BIOVOICES

CONNECTING BIO-BASED FORCES FOR A SUSTAINABLE WORLD

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Connecting Biobased Forces for a Sustainable World

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EXECUTIVE SUMMARY

This report presents an overview of the existing barriers and opportunities to commercialise bio-based applications in Europe as described in current literature, to indicate key issues in the transition to the bio-based economy. As the focus of BIOVOICES is on the market perspectives of application sectors, the aim is to select commercial applications which are relevant for different stakeholders to share their perspectives, knowledge and experiences for mutual learning.

Unravelling and describing key processes that contribute to the generation and diffusion of innovations gives more insight into the transition towards a bio-based circular economy, in particular bio-based applications that are going to the take-off phase, when it is more likely to discuss personal benefits and a broader set of environmental benefits among the quadruple helix actors. The idea of the quadruple helix model is that stakeholders from civil society, industry, academia and governments are needed to co-create the future and drive structural changes far beyond the scope of what any one organisation or person could do alone.

The results of our study show that in nearly each bio-based application sector there are products in the phase of take-off. A few applications are still in a phase of (pre)development (biomedical and 2G/3G biofuels and bioenergy), while there are also some applications in which bio-based components have been included already for a long time (construction, furniture & textile). The potential market size has been hypothesized by whether the focus of the product concepts and communication is on small groups (niches) of consumers or on all consumers. The distinction between niches and mainstream groups of consumers is important for the quadruple helix actors. While most of these actors are absent in the case of niches, and the challenge is to increase the relationships among them, in the case of mainstream consumers all the quadruple helix actors might be active, but not always collaborating. Here the challenge is to improve the current relationships among the actors.

The contribution of CSOs and citizens to the bio-based circular economy could be enlarged by paying more attention to their role as protectors and decision-makers to stimulate appropriate waste-behaviour for re-using and re-cycling of (bio-based) products. In remote regions, the community may play a significant role to contribute to the development of bio-based value chains in an entrepreneurial role. Governments could stimulate bio-based applications which are relevant for mainstream consumers by stimulating a shared vision and more coordination of policies.

Although the societal benefits of speeding up the development of a larger market for bio-based products are largely understood, the transition towards a European bio-based economy is proceeding slowly. Numerous challenges need to be overcome, both in the policy, social and technological-economic realms to further commercialise bio-based products and eventually realise a societal transition from fossil fuel dependency to a bio-based economy. Therefore it is important to take into account the perspectives of all helixes on the take-off and/or acceleration phase, i.e. more on innovation, demonstration and marketing of bio-based products to the demands of users/civil society instead of the development of products as such. In Chapter 7 we have developed an agenda from the perspective of all quadruple helixes that could be helpful for the co-creation events in 2018-2020.

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1 INTRODUCTION

The bio-based economy refers to the usage of renewable natural resources such as wood and crops for fuel and materials such as packaging and furniture. A larger market size of bio-based products would lower the usage of fossil fuels and chemicals and therefore contribute to a more sustainable society. Despite these benefits the transition towards a European bio-based economy is proceeding slowly due to several innovation challenges. For example, converting to bio-based value chains may entail high investments for businesses. Moreover, studies indicate that bio-based content alone does not justify a premium price for consumers who require personal benefits. Also public procurement agents are not convinced to get a broader set of environmental benefits (Meeusen et al., 2015a).

Multi-actor approaches are needed to identify and address the innovation challenges for bio-based value chains. Insights into interests, aspirations, barriers and perceived risks of different stakeholders' are needed in order to maximise the benefits and lower the investments of new bio-based business models within society. **In this context, BIOVOICES' overall aim is to ensure the engagement of all relevant stakeholder groups and to address and tackle bio-based related challenges by establishing a multi-stakeholder platform.** Involving a plurality of actors (voices) with different perspectives, knowledge and experiences, and animating open dialogue and mutual learning between the stakeholders will bring the development of bio-based value chains further (see www.biovoices.eu).

The goal of Task 3.1 is to provide BIOVOICES with an overview of the existing barriers and opportunities to commercialise bio-based applications in Europe as described in current literature. The main objectives are:

- to review the factors that hinder or support a proper development of bio-based value chains (e.g. bio-based plastics, fibres, bio-surfactants and bio-fuels) through a synthesis of market perspectives of several application sectors (e.g. packaging, construction etc.).
- to formulate key issues that require collaboration along the bio-based value chain.

As the focus of the project is on the market perspectives of application sectors, the aim is to select commercial applications which are relevant for different stakeholders to share their perspectives, knowledge and experiences for mutual learning.

The results of this study will be used by the partners of the BIOVOICES consortium to consider local transition issues for the commercialisation of bio-based applications in their region. As such, this document gives guidance in the search of topics that will be discussed during the co-creation events that will take place in 2018-2020 (see WP 6). This review is a pure desktop study, based on an inventory of literature and bio-based project outcomes, to indicate key issues in the transition to the bio-based economy. Documentary sources include international and national practice-based literature and scientifically reviewed bio-based project outcomes related to one or more bio-based value chains. It analyses the factors affecting the market, public awareness and acceptance of applications derived from bio-based value chains. Therefore, it will address the following issues:

- the transition to the bio-based circular economy as a main rationale for stimulating the development of sustainable bio-based value chains and its applications (Chapter 2).
- the market potential of bio-based application sectors (e.g. packaging, construction etc.) and input from bio-based materials (e.g. polymers, fibres, surfuctacts) (Chapter 3);
- the governance structures to develop a bio-based value chain (Chapter 4),
- the policies (environmental, social, trade measures, legislations, etc.) (Chapter 5);
- the enabling factors and barriers to develop bio-based applications (Chapter 6);
- a summary of key issues that can be discussed during the co-creation sessions (Chapter 7).

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2 SETTING THE SCOPE: TRANSITION TO BIO-BASED CIRCULAR ECONOMY

2.1 INTRODUCTION

The bio-based economy relies on the conversion of renewable natural resources such as wood and crops into non-food products and materials. The materials can be used in a wide range of sectors, including construction, paper and paperboard, textile and chemicals, as well as energy. Biomass (such as starch, sugar, cellulose, lactic acid and protein) is plant material (of maize, beet, sugar cane, wood (chips), potato and algae) from second or higher generation (2G) feedstock in Europe or first generation (1G) feedstock produced on lands not-used for edible biomass/food crops (e.g. margin lands and sea water). Biomass can be used both for food and non-food applications, the so-called "bioeconomy". BIOVOICES focuses on the non-food applications, which refers to the bio-based economy.

The development of the bio-based economy is driven by the desire to meet some of the big societal challenges of our time and to contribute to reaching the UN Sustainable Development Goals (SDGs) leading to a circular economy. Relevant are among others SDG 12 "Responsible production and consumption" for promoting the circular economy and SDG 13 "Climate change" to avoid global warming. Bio-based materials provide a better carbon cycle and therefore less global warming compared to their fossil alternatives, which makes the bio-based economy important for the circular economy that aims to retain as much value as possible of products, parts and materials. Therefore, stimulating the bio-based economy could contribute to the globally agreed SDGs which could serve as an orientation for a broader audience.

There are all kinds of raw materials entering the circular economy: fossil resources, minerals, metals, biomass from agriculture, forest and marine and CO_2 emissions from industry. The raw materials will be manufactured to products, traded, used and then will enter the waste hierarchy from share/maintain, reuse/ redistribute, remanufacture to recycling (mechanical and chemical), including most of the bio-based products. Therefore, both fossil-based as well as bio-based products are relevant to recycle in order to use less raw materials. Biodegradable products add organic recycling (biodegradation, composting, carbon recycling through photosynthesis) to the end-of-life options and CCU (Carbon Capture and Utilisation), the recycling of CO_2. The use of landfill is the least desirable option.

Although, the concepts of the bio-based economy and the circular economy have in common to reduce the demand for fossil carbon and to enhance the use of waste and side streams, this is not yet realised. Only 10% of the raw fossil materials has been recycled (Ellen MacArthur Foundation, 2016). Currently, the global biomass availability for bio-based resources is 15% (Piotrowski et al., 2015). It could increase to 25-30% if we use all side streams. Despite that in some bio-based sectors the cascading use of biomass (remanufacturing and recycling) has already been established for decades, such as in the pulp and paper or textile, in most bio-based sectors it is just at the beginning. Organic recycling as an expansion of circular economy still has to find its position and acceptance in the circular economy, e.g. through new legislation on fertilisers, including bio-based ones (Carus & Dammer, 2017).

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2.2 BARRIERS TO BIO-BASED ECONOMY

So far, the commercialisation of new bio-based products is still at an early stage of development. In addition, the use of traditional bio-based products, such as wood, cotton and wool, is not increasing (Dammer et al., 2017). Barriers that hamper the commercialisation of new bio-based products include the following (Peuckert & Quitzow, 2015; Hodgson et al., 2016):

- Feedstock-related barriers: the logistics of securing large quantities of biomass feedstock all year round, and the availability of feedstock at affordable prices;
- investment barriers and the perception of high investment risk;
- poor public perception and awareness of industrial biotechnology and bio-based products;
- an absence of incentives or efficient policies to increase the demand.

In addition, the BERST-project (2016) identifies among entrepreneurs a lack of an innovation culture, trust in R&D institutes and participation as barriers that hamper the development of bio-based value chains.

A more vibrant, collaborative and open-innovation ecosystem (Chesbrough, 2003) could be helpful for overcoming the barriers listed above. Innovation can be considered as a collective activity that takes place within a wide system of stakeholders. These stakeholders have a role to play in ensuring a successful translation of invention and technology development into innovation and marketable products. The concept of 'innovation system' points to the broader socio-technical context of 'societal subsystems, actors, and institutions contributing in one way or the other, directly or indirectly, intentionally or not, to the emergence or production of innovation' (Hekkert et al., 2007).

2.3 ENABLERS OF BIO-BASED ECONOMY: INNOVATION THEORY

Large-scale change involves changes in established patterns of action as well as in the structures in which they take place (Sterrenberg et al., 2007). In other words, it requires stakeholders from various sub-groups to rethink and change their practice. This is challenging and explains why it is so difficult to realise a bio-based economy in Europe.

The Technological Innovation Systems (TIS) framework can give some guidance on how to tackle innovation challenges as it focuses on key processes that are highly important for large-scale socio-technical change. At the heart of TIS are seven functions (see Box 1). These functions refer to key processes that contribute to the generation and diffusion of innovations. Unravelling and describing these functions for a specific bio-based value chain or cluster will give more insight into the dynamics of technological innovation. To raise the barriers which hamper the commercialisation of bio-based products, the seven operations/functions could be helpful depending on the specific innovation and the maturity of the innovation. These seven functions can be translated into a number of desired conditions or outcomes (Hekkert et al., 2011).

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Box 1: The seven TIS functions (Breukers et al., 2014)
F1: Entrepreneurial Activities
Activities that aim at proving the usefulness of the emerging technology in a practical and/or commercial environment, e.g. experiments, demonstrations and business ventures.
F2: Knowledge Development
Learning activities, mostly related to the emerging technology, but also related to markets, networks, users etc.
F3: Networks and Knowledge diffusion
The primary function of networks is to facilitate the exchange of knowledge between all the actors involved. Knowledge diffusion can occur in the formation of partnerships, or in meetings like workshops and conferences.
F4: Guidance of the Search
Activities that shape the needs, requirements and expectations of actors with respect to their support of the emerging technology. It also refers to the promises and expectations expressed by various actors. Important is the convergence of signals – expectations, promises, policy – in a particular direction of technology development, which may work out positively or negatively for the technology concerned.
F5: Market Formation
Emerging technologies usually cannot compete with incumbent technologies. Therefore, the creation of artificial (niche) markets is needed. This function involves activities that contribute to the creation of a demand for the emerging technology.
F6: Resource Mobilisation
The allocation of sufficient financial, material and human capital to make the emerging technology viable, e.g. investments and subsidies; the deployment of generic infrastructures such as educational systems, large R&D facilities, the mobilisation of natural resources like biomass.
F7: Lobbies, Support from advocacy coalitions
The rise of an emerging technology often meets with resistance from established coalitions with stakes in the incumbent energy system. This function involves political lobbies and advice activities on behalf of interest groups and can be regarded as a special form of Guidance of the Search, because such pleas in favour of particular technologies are attempts to shape expectations.

A critical observation is that TIS, in spite of its broad framework, fares less well in grasping societal controversies and different underlying stakeholder perspectives (Breukers et al., 2014). Though F4 and F7 do point to political issues and different interests, the focus lies on economic stakeholders.

Others indicate that large-scale socio-technical change can involve public controversy; even if the proposed alternative is expected to result in a more sustainable practice (Hoes & Regeer, 2015). Scholars in the field of science and technology studies have demonstrated that the adoption of a proposed innovation by society usually does not happen straightforwardly and can entail controversy (Bijker, Hughes & Pinch, 1987). Stakeholders may have diverse reasons for resisting bio-based innovations. First, for entrepreneurs converting to bio-based developments may entail high construction, transition and training costs (Hoes et al., 2012; Rogers, 2003). Second, the cascade of change in institutional rules and behavioural routines will potentially harm the interests and desires of others (Collingridge, 1981). And third, the outcomes of adoption are inherently uncertain (Meijer & Hekkert, 2007; Vo et al., 2007) and can potentially create unforeseen negative side-effects (Grunwald, 2007; Beck, 1997; Hughes, 1987). These strains clarify why efforts of change tend to run into resistance, inertia, lock-ins or even result in a backlash" (Hoes & Regeer, 2015). It can be anticipated that the bio-based economy can only take place if the bio-based products are comprehendible and sensible in the eyes of the effected stakeholders (Grin & Graaf, 1996, Kupper 2007; Hoes & Regeer, 2015).

Weber and Rohracher (2012) have elaborated the aforementioned critique on the TIS framework by focussing on the challenge of strategic transformation of broader systems of production and consumption. They propose a comprehensive framework that allows legitimizing and devising policies for transformative change that draws not only on a combination of market failures (i.e. information

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asymmetries, knowledge spill-over, externalisation of costs and over-exploitation of commons) and structural system failures (infrastructural, institutional, network and capabilities failures). They also include transformational failures (lack of a shared vision, demand articulation failure, lack of policy coordination and lack of reflexivity in processes in self-governance). Frenken and Hekkert (2017) have added “lack of urgency” to the proposed transformational failures. Referring to the bio-based economy this implies not only a focus on market failures, e.g. feedstock and investment barriers, entrepreneurial resistance and poor public perception, and system failures,e.g. lack of policy incentives and civil society stakeholders, but also a focus on transformational challenges, such as a shared vision.

2.4 TRIPLE AND QUADRUPLE HELIX MODELS

Structural system failures through network failures can be solved in helix models. The helix model for innovation is a useful framework to ensure that the perspectives of different stakeholders are taken into account during the innovation processes (Carayannis & Campbell, 2009; Kolehmainen et al., 2016). The triple helix model refers to collaboration between academia, industry and governments to realise innovation, social development and economic prosperity (Etzkowitz & Leydesdorff, 1995). More recently, the quadruple helix model emerged to highlight that also civil society plays an important role in realising innovation. The civil society is key in driving changes, because the citizens, eventually, make the economical choices.

The idea of the quadruple helix model is that stakeholders from all these backgrounds are needed to co-create the future and drive structural changes far beyond the scope of what any organisation or person could do alone. Both triple and quadruple helix models are based on the principles of integrated collaboration, co-created shared value, cultivated innovation ecosystems and unleashed exponential technologies. This model encompasses also user-oriented innovation models to take full advantage of the cross-fertilisation of ideas leading to experimentation and prototyping in a real world setting.

