for solid biomass to insulation material, mapped for material flow, technology routes and stakeholders

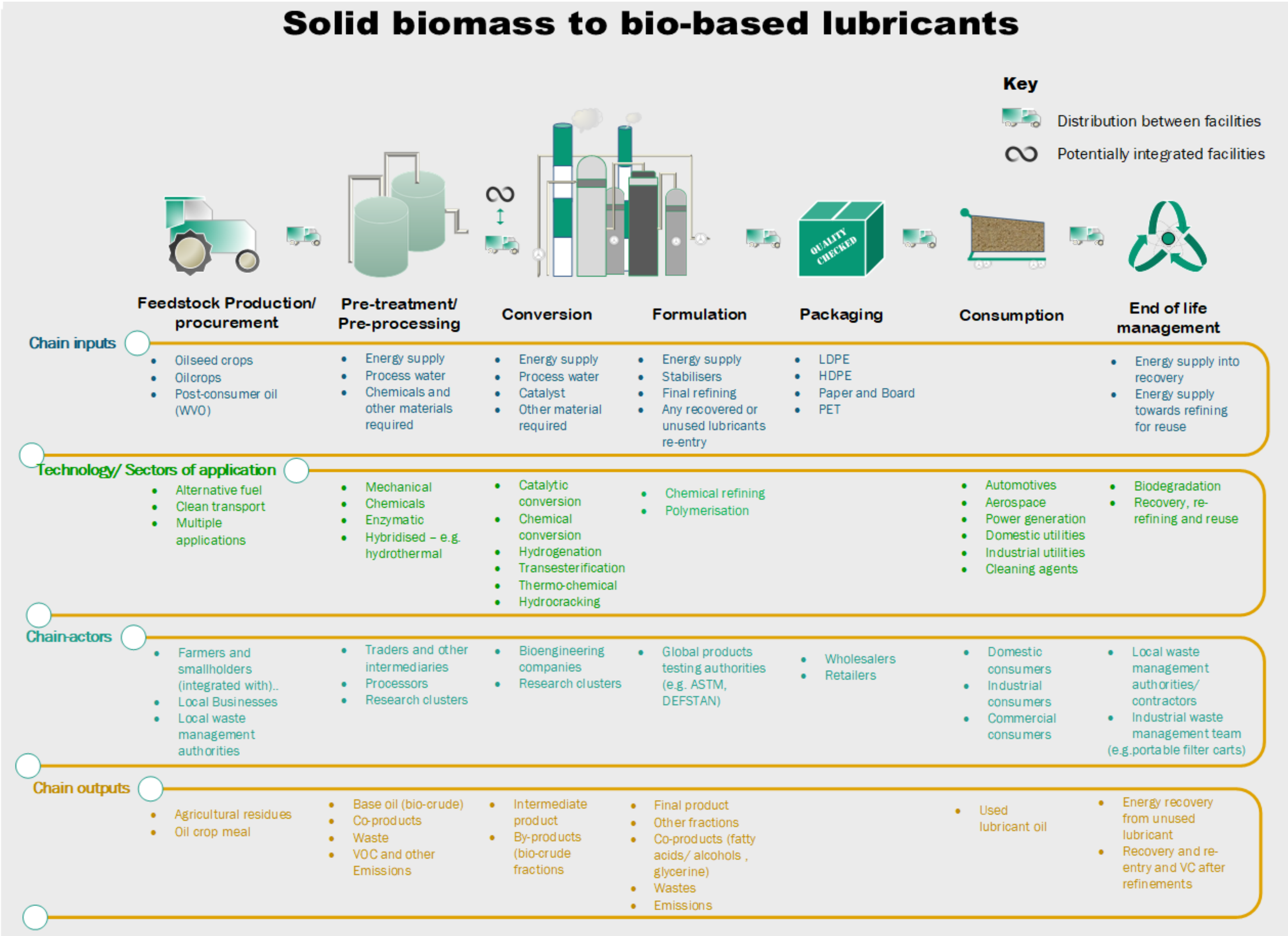

Figure 14: Value chains for solid biomass to bio-based lubricants, mapped for material flow, technology routes and stakeholders

4.4 Limitations of mapping

Value chain maps can be laborious and time-consuming to develop, depending on the complexity of the value chain under analysis. The map is only an informative tool for the visualisation of bio-based business models, identification of market opportunities and the scope of the value chain. It may not be able to highlight any changes in the dynamics associated to the factors (chain actors, inputs/ outputs and technology routes) presented in the chain.