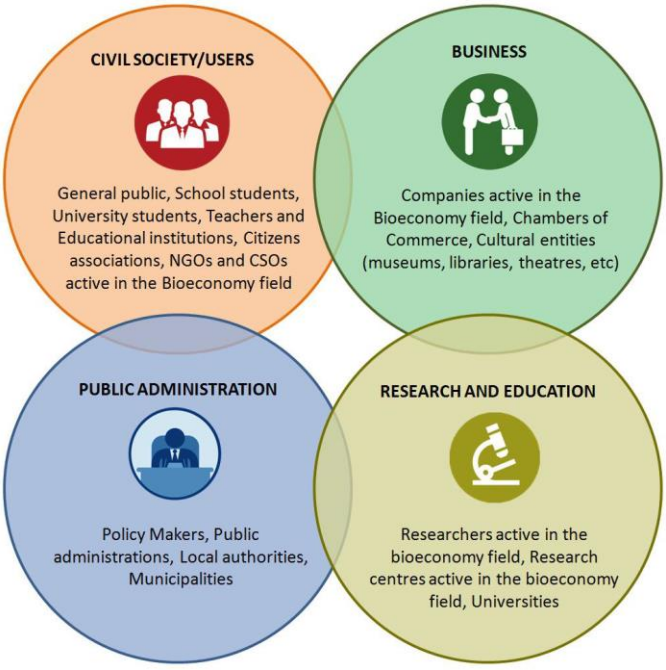

Figure 1 Quadruple Helix.

Source: Carayannis & Campbell, 2009

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A point of critique is that the triple and quadruple helix models are developed in western countries (Yuzhuo Cai, 2013). Therefore these models are mainly known and used in western Europe (Overbeek et al., 2016). In central and eastern European countries there is less experience with these models with mainly first and double helix models with research actors in existence. Therefore, one of the main priorities to start with a bio-based economy is to improve the governance structure with more actors (BIOEAST, 2017) and to consider the contribution of every other actor, i.e. policy makers, business and civil society. So far, it is not known whether these countries also have an appropriate agenda in mind that will attract policy makers and civil society with more attention for transformation challenges.

Another perspective, for more remote, rural and less-favoured regions , is given by Kolehmainen et al. (2016). They argue that in more remote, rural areas where no university or other knowledge-intensive institutions as basic elements of triple helix model are present, which makes a difference from the point of view of local development agendas. In many regions, also the business community may be scattered and insufficiently developed in terms of innovation. Furthermore, this kind of region may also have a weak public sector to enhance innovativeness. In such regions, social and community groups may often play the dominant entrepreneurial role.

2.5 DEVELOPMENT PHASES OF INNOVATIONS

Hekkert et al. (2011) points out that innovation systems pass through sequential development phases and that it can take years before an innovation reaches maturity. They distinguish five phases of development: (i) predevelopment, (ii) development, (iii) take-off, (iv) acceleration, and (v) stabilisation (Figure 2). In practice, these phases might overlap.

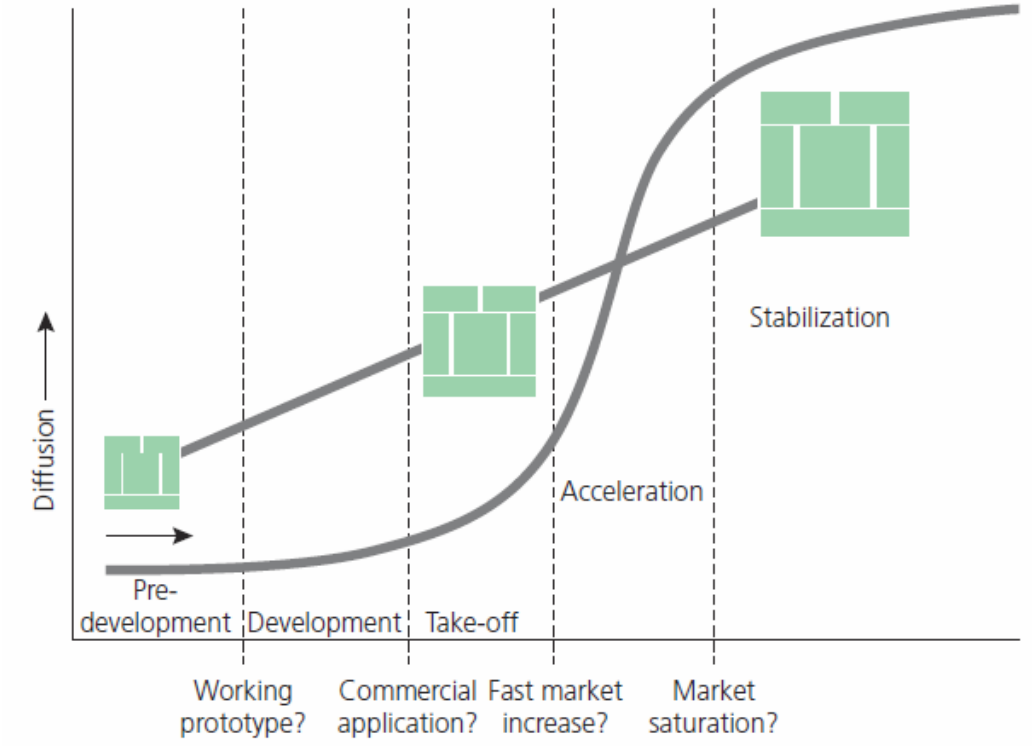

Figure 2 Phases of development

Source: Hekkert et al., 2011.

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During the Predevelopment (P) and Development (D), the bio-based economy is introduced in the planning agenda and the policy, socio-economic and R&D landscape for its establishment and operation are created. The end of Predevelopment and Development is marked by the realisation of respectively a working prototype and a commercial application. The P-phase is characterised by research development (F2), exchange and search for resources (F6). See Box 1. The D-phase is mainly characterised by the entrepreneurial activity (F1) and research development (F2).

The phase of Take-off (T) shows a substantial growth: the first competitive bio-based products are sold in the market, new companies join the cluster or value chain, the infrastructure (business incubators, training centre etc.) is established, and the cluster is able to attract both private and public funding. During the take-off, it is more likely to get brand owners and manufacturers, governments and civil society interested in the development and market uptake of the bio-based economy. The take-off phase ends with a fast market growth. For the T-phase, entrepreneurial experimentation and production is critical (F1) in tandem with counteracting resistance to change and building legitimacy (F7). Guidance of the search (F4), resource mobilisation (F6) and market formation (F5) are important supportive functions.

In the phase of Acceleration (A), the cluster is able to produce competitive bio-based products at an extensive scale and can count on an increasing demand. This phase ends with market saturation. For the A-phase market formation (F5) is the most important system function, as a growing market fuels the innovation system to develop and diffuse further. Supportive functions are entrepreneurial production (F1), resource mobilisation (F6) and guidance of the search (F4).

For participative governance and the development of the bio-based economy, the take-off and acceleration phases are most relevant. At the (pre)development stage, when the innovation is relatively unknown, consumers and civil society organisations often play a minor role among others because potential applications and potential impacts are unclear. Despite this practical argument, several scholars note that perceptions of various stakeholders need to be integrated at an early stage to be able to develop applications that are concerned valuable by consumers and citizens (Oudshoorn et al., 2004). Moreover, as described above, the role of consumers and civil society organisations can suddenly become important if public controversy emerges around proposed innovations. It is also important to avoid a lack of demand articulation and policy coordination when scaling up from the research phase to commercialisation. Therefore, it is important that those phases focus on the transformation failures (challenges) described in Section 2.3 to realise a market uptake of the bio-based economy.

2.6 RELEVANCE FOR BIOVOICES

This chapter describes the several barriers that hamper the realisation of bio-based value-chains and the various stakeholders that play a role in overcoming these barriers by rethinking and changing their practise to tackle innovation challenges. Unravelling and describing key processes that contribute to the generation and diffusion of innovations for a specific bio-based value chain will give more insight into the transition towards a bio-based circular economy. From the development phases of innovations we conclude that BIOVOICES should focus on bio-based applications in the take-off phase, when it is more likely to discuss personal benefits such as price and functionality and a broader set of environmental benefits with brand owners, manufacturers, governments and civil society interested in the development and market uptake of the bio-based economy.

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BIOVOICES aims to contribute by establishing a multi-stakeholder platform and animating open dialogue and mutual learning between the stakeholders. The idea of the quadruple helix model is that stakeholders from civil society, industry, academia and governments are needed to co-create the future and drive structural changes far beyond the scope of what any one organisation or person could do alone. Therefore, the next chapter identifies bio-based applications that are at least in a phase of take-off and discusses the contribution of the quadruple helix actors to the market uptake.

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3 BIO-BASED APPLICATION SECTORS AND THEIR MAIN MATERIALS

3.1 INTRODUCTION

The focus of BIOVOICES is on the market perspectives of application sectors in the take-off phase (or further in the accelaration phase). Therefore, the aim is to select commercial applications which are relevant for different stakeholders to share their perspectives, knowledge and experiences for mutual learning.The main applications ready for take-off are made from bio-based plastics and polymers, natural fibres (e.g. wood, bamboo, cotton, hemp and wool) and bio-surfactants. They are from at least second generation (2G) feedstock in Europe or from first generation (1G) feedstock produced on lands not-used for edible biomass/food crops (e.g. margin lands and sea water). Bioenergy-applications are in transition to change their feedstock from edible biomass (1G) to non-edible biomass (2G, see Table 1).

Bio-based applications	Used materials
Packaging, disposals & paper	Natural fibres, bio-based plastics and polymers
Construction, furniture & textile	Natural fibres, bio-based plastics and polymers
Toys, sports & cars	Natural fibres, bio-based plastics and polymers
Personal care & cleaning, biomedical, food & feed additives & biosynthetic motor oil	Biosurfactants, neutraceuticals,algae & biolubricants
Biofuels & bioenergy	2G or advanced feedstock (cellulose-based, non-edible biomass & agricultural waste)

Table 1 Bio-based application sectors and used materials

In this chapter the current and future market size of the main bio-based applications are described in Section 3.2 for packaging, disposals and paper, in Section 3.3 for construction, furniture and textile, in Section 3.4 for toys, sports and cars, and in Section 3.5 for personal care, cleaning, biomedical, food & feed additives and biosynthetic motor oil.[1] Furthermore, there will be attention for biofuels and bioenergy (Section 3.6). The chapter will conclude with an overview of the current and future market size of the selected bio-based applications sectors. Moreover a number of issues relevant for commercial application of bio-based products will be summarised (Section 3.7).

3.2 BIO-BASED PACKAGING, PAPER AND DISPOSALS

3.2.1 Packaging and disposals

Packaging and disposals protects products during distribution and storage and simplifies trade, usage and the eating of products. Bio-based packaging and disposals includes bio-based plastics and polymers and natural fibres such as paper. Examples of bio-based plastics and polymers for packaging and disposals are provided in the Bio-based Packaging Catalogue (Molenveld et al., 2015) and Figure

[1] We have checked more potential non-food applications of algae (i.e. fertiliser, filtration, industrial). According to the FP7-project EnAlgae (www.enalgae.eu) the production process of algae requires more innovation to scale up production. On a short term algae could be suitable for cleaning wastewater from the agro-food industry by extraction and recovering of phosphate.

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3. We will focus on bio-based plastics and polymers because this includes promising products in the take-off phase. Bio-based plastics have been defined according to EN16575 as products, which are (partly) derived from biomass. Biomass used for bio-based plastics stems from e.g. corn, sugarcane, or cellulose. In Europe, a bio-based product is known through its C-content (CEN/TS 16640) and the method of how it is measured (EN 16785-1 2015).

Figure 3 Bio-based plastic products

Source: www.groenegrondstoffen.nl

The family of bio-based plastics is divided into two main groups based on whether the material is (bio)degradable or not[2]:

1. non-degradable plastics that are partly or fully bio-based, such as bio-based PE, PP, or PET (so-called drop-ins) and bio-based technical performance polymers such as PTT;
2. biodegradable plastics, such as PLA and PHA or PBS;

[2] There are also fossil-based plastics that are biodegradable, such as PBAT. These plastics form a small number of biodegradable products and therefore fall out of the scope of our study.

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Biodegradation is a chemical process during which microorganisms that are available in the environment convert materials into natural substances such as water, car bon dioxide, and compost without artificial additives. The process of biodegradation depends on the surrounding environmental conditions (e.g. location or temperature), on the material and on the application.

Biodegradable and industrial compostable bio-based plastics such as bio-PLA for food packaging and disposals offer additional end of life options for certain applications in comparison to non-biodegradable and fossil-based plastics that have to be separated for recycling. An example of biodegradable bio-based plastics is the use of cellophane for sliced meat and the one-use plastic bags produced by Novamont in Italy (see Box 2 in Chapter 4). Bio-based and biodegradable plastics are also used in crop production (mainly in Italy, France, Germany, Benelux, and Spain). Biodegradable mulch films do not have to be removed and disposed of at the end of the crop cycle, but can be buried in the soil. A level playing field for these materials in the EU is required as the situation is far from being uniform among member states.[3]

However, most bio-based packaging products are non-biodegradable. Non-biodegradable bio-based drop-in plastics, such as bio-PET for bottles and bio-PE for packaging are chemical identic to their fossil PE(T). Therefore, these bio-based drop-in plastics have hardly any new properties compared to their fossil counterparts and should be price-competitive to allow for market uptake (BBI, 2017a). They can be fully mechanically recycled.

The issue of being biodegradable or non-biodegradable could harm the perception of consumers of bio-based plastics and their waste behaviour if they feel uncertain about how to deal with their end-of-life options. In combination with the required performance, it could be considered an issue that requires more communication and legislation with an effective control of being biodegradable in compliance with EN13432. An example is mentioned in Italy, where 30% of the single use bags are falsely marketed as being biodegradable (European Bioeconomy Panel, 2014). Non-biodegradable plastics are convenient as long as they are easy to separate and to collect for recycling. Sometimes it is even better that a product is non-biodegradable, because effective performance may be preferable to biodegradability, for example, a plastic water bottle should not leak water.

The production capacity of bio-based polymers is growing worldwide, but since 2015 it has only grown in line at the same speed as the total polymer market. Currently there is a constant share of about 2% of biopolymers in the total polymer market and no further replacement of petrochemical polymers foreseen at this point in time. The main reasons are low oil prices, fewer new functions, low political incentives and a slower than expected growth of the capacity utilisation rate (Dammer et al., 2017). New functions relevant to users in the future are more lightweight bio-based products compared to their metal equivalents, and fewer waste activities if the bio-based product is biodegradable.

It should be also noted that in terms of volume many products are partly bio-based, the so-called “hybrids” (Table 2). Some are non-biodegradable (Bio-PET, PTT) and others are bio-degradable (starch blends). The fact that products are hybrid could be considered as an in-between stage within the transition towards a bio-based economy, comparative to hybrid motors, hybrid warming of houses, and vegan protein in meat. Hybrids could assist businesses (e.g. product developers) in developing and testing bio-based products without having to transform their entire business model.

[3] http://ec.europa.eu/transparency/regdoc/?fuseaction=feedbackattachment&fb_id=72FDC5F4-0A1D-B942-A363D85479EE9DEF

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	Petrochemical	Hybrid = partly bio-based	100% Bio-based
Non-biodegradable	PE, PP, PET, PS, PVC	Bio-PET, PTT	Bio-PE
Biodegradable	PBAT, PBS(A), PCL	Starch blends	PLA, PHA, Cellophane

Table 2 Bio-based versus fossil plastics and biodegradable versus non-biodegradable plastics

Source: Van den Oever et al., 2017

3.2.2 Paper

In terms of volume and biomass supply, the pulp and paper sector is one of the most important parts of the bio-based economy. The raw materials are mainly bio-based, wood (and to small extent also other natural cellulose fibres) and starch as an additive to achieve the desired paper quality. Paper is also the best example of using 2G feedstock in Europe with having a paper recycling rate of 72,5 % in 2017 (www.eprc.com). Nevertheless, the pulp and paper sector seems not to market themselves as a bio-based industry (Dammer et al., 2017).