For this study, the mapping has been carried out to highlight, in general, probable material, wastes/ emissions, conversion / refining routes associated with a given feedstock and end bio-product synthesised from it. These maps do not provide explicit information on coverage of these value chains by specific sustainability schemes / certification programmes as there are diverse products and co-products that could be produced as a part of the value chain. To establish this level of detail, the goal, scope and the product of analysis would have to be established beforehand.

5 Conclusions

EU-based bioeconomy and bio-based value chains are diverse in nature and are not restricted to those value chains that have been considered in this study. The preliminary list of value chains was selected along with the STAR-ProBio consortium members based on their relevance and significance to the bioeconomy, their current activity level/ contribution and potential for growth and coverage by various sustainability and certification schemes. In preparation for the selection of case studies in Task 1.4, four to five exemplary bio-based value chains have been selected to ensure the representation of EU's diverse bio-based value chains and eventually product spectrum to contribute to the development of a harmonised sustainability assessment framework, which is the ultimate aim of STAR-ProBio. The selection of these value chains has been made based on key factors including choice of feedstock, degree of coverage by sustainability assessment schemes, preference within the EU member states, cascading use capabilities of the value chains and, variety of end-of-life options (with regards to the end-products). Value chain maps highlighting the integrated activities, actors and technology, in addition to the material flow, have provided a foresight of the scope and qualitative performance potential (in socio-economic and environmental terms) within each of the life cycle stages. Further information and modelling of interactions between the chain actors, socio-economic and environmental impact quantifications and the balance in the flow of materials into and out of a given value chain will be undertaken in the upcoming multi-disciplinary studies captured under the different work-packages (WP1-7) of this project.

6 Reference list

- European Commission, "Directive 2008/98/EC on Waste (Waste Framework Directive) - Environment - European Commission", n.d. http://ec.europa.eu/environment/waste/framework/.
- Costenoble, O, "Open-Bio: Opening bio-based markets via standards, labelling and procurement: Final-Report-Open-Bio.pdf", n.d. http://www.biobasedeconomy.eu/app/uploads/sites/2/2017/07/Final-report-Open-Bio.pdf.
- European Commission, "Landfill Waste - Environment - European Commission", n.d. http://ec.europa.eu/environment/waste/landfill_index.htm.
- Bio-based Industries consortium, "Mapping European Biorefineries | Bio-Based Industries Consortium", n.d. http://biconsortium.eu/news/mapping-european-biorefineries.
- "NatureWorks Creates Performance Chemicals Division and Launches Vercet Product Line - Bio-Based News - The Portal for Bio-Based Economy & Industrial Biotechnology", *Bio-Based News*, June 27, 2017. http://news.bio-based.eu/natureworks-creates-performance-chemicals-division-and-launches-vercet-product-line/.
- Alkhagen, M, A Samuelsson, F Aldaeus, M Gimaker, E Ostmark, and A Swerin, "Roadmap 2015-2025: Textile Material Form Cellulose", RISE Research Institute of Sweden, 2015.
- Association of Plastics manufacturers Europe, "Plastics- the Fact 2016 : An Analysis of European Plastics Production, Demand and Waste Data", . Information, Belgium, 2016. http://www.plasticseurope.org/documents/document/20161014113313-plastics_the_facts_2016_final_version.pdf.
- Carus, M, A Eder, L Dammer, K Korte, L Scholz, R Essel, E Breitmayer, and M Barth, "WPC/NFC Market Study 2014; Wood-Plastic Composites (WPC) and Natrual Fibre Composites (NFC)", Nova Institute, 2014. https://compositesuk.co.uk/system/files/documents/WPC-NFC-Market-Study-Short-Verson%202015.pdf.
- CEN European Committee for Standardization, "PD CEN/TS 16398:2012: Plastics. Template for Reporting and Communication of Biobased Carbon Content and Recovery Options of Biopolymers and Bioplastics. Data Sheet", CEN, November 2012.
- CEN European Committee for Standardization, "PD CEN/TS 16398:2012: Plastics. Template for Reporting and Communication of Biobased Carbon Content and Recovery Options of Biopolymers and Bioplastics. Data Sheet", CEN, November 2012.
- CEN, CEN/TS 16137:2011: Plastics. Determination of Bio-Based Carbon Content, Standard, CEN, 2011.
- Carrington,D, "Plastic Fibres Found in Tap Water around the World, Study Reveals", *The Guardian*, September 5, 2017, sec. Environment. http://www.theguardian.com/environment/2017/sep/06/plastic-fibres-found-tap-water-around-world-study-reveals.
- EUBIO_Admin, "Market Drivers", *European Bioplastics e.V.*, n.d. http://www.european-bioplastics.org/market/market-drivers/.
- European Bioplastics.org, *Bioplastics : Facts and Figures*, Berlin, Germany, 2016. http://docs.european-bioplastics.org/publications/EUBP_Facts_and_figures.pdf.
- European Commissions, "Towards a Circular Economy", Text, European Commission - European Commission, n.d., 2017, https://ec.europa.eu/commission/priorities/jobs-growth-and-investment/towards-circular-economy_en.
- European Parliament, *Circular Economy Package : Four Legislative Proposals on Waste*, Briefing: EU legislation in progress, 2016.

- Fritsche, Uwe R., and Leire Iriarte, "Sustainability Criteria and Indicators for the Bio-Based Economy in Europe: State of Discussion and Way Forward", *Energies*, Vol. 7, No. 11, October 24, 2014, pp. 6825–6836.
- Greene, Joseph P., "Biobased and Biodegradable Polymers", *Sustainable Plastics*, John Wiley & Sons, Inc., 2014, pp. 71–106. http://dx.doi.org/10.1002/9781118899595.ch4.
- Greene, Joseph P., "Sustainable Plastic Products", *Sustainable Plastics*, John Wiley & Sons, Inc., 2014, pp. 145–186. http://dx.doi.org/10.1002/9781118899595.ch7.
- Gurría, P, T Ronzon, S Tamosiunas, R López, S García Condado, J Guillén, NE Cazzaniga, et al., *Biomass Flows in Thr European Union*, Technical report, European Commission Joint Research Centre, Seville, Spain, 2017.
- Jerome, François, and Rafael Luque, *Bio-Based Solvents*, John Wiley & Sons, 2017.
- Majer, S, D Moosman, S Wurster, and L Ladu, Report on Identified Environmental, Social and Economic Criteria/indicators/ Requirements and related "Gap Analysis", Deliverable 1.1, December 11, 2017.
- Meyer-Kohlstock, Daniel, Tonia Schmitz, and Eckhard Kraft, "OrganicWaste for Compost and Biochar in the EU: Mobilizing the Potential", *Resources*, Vol. 4, No. 3, June 25, 2015, pp. 457–475.
- Neaţă, Gabriela, Mona Popa, Amalia Mitelut, Silvana Guidea, and Bela Pukanski, "Bio-Based Composite Use in Fertilization of Petunia and Carnation Culture", *Scientific Bulletin. Series F. Biotechnologies*, 2012. http://biotechnologyjournal.usamv.ro/index.php/scientific-papers/80-art5.
- Research, Zion Market, "Global Bio-Solvents Market Will Reach USD 9.43 Billion by 2022: Zion Market Research", *GlobeNewswire News Room*, September 22, 2017. http://globenewswire.com/news-release/2017/09/22/1131467/0/en/Global-Bio-Solvents-Market-Will-Reach-USD-9-43-Billion-by-2022-Zion-Market-Research.html.
- Schwede K, "European Parliament Supports Use of Biodegradable Mulch Films", *European Bioplastics e.V.*, n.d. http://www.european-bioplastics.org/european-parliament-supports-use-of-biodegradable-mulch-films/.
- Spatial Foresight, SWECO, ÖIR, Nordregio, Berman Group, and Infyde, Bioeconomy Development in EU Regions. Mapping of EU Member States'/regions' Research and Innovation Plans & Strategies for Smart Specialisation (RIS3) on Bioeconomy for 2014-2020, Information, DG Research & Innovation, European Commission, Brussels, 2017. https://ec.europa.eu/research/bioeconomy/pdf/publications/bioeconomy_development_in_eu_regions.pdf.

7 Supplementary information

7.1 Bioeconomy strategies established within the EU-member states

Member state	Scheme	Year	Emphasis	Nature of initiative
Austria	Eco-Electricity act	2011	Renewable energy generation	Policy and implementation
Czech republic	Czech republic bioeconomy initiative	2013	General plan for bioeconomy	Action plan
Denmark	Growth plan for water, bio and environmental solutions	2013	Knowledge and production based for bio-based product, create a market pull	Innovation and creation of demand
Estonia	Development Plan on the Promotion of Biomass and Bioenergy Use for 2007–2013	2015-2021	Development of domestic biomass for bioenergy use and reduce dependence on fossil energy	Action plan
EU	Marine Strategy Framework Directive	2015-2020	Fisheries	Policy
EU	Circular Economy Package	2015-2020	Creating industrial symbiosis between various sectors and closing the material loop	Implementation
EU	Climate change strategy	2015-2030	Increase share of renewable, clean energy while reducing overall energy footprint. Develop adaptive capacity to the effects of climate change	Implementation
EU	Single Market strategy	2015	Not precisely targeting bioeconomy development but has relevant measures	Policy strategy including a number of measures
EU	Promotion of sustainable mobilisation of wood	2007-ongoing	Policies for management of wood resources	Policy and implementation
EU	Energy Union	2014-ongoing	Energy security and efficiency	Policy and implementation
Finland	Rural Development Programme of Mainland Finland	2007-2013	Not precisely targeting bioeconomy development but has relevant measures	Identifying innovative measures to fund and develop further