New lignocellulosic biorefineries serve as a bridge between the traditional pulp and paper and new chemical sector. Relevant 2G feedstocks are agricultural residues such as tomato stems and leaves (also for packaging). The worldwide demand for environmentally friendly packaging and hygiene papers will grow strongly (Dammer et al., 2017). New technologies allow the entry of additional applications in packaging (for example shopping bags) and hygiene papers. The political debate about microplastics in the marine environment will put pressure on bio-based and degradable plastic solutions and strengthen the demand for such paper-based packaging and hygiene papers (Piccino, 2015).

3.3 CONSTRUCTION, FURNITURE AND TEXTILE

3.3.1 Construction & furniture

A wide range of natural fibres such as wood are used in construction and furniture. Bio-based plastics are also used as material. Furthermore, there are also plastics filled or reinforced with wood or natural fibres. Examples of construction and furniture products include (Dammer et al., 2017):

- House wall and roof construction, multi-storey buildings, apartment buildings (wood, clay)
- Interior walls and furniture (particle board, paper (e.g. wallpaper), cotton (e.g. drapes), wool (e.g. carpet), sisal hemp or grass (e.g. carpet), OSB, MDF, but also bio-PET by IKEA
- Insulation material (wood and cellulose fibres, natural fibres, animal fibres such as wool, straw, grass, cork, sea grass and many other natural materials; including biopolymer foams (for example PLA)
- Flooring, decking and facades (parquet, cork, laminate, WPC, biocomposites)
- Wooden window frames and doors
- Paints, glues, coatings (natural oil and waxes, bio-based plastics)

The total biocomposite production is estimated to amount to 410.000 tonnes with an overall growth rate of 3%. However, furniture and consumer goods have higher growth rates up to 30%. The Portugese company Amorim is a large producer of cork granulates, which are used in shoe soles, handles and even in space travel. IKEA (Sweden) offers wood-plastic composite chairs (Carus & Partanen, 2018). Wood- and bio-based construction materials have a positive, environmental and health friendly image in the public's eyes (Dammer et al., 2017). They are considered natural and green materials. Sustainable

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buildings have often a high share of bio-based materials, because of the higher sustainability and a pleasant living climate in the houses, e.g. regulation of moisture contents. However, communication efforts are necessary to raise awareness about natural fibres with both industry and to the public, such as hemp-fibre composites that can be used not only in cars, but also in furniture (European Bioeconomy Panel, 2014).

Northern countries particularly have issued clear statements about the importance and potential of wood construction. Unsuitable standards and norms are still a barrier for the further market growth of bio-based constructions products. In some EU member states, moisture permeable materials are not allowed as insulation in buildings at all. Only conventional insulation materials producers profit from the current regulations, while natural fibre insulation manufacturers and consumers suffer from them (Dammer et al., 2015). The forest industry would allow a highly efficient side-stream utilisation and cascade due to its well-developed infrastructure and experiences in cascading of paper. However, the barriers from the bioenergy and biofuels policy need to be overcome (non-level playing field for energy and material use), which only supports an energetic use of biomass and not a cascading use (Carus et al., 2015).

3.3.2 Textiles

Besides synthetic fibres (63% of the total share) there are three relevant bio-based fibre groups in the textile sectors, i.e.

1. natural fibres, such as cotton, jute, flax, hemp, wool, which decreased to 31% in 2015,
2. cellulose fibres, which a fast increase to 6% in 2015 and
3. and bio-based polymer fibres with very small shares (such as alginate fibres, soybean protein fibres, and non-food milk casein fibres).

The bio-based share in textiles fibres has been continuously decreasing for decades, mainly because of the (environmental) limits of the cotton production and the progress of synthetic fibres. Although 37% of textile fibres are bio-based (37 million tonnes worldwide in 2015), the textile sector does not market itself as part of the bio-based industries (Dammer et al., 2017). Furthermore, consumers are not aware of the term “bio-based”, but are highly interested in “natural” textiles. Natural fibres are often preferred in comparison to petrochemical fibres due to their comfort, soft-feel, versatility and natural ventilation.

The main driver in the textile sector is the fast-growing demand for products and how to cover this demand. A textile fibre gap of about 150 million tonnes until the year 2050 is expected than can not be solved by petrochemicals only. Therefore, huge investment in cellulose fibres and bio-based polymer fibres is needed (Piotrowski et al., 2015).

Cellulose fibres, especially viscose, have been produced since the 19th century, but the concept of bio-based industries has existed for only about a decade. Wood-based fully integrated biorefineries are a big opportunity to produce cellulose textile fibres at high volumes (Piotrowski et al., 2015).The biggest investment in this area has been Metsä fibre in Finland. Additional demand for bio-based and biodegradable textiles can arise from the increasing microplastic problem. Washing machines release thousands of small non-biodegradable petrochemical fibres per washing process. Cotton and cellulose fibres as well as some biopolymer fibres biodegrade in fresh water and more slowly also in the ocean.

2G textile fibres bring higher value added and more jobs compared to 2G biofuels that are made from the same lignocellulosic raw material. However, in contrast to 2G biofuels that are strongly supported by the European Commission and the member states, there is not a supporting policy for 2G fibres. Experts from nova-Institute have suggested that Europe would need its own textile fibre strategy. Which

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raw materials should be used for textiles in the future? Petrochemical fibres, cotton, new bio-based polymer fibres or cellulose fibres from European forests produced in advanced wood-based biorefineries (Dammer et al., 2017).

3.4 TOYS, CARS AND SPORTS

3.4.1 Toys

Bio-based toys from natural fibres are commonplace and the commercialisation of bio-based plastic toys has just started. Toy manufacturer LEGO has developed new fully bio-based plastic toy bricks and packaging materials, but also other players, such as Unga Toys in the Netherlands and Bioserie, based in Hong Kong, and the Italian biotech company Bio-on are doing so. Haba and Tecnaro produce baby toys from lignin, EKOBO and BecoThings use bamboo to produce respectively children's toys and a potty (BIOSTEP, 2015).Their products offer the same level of performance, design and consumer experience compared to non-bio-based and less sustainable alternatives. Bioserie launched bio-based toys made of 100% bio-based bioplastic in 2015. Made from annually renewable resources, they contain no petrochemicals, coating or paint and are dishwasher safe. They are the first and only products in their category to have obtained a 100% bio-based certification by USDA's BioPreferred program. In addition, also pulp and nanocellulose can also be used in combination with (bio)plastics in biocomposites, e.g. for furniture or toys (Piccino, 2015). There is a willingness among specific segments of consumers to pay more for bio-based sand toys (Scherer et al., 2017).

Figure 4 Bio-based toys exposed at the Biocoenomy Village at Maker Faire, Rome, December 2017

Source: BIOWAYS, 2017

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3.4.2 Cars

There are many reasons to fill or reinforce plastics with wood or natural fibres of all kinds. Weight savings, reduction of primery energy, shorter cycle times, scratch resistance and a lower CO_2 footprint play a crucial role in technical applications and in the automotive industry (Carus & Partanen, 2018). Biocomposites, wood and natural fibres reinforced plastics are established materials in the automotive industry for interior parts such as panels and dashboards (Dammer et al., 2017). They have reached a relevant market volume in the automotive sector (150,000 tonnes annually). The polymer used in these composites is mainly polypropylene (PP). Bio-based natural and synthetic rubber for tyres and other car parts are used worldwide (11 million tonnes in 2012). The highest share of natural rubber can be found in truck and winter tyres (Dammer et al, 2017). The cars could be partly bio-based (hybrid). Continental produces car tyres from dandelion. The main reasons to use bio-based materials are good cost-performance ratio, unique properties (mechanical properties and lightweight) and lower environmental footprint. Concerning stakeholder involvement, it should be noted that the automotive sector is competitive and only a few producers deliver any data on used materials.

The automotive sector does not communicate about being part of the bio-based economy. Bio-based or being green has only a very small impact on selling compared to high performance, innovation, lightweight and low consumption of fuel. Bio-based is not a driver in and of itself, so consequently, there are no targets to increase the bio-based shares. Without any supportive framework conditions, only a slow increase is expected due to improved properties and cost reduction in processing. Examples of possible supportive framework conditions are the “EU End-of-Life Vehicle (ELV) Directive” and the various forms of its implementation at member state level (Carus et al., 2010).

3.4.3 Sports

Bio-based flexible plastics and natural fibre composites are increasing in importance in sport applications (e.g. snow goggles, running shoes, midsoles and ski-boots). However, the majority of the bio-based polymers used in the bio-TPU (thermoplastic polyurethane) and bio-TPE (thermoplastic elastomer) are still drop-ins for synthetic polymers (Van Wijk, 2012). Without adding new functions they should be price-competitive to allow for market uptake (BBI, 2017a). Furthermore, the application markets are very familiar with the use of the fossil-based version of these materials. To illustrate, due to the material strength and the solubility in a variety of solvents, the main application market of TPE’s is the shoe manufacturing industry. Most of the bio-TPE is being used in running shoes or ski-boot applications made by companies that originally started as shoe manufacturers. So, the familiarity of the particular market with the synthetic variant contributed to the adoption of the partly bio-based TPE. Hence, the hybrid issue works well for bio-based sport products and could be relevant for the use of other bio-based plastics, such as PLA. Products made from bio-based material are tennis rackets from flax fibres by Lineo and Decathlon, and a 100% natural rubber yoga mat from Domyos sold by Decathlon.

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3.5 PERSONAL CARE, CLEANING, BIOMEDICAL CARE, FOOD & FEED ADDITIVES AND BIOSYNTHETIC MOTOR OIL

Personal care and cleaning products are used in high and increasing volumes and end up in the water streams and eventually in the sea. Bio-based alternatives that have fast biodegradation with low environmental impacts are attractive. Biotechnology offers new pathways and new building blocks to create environmental friendly personal care, cleaning, food and feed additives and biomedical care.

3.5.1 Personal care & cleaning

The market for bio-based alternatives in the personal care sector (such as tooth paste, face cream, lotion and shower gel, lipstick, pampers, shampoo and conditioner) and home care sector (laundry, dish washer & surface cleaners) is well developed compared to other bio-based applications. Special enzymes are often an integral part of cosmetic and care products. In order to be available in a sufficient amount, biological mini-factories such as cells and bacteria produce the requested substances in large steel vessels. Examples are Korres, which produces face cream from microorganisms and Ecover, which produces cleaners from rapeseed oil. One reason to explain the well developed market is that the personal care market is generally characterised by consumers willing to invest more in otherwise comparable products. Furthermore, the characteristic of being “natural/organic” gives bio-based care, cosmetics and cleaning products an extra unique selling point. Further technological and market development of bio-based produced surfactants such as rhamnolipids, which can offer better performance to consumers, are promising. There are various examples how petro-based solvents can be replaced by bio-based alternatives such as toluene being replaced by limonene for cleaning (Paggiola et al., 2016).

The impression is that the personal care sector until recently did not really market itself as part of the bio-based economy. Rebranding long standing bio-based components in a personal care formulation as “bio-based” is rather difficult and possibly not worth the investment in those companies’ marketing budgets (Dammer et al., 2017). An alternative is to continue with branding natural, organic and environmentally friendly for these applications. Raising awareness about the bio-based economy among product developers might open-up new alternatives for this sector and stimulate the development of environmental friendly products.

New biomass for personal care could be algae, which is still at a stage of early development as is shown by the project with the brilliant acronym MAGNIFICENT (Microalgae As a Green source for Nutritional Ingredients for Food/Feed and Ingredients for Cosmetics by cost-Effective New Technologies). By using green solvents, it aims to establish truly sustainable value chains in cosmetics. Producing seaweed so far is mainly for use in healthy food and feed like Olmix does in France. A technological progress towards more personal care is still at a development stage.

3.5.2 Biomedical care & nutraceuticals

Biomedical care are bio-based elements, such as sutures, bone plates, grafts and a wide variety of implants. They can provide additional functions if they are biodegradable and save medical chirurgery. PolyBioSkin (www.polybioskin.eu) aims to develop and validate pilot processes for producing prototypes of three skin-contact products (diapers, beauty masks and wound dressings).

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Nutraceuticals are in between food and drugs. Similarly, to cosmetics, the market of nutraceuticals is well developed. Bio-based products and components have specific functionalities and features that offer a range of interesting possibilities to these industries. They function within specialised markets, which focus on high-quality products. The legal protection of data, quality and safety is central to the development of innovative new products. Therefore, it is difficult to give an overview of all the products that are in the take-off phase. The company Agroceutical Products produces sustainable quantities of naturally derived galantamine in daffodils in Wales. This natural alkaloid is a key active pharmaceutical ingredient registered and approved for the treatment of Alzheimer's disease. Other natural sources of galantamine, extracted from wildflowers, are limited and unreliable.

Spirulina is one of the few species of microalgae that is easy to cultivate as a monoculture because it grows at a high pH, which helps to avoid contamination in large-scale cultivation systems. To date, research and innovation in industry, have neglected microalgae strains because investments into the basic microalgae research was not producing high business benefits (European Bioeconomy Panel, 2014). Spirulina is mainly used in food and feed (as feed for livestock and aquaculture, as a fertiliser, a water-holding agent in meat products, a protein and nutrition supplement, and as a food additive). As a protein and nutrition supplement it contributes to biomedical care, and claims to help restore and revitalise human health.

3.5.3 Food & feed additives

Generally speaking, a food additive is a substance that is added to food for a specific purpose, namely to add texture, colour or help preserve the food (Beekman et al., 2017). Many food additives are produced using biotechnology (such as sausage with Omega 3 fatty acids, lupines and algae as protein supplier, manufacturing of natural flavours and sweetener). They are classified as antimicrobial agents, antioxidants, artificial colours, artificial flavours and flavour enhancers, chelating agents and thickening and stabilising agents. Antimicrobial agents such as salt, vinegar, sorbic acid and calcium propionate are used in products such as salad dressings, baked goods, margarine, cheese and pickled foods. Antioxidants including vitamin C, E, BHT and BHA are used in foods containing high fats. Chelating agents such as malic acid, citric acid and tartaric acid are used to prevent flavour changes, discoloration and rancidity of the foods. These are all of high importance for food manufacturing companies who use them to retard spoilage, enhance food flavours, replace nutrients lost in processing and make the food more visually appealing (Dammer et al., 2017). Moreover, consumers have been turning away from artificial and synthetic food additives in ever greater numbers, in favour of more natural equivalents, in particular within sectors of the industry such as flavours, colours and sweeteners. Food additives are also subject to the continued consumer demand for food and drinks that can assist in maintaining health and wellness levels. As sugar, salt and saturated fats have been removed; opportunities have opened up for suppliers of food additives to develop replacements (Dammer et al., 2017).

MAP (magnesium, ammonium, phosphate) can be used as a fertiliser and algae as a feed additive (for an overview see: Beekman et al., 2017). Feed additives (amino acids, vitamins and minerals) are also the main ingredients that are responsible of increasing the yield of worldwide meat production. Feed additives act as a catalyst in improving the weight gain, prevention of diseases and pre vitamin deficiencies in animals and improvement of feed digestion and conversion (Dammer et al., 2017).

Though there are a large number of studies in the area of researching different food and feed additives categories, there are lack of studies to integrate these into bioeconomy. It is quite interesting that there are numerous general claims about the strategic potential of these products, while there is so little

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knowledge available on volumes, markets, economic and technological feasibility, value chains and resources (Dammer et al., 2017).

3.5.4 Biosynthetic motor oil

Biolubricants are substances that can reduce the friction between surfaces and hence reduce the heat that is generated when the surfaces moves. Usually they contain mineral oils and additives. The prefix “bio” means that biolubricants are bio-based (at least 25%), biodegradable (more than 60%) and not dangerous to the environment (according to OECD 201/202/203) (FNR 2014). Biolubricants can be made from various vegetable oils, such as rapeseed, sunflower, canola, soybean, or palm oils. The chemical industry already uses plant oils for the production of lubricants, however until now on a rather small scale. Biolubricants exist among others in the sectors of hydraulic oils, gear oils, engine oils, cooling lubricants and corrosion protection oils. They are especially important in applications that present risks for the environment, for example total-loss oiling systems, sensitive areas or where oil may leak accidentally (Beekman et al., 2017).

3.6 BIOENERGY & BIOFUELS

The bioenergy/fuel sector seems to be one of the most researched areas. On the technological side, yet fuels seem not yet to be able to create a technology push still relying heavily on policies to promote their use. The food versus fuel debate remains a hot-button issue (Beekman et al., 2017). Nonetheless, more scientific publications indicate that biofuels are not as detrimental to food security as is widely believed (Dammer et al., 2017). Carbon Capture and Utilisation (CCU) might provide an additional possible solution. Whether wood-based energy can really alleviate climate change remains to be seen, as discussions on this topic are extremely controversial at the moment (Dammer et al., 2017). Moreover, many countries in eastern and southern Europe produce a limited quantity of bioenergy, which lowers the total attribution of EU in bioenergy field.

Biogas typically refers to a mixture of different gases produced by the breakdown of organic matter in the absence of oxygen. Biogas can be produced from agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste. Biogas is a renewable energy source, which requires a short value chain. Several European research projects have focused on the processing of manure, such as BioEcoSim (www.bioecosim.eu), this project is still in the development phase. The project ISAAC aims to increase social awareness and acceptance of biogas and biomethane (www.isaac-project.it/en).

The BIOSKOH biorefinery (https://bioskoh.eu) uses local feedstock in the eastern part of Slovakia to produce 2G or advanced biofuels. The feedstock will include 2G agricultural residues (e.g. straw) in addition to the wood residues and targeted biomass production from degraded/margin lands (e.g. miscanthus, switchgrass). BIOSKOH aims to demonstrate a regional bio-based value chain, helping farmers to diversify business and to create new opportunities by exploiting currently under-used resources. BIOSKOH will also improve regional infrastructure by making substantial storage and shipment facilities available to local farmers and businesses. The local foresters and farmers have been mobilised.

Whether wood-based energy can really alleviate climate change remains to be seen, as discussions on this topic are extremely controversial at the moment. It seems to be reasonable to assume that the growth of the biofuel/-bioenergy share in the EU energy mix will heavily depend on the degree of

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subsidies they might receive and in a negative way whether technological advances make the material use of biomass more economically attractive (Dammer et al., 2017).

Many countries in eastern and southern Europe are not familiar with bioenergy practices, which has a negative impact on the total attribution of the EU in the bioenergy field. Moreover, an important barrier is the relatively low level of awareness of the general public about bioenergy and its benefits and implications and the fairly common societal belief that waste management should only be conducted by the public sector, rising suspicions and mistrust upon any other private initiatives (Tsagaraki et al., 2017).

3.7 CURRENT AND FUTURE MARKET SIZE OF BIO-BASED APPLICATIONS

There are no quantitative data to indicate and compare the market size of the bio-based applications detailed above. Therefore, based on the references included, the latest annual activity report of BBI (2017b) and to our own knowledge, we will indicate the current market size of the selected bio-based applications by the phases of development of its promising products (leaving out other products of the selected bio-based application which are still in an earlier phase of development).

BBI (2017b) considers within their projects the contribution to KPI 6: New demonstrated 'consumer' products based on bio-based chemicals and materials. The 'consumer product' needs to meet a clear market demand, to fulfil all technical requirements, to be economically viable and to match all relevant sustainability criteria. The new bio-based products planned for 2020 include: fertilisers, cosmetics, proteins, aromas, enzymes, paints, coatings, adhesives, personal care products, cleaning products, packaging solutions, lubricants and different types of bio-based plastics. Most of the new bio-based products are forest-based and derived from Innovation projects (BBI, 2017b).

The indication of the current market size by its phase of development implies that we consider whether the concerned bio-based application is still in a phase of:

- (pre)development with only a working prototype ready for commercial application;
- take-off with the first bio-based products already sold or distributed (small market size);
- acceleration with ability to produce bio-based products at an extensive scale and with an increasing demand (increasing market size);
- stabilisation with a satisfied demand at an extensive scale (stable market size).

Table 3 shows our indication of the current market size of the selected bio-based applications. The results show that in nearly each bio-based application sector there are products in the phase of take-off to uptake the market size. A few applications are still in a phase of (pre)development (biomedical and 2G/3G biofuels and bioenergy). Furthermore, there are also some applications in which bio-based components have been included already for a long time (construction, furniture & textile).

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Phase of development Bio-based applications	(Pre)development	Take-off	Acceleration	Stabilisation
Packaging & disposals		x		
Paper			x	
Construction & furniture old				x
Construction & furniture new		x		
Textile old				x
Textile new		x		
Toys (bio-based plastic)		x		
Cars			x	
Sports			x	
Personal care			x	
Cleaning			x	
Biomedical	x			
Neutraceuticals		x		
Food & feed additives			x	
Biosynthetic motor oil		x		
Biogas		x		
2G / 3G biofuels & bioenergy	x			

Table 3 Bio-based applications and their current market size (estimated phase of promising products)

Since there are also hardly data available about the future market size, we hypothesise the potential market size of bio-based applications by distinguishing groups of consumers. This distinction indicates whether the focus of the product concepts and communicating of bio-based applications is on small groups (niches) of consumers (e.g. luxury, green, sustainable, healthy, innovative etc.) willing to pay a premium price or whether the focus is on reaching all consumers who are not interested to do so.

If the focus is on niches, studies show that these consumers are environmental aware, nature related and health conscious and willing to accept a limited price premium (Kainz, 2016; Carus et al., 2014; Scherer et al., 2017 & 2018). This is important information because at present, the higher costs and prices of many bio-based products and absence of policy incentives mean that they cannot be introduced into the market without consumers being willing to pay premium prices. Examples of bio-based products relevant for specific groups are carpets, cars, cosmetics and sand toys. Moreover for a number of products their new functions, such as a better (work saving) end-of-life behaviour, may justify premium prices. In these cases, such as biomedical use, it might be relevant to pay more attention to the product concepts and communicating them to specific groups of consumers.

If the focus is on mainstream consumers, other measures are required. Business experts expect that improved market opportunities for bio-based products rather depend on environmental regulation to stimulate a circular economy and the deliberate decision to promote bio-based products via public procurement than on the emergence of a green premium market based on consumer demand of niches (Meeusen et al., 2015b). This requires both multi-actor approaches as well as a supportive regulatory environment, which is lacking now, to enable market uptake of bio-based products. Another perspective is to have a focus on hybrid bio-based products that have similar functions to their fossil equivalents. Many hybrid bio-based plastic and textile applications are competitive with their fossil equivalents. However, brand owners and manufacturers are currently not communicating them as bio-based products to consumers (Dammer et al., 2017).

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Table 4 provides an overview of the hypothesised target groups of consumers to indicate the potential market size for each type of bio-based applications. For some bio-based applications with several products available we have indicated both niches as well as mainstream consumer groups.

Target group of consumers Bio-based applications	Niches	Mainstream
Packaging & disposals		x
Paper		x
Construction & furniture old		x (hybrid)
Construction & furniture new	x	x (hybrid)
Textile old		x (hybrid)
Textile new		x (hybrid)
Toys (bio-based plastic)	x	
Cars	x	
Sports		x (hybrid)
Personal care	x	
Cleaning	x	
Biomedical	x	
Neutraceuticals	x	
Food & feed additives		x
Biosynthetic motor oil	x	x (hybrid)
Biogas		x
2G/3G Biofuels & bioenergy		x (hybrid)

Table 4 Bio-based applications and their potential market size (target group of consumers)

The distinction made between niches and mainstream groups of consumers is not only relevant from a user/civil society perspective, but also from the perspective of businesses that perceive lack of a demand and policy coordination. Often start-ups developing new products for niches are working alone or with a few partners. The consequence is that they do not only lack the networks among businesses, but also with potential users/civil society actors and governments. Hence, they lack opportunities to exchange information of their products among civil society networks and to ask governments to adjust legislation in favour of their products. Therefore, the challenge is to increase the relationships with those actors. If the focus in on mainstream consumers there is more chance that all the helix actors are active, but hardly collaborating with each other. Here the challenge is rather to improve the current relationships among the quadruple helix actors.

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4 MAIN ACTORS AND FUNCTIONS FOR BUILDING UP A VALUE CHAIN

4.1 INTRODUCTION

As the focus of the project is on improving the market features of bio-based application sectors, the aim is to select applications that are relevant for different stakeholders to share their perspectives, knowledge and experiences for mutual learning. Understanding the governance structures to develop a bio-based value chain is not only highly relevant but also a challenge, because it involves many actors. This holds in particular for the organisations that are part of the production, processing and distribution of bio-based applications, which are the internal value chain (see Section 4.2). In the bio-based value chain industries play an important role, but also feedstock providers at the beginning of the chain and consumers at the end of the chain need to change their practice in order to realise a bio-based economy. Besides the internal value chain, collaboration or cooperation with external groups such as governments and civil society organisations (CSOs)[4] is also important for, amongst other factors, the societal acceptance of bio-based products (see Section 4.3). A combination of internal and external stakeholders can be seen in triple and quadruple helix models (see Section 4.4). Sometimes the relevant stakeholders collaborate in a triple helix model at a regional level (see Section 4.5). This chapter concludes with the relevance of cooperation for BIOVOICES (in Section 4.6).

4.2 INTERNAL VALUE CHAIN

4.2.1 Overview of a bio-based value chain

A bio-based value chain consists of various companies that fulfil distinct functions. From the production of biomass untill the marketing of bio-based products, each company creates value at different stages in the production and distribution of products. In total, the value chain includes producers of biomass and feedstock (green), pre-treaters, waste-handlers, bio refineries, producers of bio-based building blocks, chemical transformers (blue), and users of bio-based products by application industries, brand owners and retail (yellow). See Figure 5.

Figure 5 Bio-based value chain and its main actors

The internal collaborations among these companies to produce and distribute bio-based products result in long value chains. Figure 6 shows the value chain for bio-based plastics with actors from biomass supply in agriculture (green) over biomass processing and conversion by bio-based industries (blue) to the production and selling of innovative bio-based products (yellow).

[4] CSOs are defined as organised civil society and can come in many forms, some informal and some as formal entities such as non-governmental organisations (NGOs). This is when a group of individuals come together for a common purpose, as in to fulfil a particular mandate driven by need.

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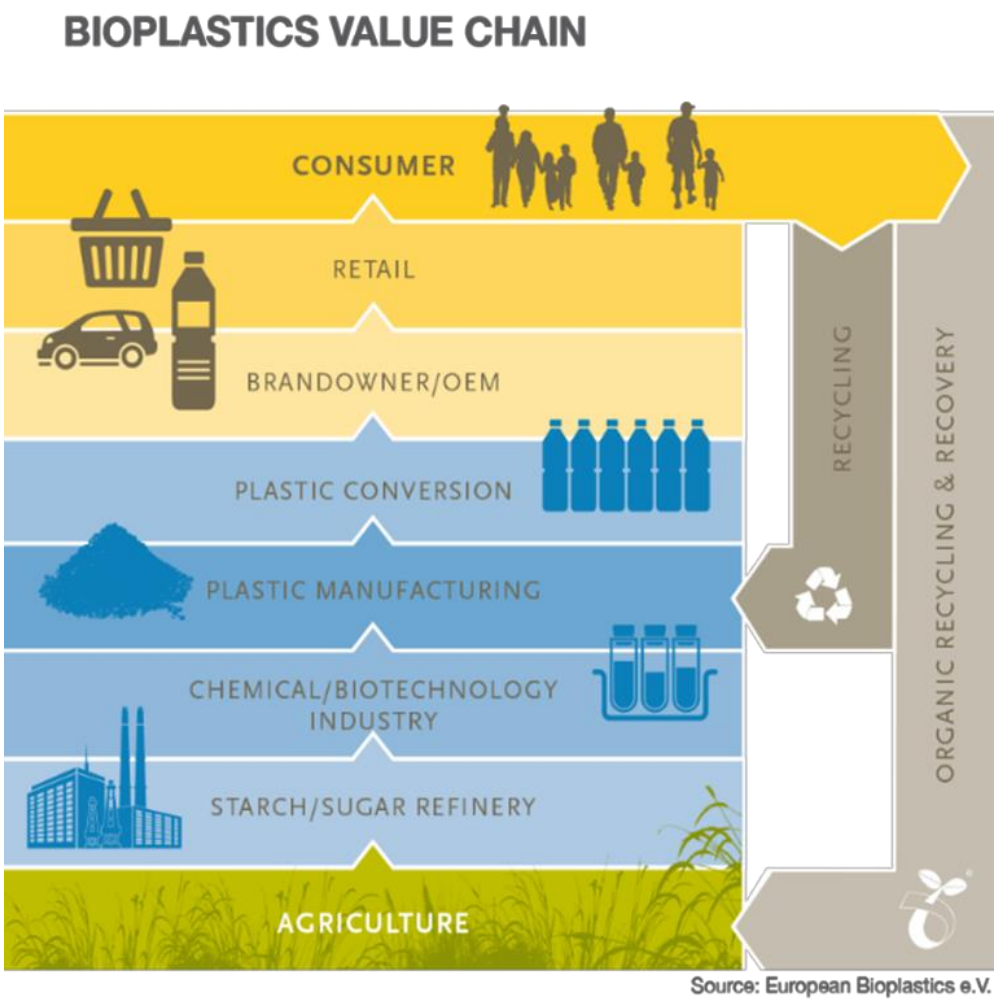

Figure 6 Bio-based plastics value chain

Source: European Bioplastics e.V., 2017

The most prominent approach in Europe is a focus on the actors in the blue zones, i.e. biomass processers and converters (Spatial Foresight et al., 2017). Here biorefineries are expected to play a key role in enabling the bio-based value chains to be developed. The creation of a multi-regional/ local value-chain, networks, growth of SME's and other employment opportunities, development of waste-management infrastructure, local skill-forging and knowledge dissemination are some of the practical benefits of a fully-functional bio-based value chain (European Parliament, 2016). 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.

Figure 7 gives an overview of the biorefineries in the European Union. The resources that are being considered are all kinds of biomass: first generation feedstocks such as sugar/starch (blue dots), vegetable oil (yellow/orange dots) as well as second generation feedstocks such as lignocellulose, biowaste, algae, syngas and biogas. Mature technologies are mainly the ones that utilise sugar, vegetable oil and pulp (1G). The 2G lignocellulose based refineries that are based on fermentation are still at a demonstration scale.