France	New Industrial France Policy	2013	Industrial bioeconomy plan	34 Industrial plans available to promote the industrial sector down the green chemicals and energy path
France	National waste plan	2014-2020	Waste reduction targets	Plan and implementation
France	French Chemical industry road map	2013	-	-
France	Action plan for wood processing industries	2013	Sustainable forestry resource management : research and innovation	-
Germany	New Products: made from nature	2012	Inform business community of the significance and opportunities of bio-based products (sourced from natural renewable material)	Information
Germany	National research strategy: bioeconomy 2030	2013	Inform business community of the significance and opportunities of bio-based products (sourced from natural renewable material)	Policy
Germany	Quality check-Sustainability standard project	2013	Product labelling on product's sustainability performance	Labelling / information
Germany	National Action plan for substance recovery from renewable raw material	2009-2010	Research and development of techniques to recover useful material from biomass and application	Information/ research strategy
Germany	Biorefineries road map	2012	Development of an awareness on the present and future bio refining technologies	Information
Hungary	National Environmental Technology Innovation Strategy	2011		Industrial sector implementation
Ireland	TEAGASC: The agriculture and food development authority	2008	Research and innovation in the agri-food sector via stakeholder engagement	Research and innovation investment
Ireland	Ireland waste management policy	2012-ongoing	Policies and implementation for waste management	
Italy	Italian	2014-	Policy framework to	Policy

	Bioeconomy strategy	2020	prioritise funding for bio-based industries and agro-food sector	
Italy	Environmental Annex to the Stability Law	2014	Circular Economy via Green Public Procurement (GPP)	Policy
Italy	Environmental minimum criteria - Green public procurement National Action Plan	2016	Companies and service providers to the public authority are required to adopt this to apply for public tenders	Policy
Italy	National programme for waste reduction	2016	50% share of "green purchases"; valorisation of agri-sector by-products;	Potential measure
Latvia	Bioeconomy strategy under development	-	-	-
Netherlands	Program Biobased Economy (BBE)	2012	Technological innovation and market development along all biomass value chains, mainly vegetable and animal biomass for non-food applications (materials, chemicals, energy and biofuels)	Co-ordination and management function within the government
Netherlands	Biorenewables Business Platform (BBP)	2010	Sustainable production of biomass, sustainable import chains, co-production of biochemical, biomaterials and biofuels, production of green gas, innovations in biochemical	Multi-stakeholder platform promoting structural changes in the agro and industrial sectors and in the energy supply
Netherlands	Platform Agro-Paper Chemistry	2011	Lignocellulose as a raw material. Chemical building blocks from plants. Protein cascading	Industrial partnership of agrifood, paper and chemical industries
Netherlands	Bio based Business accelerator	2012	Energy, waste & organic residues, materials, (fine) chemistry, food, agro, water and green space	Network of companies, governments, knowledge institutions and intermediaries / service providers
Netherlands	Dutch Biorefinery Cluster	2014	Concept of total merit of the raw materials and residual flows: Water, fiber, protein and minerals, etc	Multi-stakeholder initiative driven by business with support of research institutions and government agencies

Netherlands	Action plan for increasing resource efficiency	2012	General material use efficiency	Action plan
Slovenia	Strategy of Agriculture	2012-2020	Focus on food-security, sustainable production, products form agri-food industry other than food and feed and sustainable rural development	Action plan
Slovenia	Rural development plan	2014-2020	Sustainable supply and use of renewable energy sources and agri-food resources	Action plan
Spain	Spanish Bioeconomy strategy – 2030 Horizon	2016	Strategic advancement and maintenance of competitiveness in efficient use of agricultural by-products and agro-forestry products like wood, cork, resin and timber for paper and other bio-based products. Potential for use of agricultural by-products comes from responsible intensification and sustainability of the primary food production systems	Implementation
Sweden	Swedish Research and Bioeconomy strategy	2012	General bioeconomy plan	Research and innovation strategy ; No strategy available as yet.