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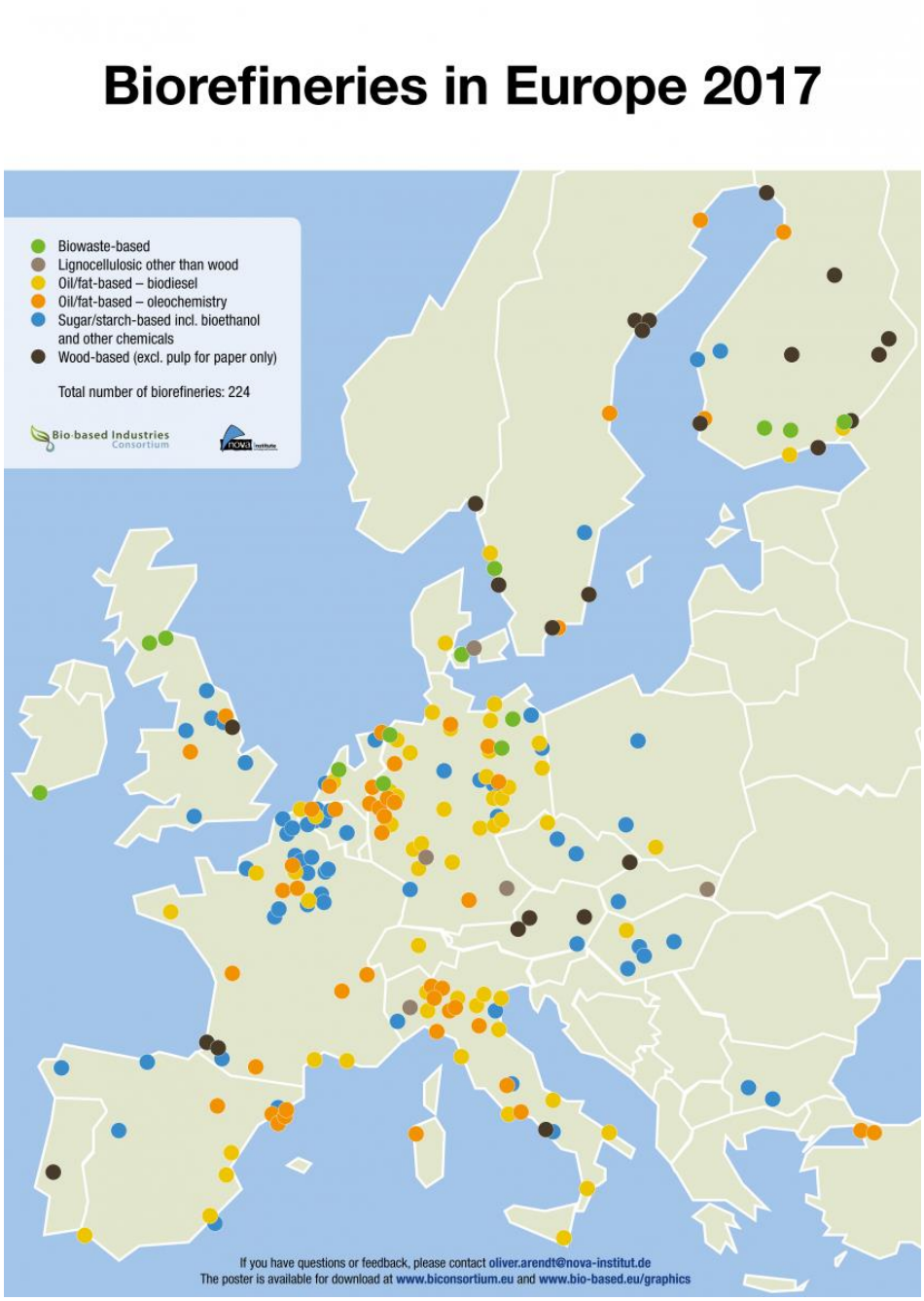

Figure 7 Biorefineries in Europe

Source: Bio-based Industries & Nova Institute, 2017

Priority for processing and converting functions is also shown in the research agenda of Europe's bio-based industries. The focus is on the upstream sectors with projects fostering supply of sustainable biomass feedstock and optimising efficient processing for integrated biorefineries (BBI, 2017a). In research agenda's of the European Commission and Biobased Industries (BBI), it is planned to increase attention on shorter value chains at a regional level. There are also BBI-proposals that pay attention to downstream adoption. These focus on application sectors (such as brand owners) in projects about developing and accelerating the market-uptake of bio-based products and applications.

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4.2.2 Upstream sectors

Upstream sectors include the production of biomass, agricultural residues and waste-products. Many biorefineries of 1G feedstocks use biomass resources from non-European countries, such as sugar/starch and vegetable oil. This holds in particular for the bio-based regions in northwestern Europe with good harbour infrastructure.

However, to an increasing extent projects also focus on the local feedstocks in Europe, i.e. the producers and waste-handlers and their (new) resources of agro-based biomass and feedstock. To enhance a circular economy it is also necessary to use more local waste. The FIRST2RUN project (www.first2run.eu) in Sardinia aims to demonstrate the environmental sustainability and economic profitability of an integrated biorefinery in which low input and underutilised oil crops grown in arid and marginal lands are valorised for the extraction of vegetable oils. These oils will be further converted into building blocks for high added value bio-based products (e.g. plastics and cosmetics). The project promises to have no impact on valuable land use for food production and to generate new incomes for local farmers. The farmers organisation (Coldiretti) is involved at the national level. So far, it is not known to which extent local producers are involved. The Italian company NOVAMONT has already developed the Matrica concept to involve local farmers. See Box 2.

Box 2: 3G biorefinery (www.matrica.it)
Matrìca is a third-generation biorefinery that will produce a range of chemical products through processes with low levels of environmental impact and strong collaboration with farmers, researchers and institutions. The objective is to transform feedstock, at a low cost, from renewable, non-food sources (compatible with the local area and cultivated on outlying plots) into bio-products, without negatively affecting the food chain or impoverishing other resources. It is a model that has what it takes to trigger local regeneration in economic, environmental and social terms, making the most of existing local resources and skills, with a positive impact on long-term employment prospects. Matrìca has created an innovative range of bio-products (bio-plastics, bio-lubricants, home and personal care products, plant protection, additives for the rubber and plastics industries, food fragrances, etc.). The new production facility will help to bolster the area's competitiveness and commitment to innovation, maximizing the potential for growth on various fronts: from the primary sector (agriculture, the rearing of livestock and beekeeping), to the secondary sector (farming vehicles and equipment, logistics and the manufacturing side of the processing of bio-based products) and even the tertiary sector (partnerships with local universities and research bodies).

Similar to the Matrica biorefinery in Sardina, the BIOSKOH biorefinery (https://bioskoh.eu) is using local feedstock in the eastern part of Slovakia. The local foresters and farmers have been mobilised. The feedstock will include 2G agricultural residues (in addition to the wood residues). The LIBBIO project (www.libbio.net) aims to increase the crop yield and the percentage of lupin beans from Andean lupin plants on marginal lands in Europe. Andes lupin will be grown as a summer crop in northern and central Europe and as winter crop in Mediterranean conditions. Once adapted for European conditions, these plants will offer the potential to produce food, animal feed and bio-energy products. Companies show that there are more new resources of biomass and feedstock possible, such as miscanthus used in building materials, bio-based plastics (www.novabiom.com) and in hygiene paper (www.wepa.nl). The websites of those projects show mainly research and education institutes and bio-based companies as partners. Therefore, it seems that currently they lack or do not need biomass producers and waste handlers.

A relevant project to analyse the sustainable delivery of non-food biomass feedstock of the whole value chain - from primary biomass to end-use of non-food products – is the S2Biom project (www.s2biom.eu). S2Biom gives an overview of EU28 countries, Western Balkans, Moldova, Turkey and Ukraine and estimates the availability of lignocellulistic biomass potentials. The results aim to

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facilitate integrated design and evaluation of optimal biomass delivery chains and networks at national, regional and local scale.

4.2.3 Downstream sectors

Attention that has been paid to the downstream and application sectors has focused in particular on citizens. Citizens may be involved in the circular bio-based economy in various ways (see Section 4.4). With consumption of bio-based products being one of the key roles citizens can play. A number of representative surveys have been done to investigate the awareness and propensity/inclination of consumers to buy bio-based products.

Studies have been done about the (un)familiarity with bio-based products, in terms of awareness and associations. During the FP7-project Open-Bio, a cross-national representative survey with (paid) consumer panels was run in six European countries (Czech republic, Denmark, Germany, Italy, the Netherlands and Slovenia) (Meeusen et al., 2015a; Sijtsema et al., 2016). Of the in total 6,228 respondents 57% were older than fifty years. Furthermore, a non-representative cross-national survey has been conducted with 452 mainly younger and higher educated respondents on a voluntary base (Karachaliou et al., 2017), and a national representative survey with 1,673 respondents in Germany (Blesin et al., 2017). The results from those surveys show that the awareness of the bio-based products seems to lie around 50%. The 50% awareness levels can be a barrier for further market development of bio-based products, if the marketing is focused on the bio-based position (Pfau et al., 2017).

Issues that were often automatically associated with ‘bio-based’ are ‘biodegradable’ or ‘organic’, which could lead to too high expectations and misconceptions of bio-based products (Blesin et al., 2017). Other studies also show that people assume that bio-based production is primarily aimed at finding environmentally friendlier solutions at a global scale. This assumption can also result in such a positive attitude towards bio-based products that expectations are too high (Pfau et al., 2017). Health and safety were also relevant positive associations with bio-based products on a personal scale, especially in Italy, Czech Republic, and Slovenia (Meeusen et al., 2015a; Karachaliou, et al., 2017). However, participants do not seem to trust bio-based producers completely regarding their claims and are concerned about ethical issues.

Furthermore, consumers do not expect economic benefits on a personal scale in terms of better performance or reduced cost. Since personal benefits are most influential on buying decision (Meeusen et al., 2015a), this could provide barriers for further market development.In addition, a representative survey among German (1,031) and French (1,009) consumers indicates that they are most likely to purchase the fully bio-based product compared to a conventional one or a hybrid one. Furthermore, the results (Reijnders et al., forthcoming) show that consumers prefer clear messages, such as that products can be discarded alongside organic waste, substantiated claims about environmental benefits, and sincere intentions of the brand owners regarding the content of the packaged product.

Although two-thirds of the participants of the aforementioned surveys state a preference for bio-based products over conventional products, only 12% have ever consciously chosen bio-based products over conventional ones (Pfau at al., 2017). The difference between “stating” and “acting” is well-known in social-economic research. Consumers drawn to environmentally friendly products are willing to pay more for them, even if the higher price is for equal product functionalities. Most consumers, however, are relatively unaffected by the fact that a product is bio-based and would be willing to pay a little bit more if the benefits are clear to them. Also, the provision of labels, which explain bio-based products is seen merely as an added value. The results indicate that currently bio-based products are only a niche market, which cannot automatically be extrapolated / diffused to broader user groups. To extend the

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user groups it is important to explain the contribution of bio-based products to a circular economy. Hence, to analyse the consumer preferences whether the products should be bio-degradable or recyclable and to develop a “nudging” waste infrastructure to support consumers in responsible consumption behaviour.

So far, brand owners are less involved in the bio-based value chain. Some brand owners of consumer products took the initiative that actors along the value chain carry the burden and absorb the higher product costs, i.e. Coca-Cola and IKEA. It allows those brands to focus on image and branding, looking at the problem from a different perspective (Pfau et al., 2017). Furthermore, to an increasing extent, brand owners consider the SDGs to mitigate climate challenges and sustainable production and consumption. Bio-based products might support them to reach these goals and targets. An example is UNILEVER, which states that in 2025 it will only use packing that could be reused, recomposted or recycled.

BIOPEN, started in 2017, aims to accelerate and support business development of bio-based industries and downstream sectors (www.biopen.eu) by setting up an open-innovation platform addressing strategic cross-cutting challenges such as: clustering and networking to develop new value chains, stakeholders engagement and support of co-innovation partnerships alongside existing and new value chains, and the creation of a knowledge centre. BIOPEN has also a number of well-distributed industrial clusters from Europe in Germany, Italy, the Netherlands, Poland and Turkey. Also BIOBRIDGES, which will start in the second half of 2018, aims to focus more on the cooperation with brand owners and consumers.

4.3 EXTERNAL STAKEHOLDERS

Public and civil organisations are also key to the realisation of bio-based value chain. External stakeholders include both governmental organisations and civil society organisations (CSOs), and may geographically differ from international to local. The role of governments may vary from facilitating the pre-development of the bio-based value chain by delivering of public resources and guidance of research, legislation by creating a level playing field or stimulating bio-based application development through public procurement procedures and by providing other economic incentives (for example additional taxes on non-bio-based products and subsidies for bio-based projects and products).

CSOs and NGOs play an important role in mobilising normative pressure which is usually necessary to trigger value chains to change their practice (Geels & Schot, 2007). CSOs and NGOs can play different roles in the bio-based economy. Some focus on disrupting the status quo through confrontation, whilst other organisations seek constructive collaboration with business, government and other stakeholders to develop alternatives (Meeusen et al., 2015b). So far, the number of CSOs and NGOs that cooperate with other stakeholders in the bio-based economy is quite low. Since most of their attention is directed to research projects where the issue of sustainability is the main objective, one could also argue that the low participation is caused by the technology development driven research agendas.

At the heart of many recent research and innovation agendas is that the outcomes of current bio-based economy value chains focussed on technology development with sustainability assessments. However, this focus does not necessarily fit the needs of society as a whole, as it does not “chime” with the demands of citizens and local producers who are more interested in delivering local societal objectives. It is therefore important that civil society becomes involved and provides input into these agendas in order to assure that the outcomes of the bio-based economy value chains do fit the needs of society.

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Most NGOs appear to have a watchful to critical stance towards the use of biomass for the production of bio-based products (Meeusen et al., 2015b). They are wary of potentially negative environmental and social impacts of feedstock production and ask for transparent and credible information on sustainability aspects of bio-based products and their production processes. Although it is still possible to distinguish NGOs/CSOs from the environmental movement (e.g., Greenpeace, Friends of the Earth, and the WWF) and NGOs/CSOs from the social movements (e.g., Oxfam, Fairtrade, BEUC), the scopes of most NGO/CSOs have been expanding to cover both environmental aspects and social aspects. Corporate engagement has been an important issue for major NGOs/CSOs. A small number of NGOs now focus on confrontational relationships (polariser). Most NGOs actively in the bio-based economy have partnered or are partnering with companies corporations in their campaigns and operations (Meeusen et al., 2015b). They are actively working on issues related to bio-based products and sustainability certification. They are most relevant as interlocutors (CAN, ECOS, WWF, EEB, and IUCN).

As a first step to create broad acceptance of bio-based products and processes, CSOs should be involved in discussions regarding the implementation of the bio-based economy. This holds in particular for CSOs who seek constructive collaboration with business, government and other stakeholders to develop alternatives (Meeusen et al., 2015b). Together with built-in participation, civil society must have the opportunity for intervention in later stages of the bio-based economy (Bio-STEP, 2018) .

CSOs focus on societal impacts of the bio-based economy and its transformation failures rather than on technological/scientific development or business development and its market failures. Mission-driven CSOs can focus more on policy impacts and the needs of citizens than on scientific publications and building up academic track records. Their mission is to influence national or regional bio-based economy policy-making. Although to an increasing extent CSOs are interested to participate in bio-based research and coordination projects, the issue of bio-based economy is not high on their agenda (Bio-STEP, 2018). If bio-based research and innovation agendas want to safeguard their legitimacy vis-à-vis European citizens, the globally agreed Sustainable Development Goals (SDGs) could serve as an orientation to create more urgency and a better demand articulation to implement the bio-based economy. The CIMULACT project (www.cimulact.eu) has demonstrated that up-stream engagement of citizens in research and innovation agenda-setting is possible. It marks a shift, demonstrating that open science is not just about making science available to people, but also about engaging people in helping set the direction for research and innovation.

4.4 BIO-BASED QUADRUPLE HELIX MODEL

In Chapter 2 the quadruple helix model for innovation was introduced to highlight that collaboration between academia, industry, governments and civil society is needed to realise large scale innovation. In the case of BIOVOICES, which focusses on the commercialisation of market applications, it is important to focus on the contribution of policy-makers, civil society and businesses that are currently less present in the internal value chain (local feedstock producers and brand owners). Furthermore, research and education is important to contribute market opportunities.

The role of policy makers is to guide research, provide resources (through research programmes) as well as to help create legitimate and feasible market opportunities. Guiding research and mobilising resources is not evident in all countries. A manifesto of the Mezzogiorno shows their unfulfilled role as key drivers of socio-economic development in governments trying to reduce costs and save resources in order to face the pressing financial aspects of the crisis (Koukios et al., 2018). Improved reputation of bio-based products could be created by better cooperation with CSOs and academia, while more market opportunities could be created by setting defaults that enhance the circular bio-based economy

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compared to the fossil-based economy (legislation), by acting as a pump-priming customer of bio-based products, and by providing economic incentives (via taxes or subsidies).

The role of businesses is both to provide feestock, to develop, innovate and sell new products and to consider their corporate sustainability to contribute to a circular bio-based economy. The provision of feedstock and improved market uptake could be relevant subjects for mutual cooperation with policy makers and civil society to enhance the circular bio-based economy. It should be noted that the governance structure differs substantially between European countries. See Box 3 to consider the Germand and Italian policy strategies. The Italian case could be also considered as an example to deal with transformational challenges, i.e. to solve the problems with plastic waste.

Box 3: Comparing policy strategies for a transition to a bioeconomy in Europe: The case of Italy and Germany (Imbert et al., 2017)

Although Germany and Italy are both frontrunners of Europe's bioeconomy, their policy strategies reveal fundamental differences. The German policy strategy has been developed by the government, with the Ministry of Education and Research as the initial proponent. The strategy is highly formalised and has included the development of institutional capacities for horizontal policy coordination, stakeholder engagement, monitoring and review and acquisition of strategic knowledge. It builds on a long-term vision for the transition towards a bioeconomy and aims at positioning Germany as a strong location for research and innovation in this future growth market. It lacks a strong framework for supporting market development in the bio-plastics sector and investment in productive capacities. This is partly related to an ambiguous relationship to the bio-plastics sector from the chemical industry, on the one hand, and environmental NGOs and the environmental bureaucracy, on the other. The former is still strongly invested in the existing petroleum-based regime, while the latter has articulated strong reservations regarding the improved environmental performance of bio-based plastics compared to conventional plastics.

The Italian policy strategy, on the other hand, is strongly emergent in nature and has been characterised by a bottom-up, stakeholder-driven strategy process. Rather than a formalized strategy process, the cornerstone of the Italian policy strategy has been legislation favouring bio-based plastic bags, which has helped stimulate the formation of Europe's leading market for bio-plastics. Upholding this legislative approach against the resistance of other EU countries has also been a centrepiece of Italy's – ultimately successful – European engagement. Another key component of the strategy has been the support for investment in biorefinery projects on failing industrial sites, in an effort to confront the crisis of Italy's traditional chemical industry. Support for R&D and cluster development has also taken place, but stakeholders cite a relatively high reliance on European research and innovation programming. The more formalised strategy process launched in 2016 is also formally linked to its Smart Specialisation Strategy under the European Cohesion Policy and represents a vehicle for accessing related funding opportunities.

In a nutshell, the Italian policy strategy represents an emergent strategy driven by industrial stakeholders with a strong emphasis on market development, while Germany has pursued a government-led, top-down strategy focused on knowledge development and innovation. In Germany, the government is seeking to prepare the transition towards bioeconomy within the context of its well- established and successful chemical sector. Sustainability concerns represent an additional barrier for more ambitious measures aimed at promoting markets for bio-based plastics. The Italian policy strategy, on the other hand, has been devised in the context of a struggling chemical sector, where bio-based plastics represent a short- to medium-term option for diversification and reanimation of failing industrial sites. Moreover, with a less advanced recycling sector, bio-based plastics have long represented an alternative strategy for mitigating the environmental impacts of plastic waste and are supported by Italian environmental NGOs. This reconfiguration pathway is supported not only by environmental pressures but by other weaknesses in the existing regime. The crisis of Italy's struggling chemical regime, on the one hand, and the less-established waste management regime, on the other, have favoured the emergence of new actors and alliances who are driving Italy's emergent policy strategy.

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Citizens may be involved in the circular bio-based economy in various ways. From the distinction in roles made in nature and landscape research (Overbeek, 2008; De Boer et al., 2014) three different roles, i.e. 'consumers', 'protectors' and 'decision-makers' could be distinguished:

- Consumers are people who relate to the circular economy by the decision to buy bio-based products. There are many ways of persuading consumers to buy sustainable products, which can be linked to the product, the person, or the physical and social environment.
- Protectors perform activities for the benefit of the circular bio-based economy, such as appropriate waste-behaviour (e.g. separation, composting etc.) for recycling and re-use of products.
- Decision-makers express their involvement by joining in circular bio-based economy campaigns and citizen's initiatives and by collecting knowledge about such activities.

The contribution of citizens to the bio-based circular economy could be enlarged by paying more attention to their role as protectors and decision-makers to stimulate appropriate waste-behaviour for re-using and re-cycling of (bio-based) products. Furthermore, their involvement with and acceptance of the bio-based economy could also stimulate their behaviour to buy more bio-based products. At a regional level, it could be hypothesised that regions with a more re-use of local collected waste ("local 2G"), have a positive impact on the acceptance of the bio-based economy.

Besides those four quadruple helix groups who represent public and private interests and perspectives, there are also actors who act as intermediate actors between them. Intermediate actors could stimulate, connect or facilitate actors to innovate. Examples of stimulating actors are journalists and trend watchers. Intermediary organisations or 'bridges' to connect different stakeholders in clusters or thinktanks are particularly important as many technologies are still rather immature and cooperation between different sectors is required.

4.5 REGIONAL COOPERATION

The supply of biological resources or industrial knowledge is actively used for the deployment of the bio-based economy in a region. Regional bio-based economy ecosystems in Western Europe are built around the usual stakeholders of regional innovation systems. Governments and public administration, businesses and representatives of sectoral associations and business intermediaries, as well as academic, scientific and technological institutions collaborate in clusters as intermediary organisations. They are mainly triple-helix oriented with a focus on business interest groups to solve market and system failures that do not include civil society to solve transformation failures. Clusters are an important tool to gather stakeholders around specific bio-based economy sectors/products, especially in strongly industrialised regions, but also increasingly in rural regions (BERST, 2016). Therefore, bio-based related clusters often need to integrate also producers of biological resources, i.e. farmers and fishermen, as well as their associations. Regional governments could be a driver by taking political decisions to promote economic development, to reduce the dependence of a region or country on imported raw materials and fuels, and to respond to environmental or territorial challenges (e.g. loss of population in rural areas, climate change).

However, many regions report the lack of specific bio-based bodies or networks. Some of them have additional emergent players, such as councils, thematic platforms and networks, and specialized technology, research and innovation centres (Spatial Foresight et al., 2017). The analysis of the different features of the bio-based economy in European countries and regions shows a variety of drivers towards the bio-based economy, regional capacity and maturity, and different approaches. To

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understand the diversity in thematic orientation and value-chain approach a typology of regional bio-based economy profiles has been elaborated (Spatial Foresight et al., 2017):

1. Regions with a natural resources and heritage driven bio-based economy profile (e.g. Canary Islands, Extremadura, Latvia & Bulgaria);
2. Regions with a research driven bio-based economy profile (e.g. Madrid, Helsinki, Lodzkie);
3. Regions with a primary value chain bio-based economy profile (incipient, e.g. Galicia, Crete, Norte Portugal, West Romania);
4. Regions with a primary value chain bio-based economy profile (advanced, e.g. Emilia-Romagna, Värmland, Weser-Ems, Lappi. Approach: Value aggregation, specialisation in value chains, new products from available biomass and residues, R&I on bio-refineries and bio-based products)
5. Regions with an industrial biotech profile (e.g. North-Rhine-Westphalia, Nord-Pas-de-Calais. Approach: Technological conversion, developing new value chains, integrating fossil-based and bio-based technologies, developing circular approaches)
6. Regions with an integrated and advanced bio-based economy profile (e.g. South-Holland, Flanders, Skåne, Scotland. Approach: Transition, developing new value chains, combined value cycles with primary/industrial sectors, new bio-based manufacturing technologies, and circular approaches).

Within this typology, triple helix organisations are mainly found in the regional profiles 4–6. It is difficult to align all EU regions and countries to only one of the types of the typology, because most regions and countries have a heterogeneous approach to the development of the bio-based economy (BERST, 2016; Spatial Foresight et al., 2017).

A number of actors in research & education and public administration are also active in cross-regional cooperation. The Biobase NWE project aims to accelerate the growth of the bio-based economy: EU and local partners joined forces by providing financial, technological, training, networking and political support to enterprises innovating in bio-based products and processes (www.biobasenwe.org). The BIOCAS project aims to turn rural areas into smart specialised regions for the integrated and local valorisation of biomass, based on biomass cascading principles (www.northsearegion.eu/biocas). The focus of BIOCAS is to realize triple helix alliances with all stakeholders involved in the value chain to realize a more sustainable conversion of biomass.

4.6 RELEVANCE OF COOPERATION FOR BIOVOICES

To evaluate the relevance of the cooperation analysed in this chapter, we will consider the functions assumed to take place during the take-off phase. During the take-off phase it is more likely to get brand owners and manufacturers, governments and civil society interested in the development and market uptake of the bio-based economy. In this phase entrepreneurial experimentation and production is critical in tandem with building legitimacy and market formation.

The results of the analysis before indicate that mainly internal stakeholders are active. We have analysed a number of innovative projects building up a long value chain with many actors and functions mainly relevant for internal cooperation. The focus of those chains is on pre-treaters, waste-handlers, bio-refineries, producers of bio-based building blocks and chemical transformers. So far, feedstock producers and brand owners and manufacturers are less involved in those value chains. To an increasing extent, brand owners consider the SDGs to mitigate with climate challenges and sustainable production and consumption. Bio-based products might support them to reach these goals and targets.

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The question is how they could be involved through in-built participation and setting/evaluating agenda's for the commercialisation of working prototypes. It is also important to investigate whether shorter value chains are possible and available in order to improve the internal cooperation at a regional level.

Furthermore, the cooperation with external stakeholders could be improved with more governments and civil society interested in the development and market uptake. Moreover, a coherent product concept for market formation is still missing. Therefore, it is important to prepare a better match with consumers and CSOs, as they are relatively unaffected by the fact that a product is bio-based and would be only willing to pay more if the benefits are clear to them (Meeusen et al., 2015a; Karachaliou et al., 2017). The contribution of CSOs and citizens to the bio-based circular economy could be enlarged by paying more attention to their role as protectors and decision-makers to stimulate appropriate waste-behaviour for re-using and re-cycling of (bio-based) products. In remote regions, the community may play a significant role to contribute to the development of bio-based value chains. In such regions, social and community groups may often play the dominant entrepreneurial role.

So far, in many projects it has been difficult to involve citizens and local producers. BioSTEP (www.biostep.eu) distinguished stakeholders and citizens that do not formally identify with stakeholder groups (BioSTEP, 2018). Many public engagement practices draw on instrumental rationales, which are generally connected to providing knowledge or understanding to fill a deficit, known as 'the deficit model'. There is still a long way to go in the transition from a 'deficit'-oriented approach to a 'democracy'-oriented approach in more participatory forms of scientific governance. As shown in the CIMULACT project (www.cimulact.eu), the motivations to engage in discussions about the bio-based economy are fuelled by a broader ambition to participate in policy decisions that may have ambiguous effects or a willingness to support the transition towards a more sustainable society. Engagement practices can take more 'consultative' (advisory, prescribed) or 'participatory' (non-directive, flexible) forms. Hence, for BIOVOICES the challenge is not only to include more actors, but also to engage them in a participatory way.

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5 POLICIES AND SECTOR AGREEMENTS TO ENHANCE THE BIO-BASED ECONOMY

5.1 EU POLICIES AND REGULATION

Table 4 (see 3.7) has shown several bio-based applications where policies and sector agreements could help to improve the market uptake. For the T-phase, entrepreneurial experimentation and production is critical (F1) in tandem with counteracting resistance to change and building legitimacy (F7). Therefore, the question is which policies and sector agreements contribute to enhance the bio-based economy. A large number of studies discuss policy issues that hamper the development of the bio-based economy. For example, while for bioenergy and biofuels there is a comprehensive set of many different support mechanisms in a large number of countries worldwide, there are almost none for the material sector (Dammer et al., 2017). Several authors discuss the impacts of this imbalance, stating e.g. higher costs and restricted access to biomass for material uses due to artificially high prices caused by the support system (OECD, 2014). In addition to the lack of a level playing field between energy and material uses, issues such as the difficult market access of bio-based materials, insufficient public procurement practises, and non-biodegradability are main topics. Also, while food, feed, bioenergy/biofuels and bio-based materials are all part of the European bioeconomy, their specific policy frameworks are very different.

Legislation for a level playing field between energy and material uses
Many countries in Europe use raw material from abroad to refine it for biofuels and bio-based materials. There is a European directive to use sustainable biomass for biofuels (The Renewable Energy Directive 2009/28/EC). This directive implies that biofuels shall not be made from raw material obtained from land with high biodiversity value, such as rainforests or protected nature areas, and not from land with high carbon stock, namely wetlands and continuously forested areas.

There are a number of recommendations in place for energy and material uses to create a level playing field in Europe for sustainable biomass, which have not been taken to implementation by policy makers. Legal sustainability requirements for bio-based products are still not harmonised in Europe, because all member states have their own biomass policy for biofuels. The European policy directive for biofuels offers a starting point for sustainable bio-based materials. However, others find it insufficient, because the biofuels policy does not take account of (in) direct land use change (LUC and ILUC), such as in a negative way less food security and more deforestation in America (Carus et al., 2016). Examples of positive ILUC mitigating strategies are also possible by prioritising abandoned and unused degraded lands and increasing agricultural yields (Woltjer et al., 2017). See the projects mentioned in Section 3.2.

Market access of bio-based products
A related issue to the level playing field is how policy can and does influence the market access of bio-based products. Table 4 shows a number of bio-based applications which are relevant for market uptake by mainstream consumers, but lack legislation for a level playing field with their fossil-based equivalents. So far, there is no common understanding, agreement or strategy in Europe on the question which bio-based plastics can and should play a role in sustainable packaging and the circular economy. The same holds for wood construction and textile.

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The Commission Expert Group for Bio-based Products (2017) evaluated the progress made in implementing recommendations towards standardisation, certification and tax incentives from 2013 to 2015. While the steps taken towards standardisation and certification were rated positively – the only gap being actual usage of the standards by companies to declare their products and by governments for the setting of incentives –, more implementation of 'stronger' market tools, i.e. targets and tax incentives, was found to be lacking.

European standards for access to market

Despite the steps taken forward, European standards for access to market are still absent. CEN/TC411 is developing European Standards and other deliverables covering horizontal aspects of bio-based products, and also in relation to specific types of bio-based products[5]. These voluntary standards are being developed through a process of collaboration among experts and representatives from business and industry, research bodies, public authorities and agencies, consumer and environmental groups, and other interested stakeholders. In the area of bio-based products, CEN cooperates closely with the European Commission in order to develop standardisation activities that correspond to the objectives of European Union policies, whilst also meeting the needs of industry and other stakeholders. In Chapter 3, the European regulation in terms of standardisation has been explained for bio-based plastics through European norms for its C-content (CEN/TS 16640) and method how to measure it (EN 16785-1 2015). Other issues to be agreed are among other sustainability criteria and life cycle assessments.

Certification schemes

Although there are no mandatory requirements at EU level, some countries have taken initiatives to develop mandatory biomass certification system and regulations that cover the whole supply chain. These are Belgium and UK and to a lesser extent the Netherlands, Italy and Spain. Several voluntary biomass certification systems concerning sustainability criteria also exist. These can be divided into Sustainable Forest Management Systems (SFMS) that provide guidelines and rigorous assessment for forest management and other certification systems created by electricity suppliers, pellets producers etc. Important SFMS include Forest Stewardship Council (FSC), Programme for the Endorsement of Forest Certification (PEFC), International System for Carbon Certification (ISCC and ISCC+), Roundtable on Sustainable Biomaterials (RSB) and Better Biomass.

Tax incentives

Targets and tax incentives relay on national political frameworks to support the use of bio-based applications if they satisfy societal demand, e.g. SDG. There is not one European political framework. The understanding and political framework for bio-based plastics differs from one member state to the other. Political targets of the packaging sector are: avoid, reduce and recycle. The correlation between framework conditions and market success of bio-based packaging is high and also affects future projections. A positive framework to support the use of bio-based plastics by a ban of fossil-based plastics, such as in Italy or France, will guarantee market growth and investments; a negative setting to avoid the use of plastics in general, such as in Germany and in the Netherlands, will put successful developments in the bio-based economy at stake. Italy and France favour the use of biodegradable plastics through legislation, other countries do not see this as an option to enhance a circular economy (Dammer et al., 2017).

Public procurement

Green public procurement refers to Europe's public authorities as major consumers. By using their purchasing power to choose environmentally friendly goods, services and works, they can make an important contribution to sustainable consumption and production. This is referred to as Green Public

[5] http://www.biobasedeconomy.eu/centc-411-bio-based-products/

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Procurement (GPP) or green purchasing (http://ec.europa.eu). National and/or European policy to stimulate the development of bio-based applications include preferring bio-based products when purchasing public goods. GPP schemes are less developed in Europe than in the United States, where governments have created a bio-based preferred programme. Most ambitious GPP strategies in EU Member States support the use of sustainability criteria in various sectors such as energy, textiles, catering, wood and cars, but rarely promote specficcally the use of bio-based products. The sustainability criteria are not necessarily bio-based, but rather "non-toxic, organic, less water use, less carbon emissions, sustainable land-use management etc." The European Union is boosting standards and labelling for bio-based products as part of the Bioeconomy Strategy as well as through the Public Procurement Network (Horizon 2020 “Bioeconomy”).

The uptake of bio-based products in public procurement is closely linked to the question whether the targeted purchase of bio-based products can be justified based on existing practices and guidelines (Peuckert & Quitzow, 2015). Although significant progress has been made over the last few years and some member states have started pilot projects on bio-based procurement, additional scientific and standardisation work, labelling and communication are crucial for further development (www.open-bio.org). Since there is no binding preference for bio-based products and no official EU sanctioned product list, significant commitment and resources are required to make progress on this topic. Experts from public procurement see high barriers towards achieving a widely-accepted bio-based procurement. These are both rooted in public procurement law as well as practice. Therefore, significant commitment and resources are still required to make progress on this topic.

The InnProBio project (http://innprobio.innovation-procurement.org/home) aims to develop a community of public procurement practitioners in 12 member states interested in innovative bio-based products and services. Results highlight the lack of funding for the often higher-priced bio-based solutions as the main hurdle, as well as the associated low return on investment within the legislatory period, which creates unwillingness among local politicians to support such solutions. Moreover, producers often seem to be reluctant to sell their goods to public procurers, which in turn claim to have insufficient knowledge of respective producers and face legal hurdles related to standardisation of bio-based products.

Biodegradability and circular economy

Low expertise and less trust in existing standards and labelling on biodegradation in different environments and limited knowledge in the public, politicians and CSOs concerning the assessments of the properties, opportunities and benefits of bio-based materials hinders the growth of them (e.g. bio-based plastics). The evidence base around the nexus of biodegradability, best end-of-life option and policy design for plastics in a circular economy is still lacking. There are neither comprehensive assessments that evaluate the net environmental and climate benefits that bio-based products claim to entail over products made entirely from non-renewable resources.

The framework is still in development in most EU member states, and also at an EU level. The European Parliament’s plenary encourages countries to support the use of bio-based materials for the production of packaging and to improve market conditions for such materials and products. After finishing the framework, logos and labels could be used to inform consumers and retailers about the biodegredability of the end products. Furthermore, none of the investigated countries (Finland, Germany, Poland, Spain, UK) had dedicated policies on cascading use of wood (Dammer et al., 2016).

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5.2 SECTOR AGREEMENTS TO ENHANCE SUSTAINABLE BIOMASS

There are several sector and product certification schemes with which businesses could set extra voluntary conditions - over and above the legislation - to other businesses in the value chain. These schemes are established through consultation of businesses and CSO's in working groups and round tables.

A part of these certification schemes has a label that can be used on consumer products (B2C-labels such as FSC for certified wood), while other schemes are mainly oriented at businesses (B2B-labels such as NTA8080). In countries including Germany, the United Kingdom and France the sustainability of a bio-based product has been determined by the production of raw materials and not by its application. Therefore, the exisiting certification schemes for biofuels could be used for bio-based materials if adapted (Vis & Pfau, 2016).

There are already some certification schemes for sustainable agricultural biomass with a focus on biodiversity, e.g. Roundtable on Sustainable Biomass (RSB), Better Biomass and ISCC-plus. Nature organisations were involved with the establishment of these schemes. Indirect Landuse can become an important issue for oil, sugar and starch products (not for lignocellulose). Better Biomas (NEN) has included a module "ILUC-safe" for the cultivation of biomass on former margin lands. So far, this module has not yet been applied by its certification holders.

5.3 RELEVANCE OF POLICIES AND SECTOR AGREEMENTS FOR BIOVOICES

Table 4 has shown a number of bio-based applications which are relevant for market uptake by mainstream consumers, but lack legislation for a level playing field with their fossil-based equivalents. So far, there is no common understanding, agreement or strategy in Europe on the question which bio-based plastics can and should play a role in bio-based circular economy. The policy intervention measures for almost all European countries with regard to their bioeconomy strategies, refer to promoting innovation, infrastructure, commercialisation and adequate policy framework conditions instead of improving the demand articulation of bio-based products. Testing the potential of public procurement to facilitate the creation of buyer groups could be helpful, in particular for bio-based products targeted at mainstream consumers which have to compete with cheaper fossil-based equivalents. Furthermore, there is no policy coordination. More societal urgency to enhance the circular economy could support transformational challenges and to increase the market uptake of bio-based products.

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6 PESTEL ANALYSIS OF ENABLING FACTORS AND BARRIERS TO DEVELOP BIO-BASED APPLICATIONS

6.1 INTRODUCTION

To report a synthesis of market perspectives, we will start with an overview of the main issues to commercialise bio-based applications in the relevant value chains in the take-off phase in Europe (6.2). This implies that those commercial applications have already solved or do not face barriers for scaling up which are relevant in the stage of (pre)development. Those barriers are feedstock-related such as the high costs of biomass feedstock produced in the EU, and industry-related such as the low technology readiness level and commercialisation status for many bio-based products, plus lack of internal cooperation among relevant stakeholders. Here, attention will focus on the market-related barriers such as higher price and lower performance of bio-based applications compared to conventional products, lack of legislation, and low public awareness of the benefits of using bio-based products. An analysis of the Political, Economic, Social, Technological, Environmental, and Legislative factors (PESTEL) will be made to elaborate issues for improvement and required collaboration among actors along the bio-based value chains (6.3). The PESTEL factors will be analysed to indicate the factors affecting the market, public awareness and acceptance of bio-based applications.

6.2 VALUE CHAINS

Many bio-based application sectors include plant biomass to different extents. A number combine plant and fossil biomass into their hybrid products, such as in non-biodegradable bio-based plastics and in viscose textiles. The hybrid setting might facilitate the access and trust of consumers in the transition towards a bio-based economy, but might be also a weakness if the overal image of the application is not bio-based (automotive sector) or does not improve the functional performance.

6.2.1 Bio-based plastics and polymers

Bio-based packaging products and disposals are particularly relevant for showcasing the bio-based economy. The bio-based plastics market and technology is growing. However, there are also concerns that may hinder their growth and market uptake:

- The end-of-life options for certain applications (bio-degradable or mechanical recyclable) are relevant for consumers and could be better clarified, both in its meaning as well as in describing the required waste behaviour. In order to facilitate the mechnical recycling of bio-based plastics, it is important to createe homogeneous amounts of waste streams in order to facilitate the purification.Therefore, it is important to promote packaging and disposals among households with a high number of consumers and events, which are able to collect large homogenous amounts of waste streams. However, the relevant infrastructures are often lacking.
- The fact that products are hybrid could facilitate the interest of consumers and of manufacturers and brand owners that would like to transform their current applications. However, since in those situations the performance will not differ so much, the production costs should be compatible with conventional products.

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- Furthermore, there is a lack of standardisation and the absence of a framework for their further market uptake, in particular for single-use of products.

6.2.2 Fibres

Natural, wood and cellulose fibres have already many application areas in bio-composites (light weight), insulation and textiles. They also have a positive, environmental and health friendly image to the public, and improve the sustainability impacts. Besides, there are also concerns that may hinder their growth and market uptake:

- They are not framed as “bio-based”. The fact that the pulp and paper, construction and textile manufacturers are not aware of being part of the bio-based industry and neither do consumers. This might be considered a weakness in promoting the bio-based economy. However, it could be also an opportunity to discuss and compare the features and sustainability of bio-based products.
- Furthermore, the meaning of “bio-based” does not offer an additional value for many old application sectors, because consumers consider the content a natural/organic matter, such as wood in construction & furniture, pulp in paper, and cotton in textile. Often, the old bio-based application sectors, such as textile, are losing their market share in favour of their fossil counterparts or hybrid products (Dammer et al., 2017).
- Biofuel policies can be a hurdle for bio-based textile fibres. 2G biofuels are strongly supported by the European Commission and the member states – in contrast to 2G textile fibres, which bring higher value added and more jobs compared to biofuels but are made from the same lignocellulosic raw material.

6.2.3 Biosurfactants, biolubricants, neutraceuticals and algae

Biosurfactants are used in high and increasing volumes of applications of personal and home care and have a well-developed market with both mainstream consumers and niches. Their fast biodegradation with low environmental impacts is attractive for consumers. Furthermore, they are also widely used as gelling agent in colloid applications. However, there are also some hurdles for further commercialisation are also noticed:

- The impression is that oleochemistry until recently did not really consider itself part of the bio-based economy accompanied by doubts about rebranding long standing bio-based components in a formulation as “bio-based”.
- Difficulties in recovering pure biosurfactants (for pharmaceutical, cosmetic and food applications).
- Their potential for health benefits has still to be proven with more products.

6.2.4 Bioenergy and biofuels

Despite the significant benefits that derived from the production and consumption of bioenergy, such as a non-level playing field for energy and material use, which mainly supports an energetic use of biomass (Carus et al., 2015), there are some barriers that hinder their further uptake with 2G feedstock:

- Many countries in eastern and southern Europe are not familiar with bioenergy practices, which has negative impact in the total attribution of EU in bioenergy field. Moreover, an important barrier is the relatively low level of awareness of the general public about bioenergy and its benefits and implications and the fairly common societal belief that waste management should

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only be conducted by the public sector, rising suspicions and mistrust upon any other initiatives (Tsagaraki et al., 2017).

- Absence of a stable financial, policy and regulatory support.

6.3 PESTEL ANALYSIS

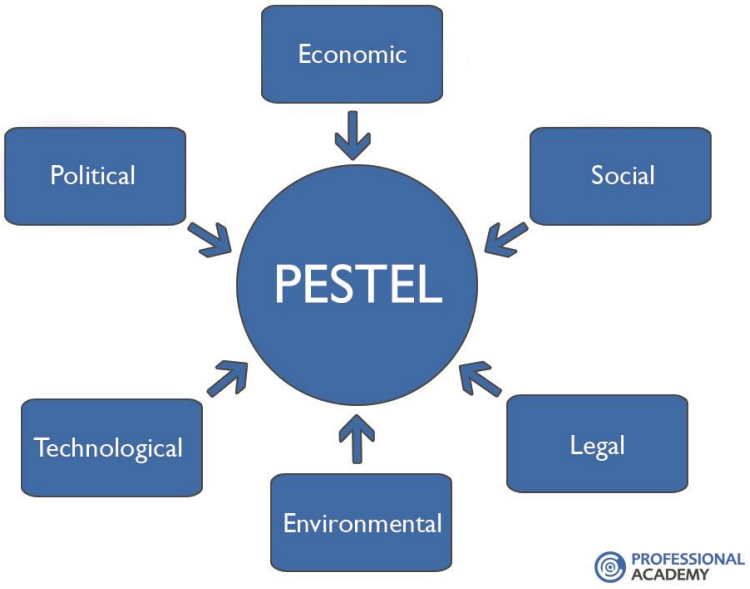

Figure 8 PESTEL analysis

Source: Professional Academy

6.3.1 Political factors

Political factors determine the extent to which government and government policy may impact on an organisation or a specific industry. This would include political policy and stability as well as trade, fiscal and taxation policies too. Political issues can be regarded from the following angles: policy coherence, legislation, standardisation, and public procurement schemes.

So far, there is low political support to enhance the bio-based economy and to create a level playing field in Europe to use sustainable biomass for applications. This holds in particular for applications made from bio-based plastics and cellulose fibres that have to compete with biofuels. Legal sustainability requirements for bio-based products are still not harmonised in Europe, because all member states have their own biomass policy for biofuels. The European policy directive for biofuels offers a starting point for sustainable bio-based materials. However, some member states find it insufficient, because the biofuels policy does not take account of (in) direct land use change (LUC and ILUC).

As mentioned before, there is no common understanding, agreement or strategy in Europe on the question of which bio-based plastics can and should play a role in sustainable packaging and the circular economy. The same holds for wood construction and textile fibres. The political framework for bio-based plastics differs from one member state to the other. A positive framework, such as in Italy or France, will guarantee market growth and investments; a negative setting with a focus on avoiding and

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reducing, such as in Germany and in the Netherlands, will put successful developments in the bio-based economy at stake. Italy and France favour the use of biodegradable plastics through legislation, other countries do not see this as an option to enhance a circular economy.

Voluntary standards are being developed (CEN). Low expertise and trust in existing standards and labelling on biodegradation in different environments accompanied by limited knowledge among the public, politicians and CSOs concerning the assessments of the properties, opportunities and benefits hinders the growth of bio-based materials (e.g. bio-based plastics).

Public procurement schemes in Europe are less developed than in the United States, where governments have created a bio-based preferred programme. Although significant progress has been made over the last few years and some member states have started pilot projects on bio-based procurement, additional scientific and standardisation work, labelling and communication are crucial for further development. So far, there is no binding preference for bio-based products and no official EU-sanctioned product list.

6.3.2 Economic factors

These factors impact on the economy and its performance, which in turn directly impacts on the state or organisation and its profitability (e.g. interest rates, employment or unemployment rates, raw material costs and foreign exchange rates).

The socio-economic effects of the bio-based economy are not well known as a whole. At the level of countries, the following bar chart compares the total turnover and employment of the bio-based economy for each member state of the EU-28 in 2015 (Piotrowski et al., 2018). Figure 9 shows clear differences between groups of member states, e.g. the eastern European countries Poland, Romania and Bulgaria apparently are stronger in less value-added sectors of the bio-based economy that generate a lot of employment. In comparison, western and northern European countries generate much higher turnover compared to the employment generated. The countries with the largest relative differences between turnover and employment in 2015 are Ireland, Finland and Belgium. Germany and Italy have the highest turnover and employment.

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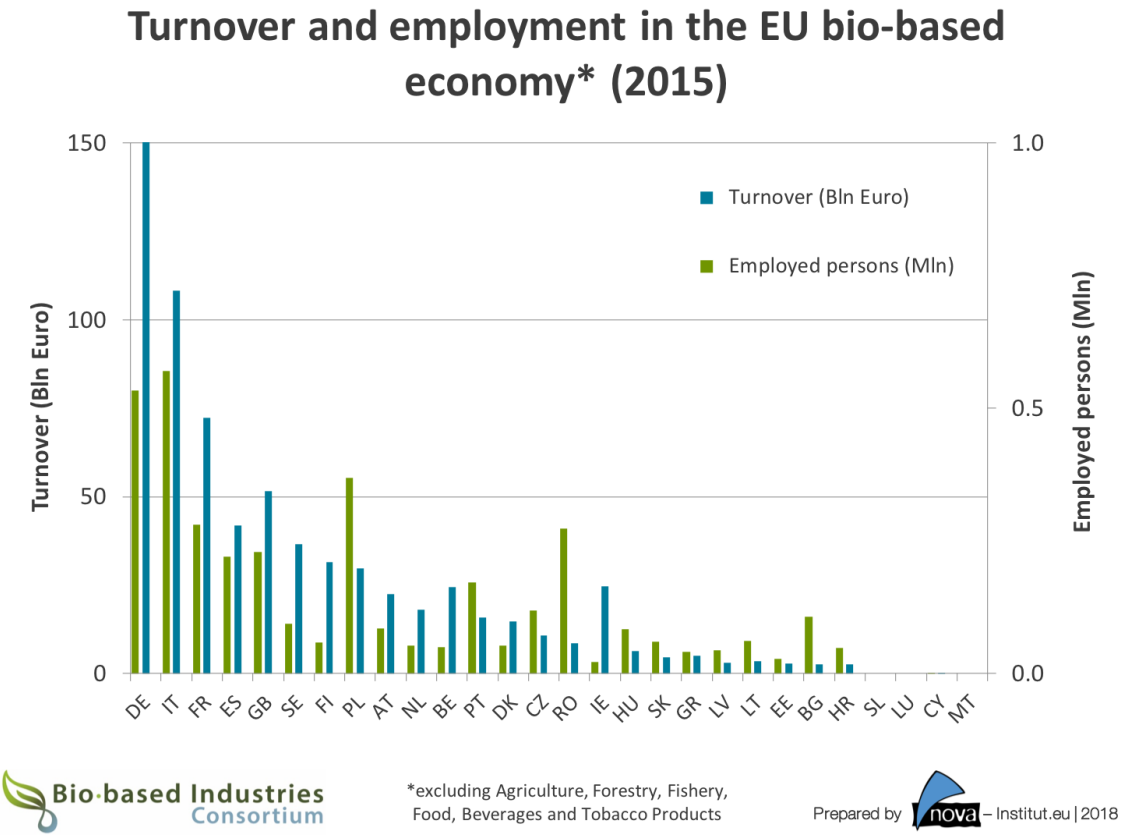

Figure 9 Turnover and employment in the EU bio-based economy

Source: Bio-based Industries & Nova-Institute, 2018

In the chemical industries, the overall bio-based share increased from 12% in 2008 to 15% in 2015. Denmark has the highest bio-based share in the chemical industry in 2015, which is mainly due to the high production of enzymes. Latvia and Sweden follow primarily due to a large production volume of charcoal and tall oil (Piotrowski et al., 2018).

The contribution of the different chemical products to the total value and volume of bio-based chemicals shows that odoriferous substances for the food or drink industries dominate in terms of bio-based production value while animal or vegetable fertilisers dominate in terms of production volume (Piotrowski et al., 2018). Most of the employment in the bio-based economy in the EU-28 is in textile and textile products, the forest-based industry and paper and paper products. These sectors are relatively labour-intensive with comparably low value added. On the other hand, the production of bioenergy and biofuel products requires relatively little labour compared to their turnover. (Piotrowski et al., 2018).

There are a few sector-specific studies on the wood processing and the pine chemicals industries and the Industrial Biotechnology sector in Europe (Dammer et al., 2017; van Meijl et al., 2016). The studies assessed found positive contributions of the material sectors, which create much more value added and employment per tonnes of biomass than the energy sectors. This is mostly due to the longer and more complex value chains of the material usages (CEPI, 2011; Rajendran et al., 2016). The share of 100% bio-based plastics in total plastics production is small and is expected to grow only gradually. The same holds for wood chips, fibres, agroceuticals and algae. The main reasons for this slow progress are the

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use of too costly techniques, current low oil prices, restricted functionalities, fewer new functions, and low political support to increase the level playing field. As long as a bio-based product is more expensive than its fossil-based counterpart it can only enter the commercial market if e.g. its qualities or functionalities are better than the other products. A quite new issue is the use of biomass from margin/degraded lands in southern and eastern Europe to increase the agricultural feedstock supply without competing with food claims.

6.3.3 Social factors

These factors focus on the social environment and identify emerging trends underpinned by customers' needs and wants (e.g. family demographics, education levels, cultural trends, attitude changes and changes in lifestyles).

Among consumers in general is a trend towards more ecologically conscious, 'sustainable' consumption. This goes hand in hand for increased information requirements about products in order to make an informed buying decision. Therefore, the 50% awareness levels of bio-based products can be a barrier for further market development, if the products do not inform well their sustainability performance. Furthermore, civil society organisations feel less urgency to become involved in the bio-based developments.

In addition to this, producers low willingness to communicate the bio-based concept, unavailability of the bio-based products in the large distribution and scarce information about end-of-life are still factors hindering the wider uptake of bio-based products. Plastic soup scandals may increase the urgency to decrease plastic waste.

6.3.4 Technological factors

These factors consider the rate of technological innovation and development that could affect a market or industry (e.g. changes in digital or mobile technology, automation, research and development, new methods of distribution, manufacturing and also logistics).

Many new bio-based applications are in a stage of development and not in a mature stage yet. The claim that bio-based products offer additional functionalities to end consumers could not be substantiated by scientific studies (Dammer et al., 2017). However, there are also many hybrids and bio-based products with a good market share, which are not known as such, because they are sold as natural or organic.

6.3.5 Environmental factors

These factors relate to the influence of the surrounding environment and the impact of ecological aspects. With the rise in importance of CSR (Corporate Sustainability Responsibility), this element is becoming more important. Factors include climate, recycling procedures, carbon footprint, waste disposal and sustainability.

There are few studies that aim to provide a comprehensive overview of the complex connections between the bio-based economy and climate change. LCA methodology is an important cause for this problem, since it makes it necessary to decide on clear system boundaries, make assumptions and compare impacts with specific counterparts for each product (Dammer et al., 2017). Current efforts on under-exploited residues and technologies focus on improved green methods to reduce waste volumes. Positive impacts can be achieved under a clearer reframing of waste as a by-product and a focus on cascading. Furthermore, there might be (in)direct land use effects caused by an (in)direct change of

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feedstock cultivations. So far, this is more relevant for biofuels than for bio-based materials which use a relative small number of hectares. More attention to climate goals may increase the urgency to buy bio-based products..

6.3.6 Legislative factors

An organisation must understand what is legal and allowed within the territories in which they operate in and must be aware of any change in legislation and the impact this may have on business operations. Factors include employment legislation, consumer law, healthy and safety, international as well as trade regulation and restrictions. Political factors do cross over with legal factors; however, the key difference is that political factors are led by government policy, whereas legal factors must be complied with.

So far, there is low political support to create a level playing field in Europe for sustainable biomass for applications. This holds in particular for applications made from bio-based plastics and cellulose fibres that have to compete with biofuels. Legal sustainability requirements for bio-based products are still not harmonised in Europe in standards or certification, because all member states have their own biomass policy for biofuels.The European policy directive for biofuels offers a starting point for sustainable bio-based materials. However, some member states find it insufficient, because the biofuels policy does not take account of (in) direct land use change (LUC and ILUC).

Furthermore, there is no common understanding, agreement or strategy in Europe on the question ofwhich bio-based plastics can and should play a role in sustainable packaging and the circular economy. The same holds for wood construction and textile fibres. The political framework for bio-based plastics differs from one member state to the other. Italy and France favour the use of biodegradable plastics through legislation: other countries do not see this as an option to enhance a circular economy.

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7 QUADRUPLE HELIX LEARNING AGENDA FOR CO-CREATION EVENTS

Although the societal benefits of speeding up the development of a larger market for bio-based products are largely understood, the transition towards a European bio-based economy is proceeding slowly. For example results show that there is a constant market share of about 2% bio-based plastics in and growth is not foreseen at this point in time (Dammer et al., 2017). Numerous challenges need to be overcome, both in the policy-, social- and technological-economic realms to further commercialise bio-based products and eventually realise a societal transition from fossil fuel dependency to a bio-based economy.

In Chapter 2 we highlighted that such a large scale socio-technical transition requires several functions of the Technological Innovation system (TIS). In BIOVOICES we focus on bio-based applications that are already in the take-off and/or in the acceleration phase. Furthermore, we do not only pay attention to market and system challenges related to TIS, but also to transformational challenges. Actors across the quadruple helix have a part to play to stimulate further take-off and/or acceleration of bio-based products. Below we address for the helix's, i.e. users/civil society (i), business (ii) and public administration (iii), the summary of the main barriers and opportunities for change and to which of the TIS functions it relates. Moreover we formulate learning questions that can be addressed by the partners of the BIOVOICES consortium during the Mobilisation & Mutual Learning events that take place in 2018 - 2020. Actors from research and education (iv) will participate in these events as they are part of the quadruple helix. Therefore it is important for their activities to take into account the perspectives of the other helixes on the take-off and/or acceleration phase, i.e. more on innovation, demonstration and marketing of bio-based products to the demands of users/civil society instead of the development of products as such.

Users/civil society

Studies indicate that many consumers are not willing to pay extra (a premium price) for bio-based products if this is the only difference between the bio-based products and the fossil-based products that are offered. Although most consumers are vaguely aware that bio-based products have environmental benefits, this alone is not sufficient to change their buying decisions. Additional benefits such as extra functionalities, a clear sustainability performance and an improved design are needed for consumers to justify the premium price (Meeusen et al., 2015a). Furthermore, it is relevant to know whether the focus of the product and communication concepts is on reaching all consumers who are not interested to pay more or on specific groups of consumers (e.g. luxury, green, sustainable, healthy, innovative, etc.) willing to pay a premium price.

If the focus is on niches, studies show that these groups are environmental aware, nature related and health conscious and willing to accept a limited price premium (Kainz, 2016; Carus et al., 2014; Scherer et al., 2017 & 2018). Moreover, for a number of products their new functions, such as a better (work saving) end-of-life behaviour, may justify premium prices. Therefore it might be relevant to pay more attention to the product and communication concepts to these groups of consumers. If the focus is on mainstream consumers, environmental regulation to stimulate a circular economy and the deliberate decision to promote bio-based products via public procurement are considered important (Meeusen et al., 2015a). Another perspective is to focus on hybrid (combination of bio-based and fossil-based) products, which have similar functions to their fossil equivalents. Entrepreneurial activities and

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innovation, but also more market activities and legitimation are needed to develop bio-based product and communication concepts that deliver additional value to consumers, thereby speeding up the demand for specific bio-based products.

Bio-based plastic packaging and disposals are an important showcase of bio-based products for mainstream consumers. Bio-based plastics can be both bio-degradable and non-bio-degradable. Most consumers associate bio-based with bio-degradable and may therefore have too high expectations of the environmental impact of bio-based products. Moreover, due to this misunderstanding consumers might manage the waste of non-bio-degradable bio-based plastic incorrectly. Overall, consumers do not like inconsistencies in the product image or insecurities about quality and end-of-life behaviour. These issues links to guidance of research, networks and knowledge diffusion.

In sum, the following main learning questions have been formulated:

- Which additional functionalities/sustainability and design do users/civil society expect from specific bio-based products that are currently in the take-off and/or in the acceleration phase?
- Which consumers are able to describe their expectations of bio-based products and which not (yet)? Does this imply a focus on targeting at niches or on mainstream consumers?
- Which information about bio-based products and the bio-based economy should consumers have in order to make an informed buying, using and disposing decision?
- To which standards should bio-based products comply? Are bio-based labels desirable? If so, under which conditions?
- Which instruments should be used to communicate clearly to users/civil society about the additional features of the bio-based products / segment?

Users/civil society and other interest groups play an important role in shaping and lobbying for socially and environmentally desirable bio-based products. So far, in many projects it has been difficult to involve users/civil society and interest groups. Moreover, many public engagement practices focus on providing information instead of engaging users/civil society and interest groups to further develop and realise a bio-based economy. Or in other words, most of these practices focus on information provision that is featured by one-way communication, i.e. from stakeholders to the public, aimed at increasing public awareness of the potential benefits of the bio-based economy. Hence, for BIOVOICES the challenge is not only to include more actors, but also to engage them in a participatory way. This is in particular relevant for applications that focus on mainstream groups, and have to be checked at sustainability features in order to scale up. Most NGOs actively in the bio-based economy have partnered or are partnering with companies corporations in their campaigns and operations (Meeusen et al., 2015b). They are actively working on issues related to bio-based products and sustainability certification. A small number of NGOs now focus on confrontational relationships, but are also relevant for upscaling. These issues result in the following learning questions:

- Which issues should bio-based products/practices that are currently in the take-off and/or in the acceleration phase address to gain support by users/civil society and other interest groups (e.g. provide an answer for the plastic soup issues)?
- Which type of roles can and would users/civil society and other interest groups like to play in further developing and diffusing specific bio-based products that are currently in the take-off and/or in the acceleration phase?

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Business

The results of Chapter 4 indicate that feedstock producers (i.e. farmers), brand owners and manufacturers are, so far, less involved in the development of the bio-based economy. These groups play an important role in the realisation of guidance of the search, market formation and resource mobilisation which are essential functions to develop bio-based alternatives that can compete with current embedded fossil-based products.

Natural, wood and cellulose fibres have already many application areas in bio-composites (light weight), insulation and textiles, but are not framed as “bio-based”. Consequently, the pulp and paper, construction and textile manufacturers do not consider themselves as part of the bio-based industry and neither do consumers recognise this. Also bio-based components used in dashboards in cars, in food and feed additives categories, in applications of personal and home care, and in neutraceutical industries are not communicated as such. Most of them (excluding food & feed additives) function within specialised markets which focus on high-quality products. This might be considered a weakness to further market and promote the bio-based economy.

As such we formulated the following learning questions:

- Which barriers and opportunities do producers, manufacturers and brand owners perceive for upscaling the feedstock that is needed for bio-based products that are currently in the take-off and/or in the acceleration phase?
- Which behavioural and institutional changes could contribute to waste behaviours of businesses that contributes to more feedstock availability for the bio-based economy?
- Which bio-based products that are currently in the take-off and/or in the acceleration phase are considered desirable from brand owners and manufacturers perspective? Why?
- What is the awareness of bio-based among brand owners, retail and producers?
- Which potential benefits, barriers and risks do brand owners, retail and producers perceive with regard to branding their products as bio-based?

Often businesses developing new products for niches are working as a start-up on their own or with a few partners. The consequence is that they do not only lack the networks among businesses, but also with potential users/civil society actors and governments. Hence, the challenge is to increase the relationships among those actors. If the focus in on mainstream consumers there is more chance that all the helix actors are active, but not necessarily in a good cooperation. Here the challenge is to improve the current relationships among the quadruple helix actors. These issues result in the following learning questions:

- Which type of network building can and would businesses like to play in further developing and diffusing bio-based products among mainstream consumers that are currently in the take-off and/or in the acceleration phase? Which type of network do they have already?
- Which type of network building can and would businesses like to play in further developing and diffusing bio-based products among specific target groups that are currently in the take-off and/or in the acceleration phase? Which type of network do they have already?

Public administration

These is no consensus among European member states on which bio-based products should be stimulated. For example, some member state stimulate the development of bio-based plastics, while other member states focus on avoiding and reducing plastics in general. This absence of agreement and focus hampers market formation and support. Therefore we pose the following learning questions:

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- Which bio-based products are considered desirable by all members states and why?
- Which uncertainties need to be addressed for specific bio-based products in order to make informed decisions about the desirability of these bio-based products?

In addition there is no uniform policy among European member states with regard to stimulating the bio-based economy. Also there is no uniform regulation with regard to bio-based products and the bio-based economy. The market of most businesses and/or initiatives active in the bio-based economy goes beyond the border of individual member states. The absence of clear, uniform regulations hampers these businesses and/or initiatives to invest and slows down their development. In addition, it creates regional differences with regards to expected success for bio-based businesses and/or initiatives (no level playing field). Therefore we formulate the following questions:

- Which legislation hampers the take-off and acceleration of bio-based products?
- Which policy instruments (e.g. public procurement, subsidies, standardisation, regulations) are considered successful to stimulate the market uptake of bio-based products?
- What hampers and stimulates public procurement and launching customer activities for bio-based products by (local) governments?

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