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BBI	-	Bio-based Industries
BBI-JU	-	Bio-based Industries Joint Undertaking
BIO-TIC	-	"The Industrial Biotech Research and Innovation Platforms Centre" project
CAP	-	Common Agricultural Policy
CCS	-	Carbon Capture and Storage
CCT	-	Common Customs Tariff
CCU	-	Carbon Capture and Utilisation
Cefic	-	The European Chemical Industry Council
CFP	-	Common Fisheries Policy
CN	-	Combined Nomenclature
CRISPR	-	Clustered Regularly Interspaced Short Palindromic Repeats
CTO	-	Crude Tall Oil
DNA	-	Deoxyribonucleic Acid
EC	-	European Commission
ECB	-	European Central Bank
ECJ	-	European Court of Justice
EED	-	Energy Efficiency Directive
EIB	-	European Investment Bank
EIP-AGRI	-	Agricultural European Innovation Partnership
EP	-	European Parliament
EPBD	-	Energy Performance of Buildings Directive
ESIF	-	European Structure and Innovation Fund
EU	-	European Union
EUA	-	EU Allowances
EU ETS	-	European Union Emission Trading Scheme
FP	-	Framework Programme
FQD	-	Fuel Quality Directive
GHG	-	Greenhouse Gases
GMO	-	Genetically Modified Organism#
Horizon 2020	-	European Framework Programme for Research and Innovation
iLUC	-	indirect Land Use Change
ISSC+	-	International Sustainability and Carbon Certification+
JRC	-	Joint Research Centre
KBBPPS	-	"Knowledge Based Bio-based Products' Pre-Standardization" project
LMI	-	Lead Market Initiative
OECD	-	Organisation for Economic Co-operation and Development
PtL	-	Power-to-Liquid
PCC	-	Precipitated Calcium Carbonite
PPP	-	Public-Private Partnership
R&D	-	Research and Development
REACH	-	Registration, Evaluation, Authorisation and restriction of Chemicals
RED	-	Renewable Energy Directive
RIS3	-	Research and innovation strategies for smart specialisation
RSB	-	Round Table on Sustainable Biomaterials
SC2	-	Societal Challenge 2: Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy
SME	-	Small- and medium-sized enterprises
STAR4BBI	-	"Standards and Regulations for the Bio-based Industry" project
SVHC	-	Substances of Very High Concern
TARIC	-	Integrated Tariff of the European Union
TIS	-	Technological Innovation System
TRL	-	Technology Readiness Level
UNICA	-	União da Indústria de Cana-de-Açúcar (Brazilian Sugarcane Industry Association
USDA	-	United States Department of Agriculture
WFD	-	Waste Framework Directive

1 Executive Summary

This report was prepared within the context of RoadToBio, which is an EU-funded project in the Horizon 2020 research and innovation programme. RoadToBio aims to pave the way for the European chemical industry towards a higher bio-based portfolio and competitive success based on the benefits offered by the bioeconomy. The project will deliver a roadmap for the chemical industry that specifies benefits as well as barriers towards a bio-based economy to meet the societal needs in 2030.

The roadmap developed in RoadToBio will contain two main components: first, an analysis of the most promising opportunities ("sweet spots") for the chemical industry to increase its bio-based portfolio as well as the technological and commercial barriers and the hurdles in regulations and acceptance by society, governing bodies and the industry itself, and second, a strategy, action plan and engagement guide to overcome the existing and anticipated barriers and hurdles as mentioned above.

The goal of this report is to assess existing regulatory barriers that hinder the production and market uptake of bio-based chemicals and materials. Although a widespread uptake has been in political focus for some years, a large increase of biomass user for the production of bio-based chemicals and materials has not been achieved. Policy making and resulting regulatory barriers remain a field of concern and lead to a number of identified hurdles, which in turn impede the development of bio-based production economies in the European Union. In recent years, there has been ongoing discussion and evaluation of regulatory barriers and hurdles caused by a lack of policy coherence, but even though many issues were highlighted by different studies, actual progress to remove the barriers is still lacking. A lot of knowledge on regulatory hurdles and barriers for the bio-based economy has been collected through several earlier, publicly accessible, studies.

This report synthesizes existing knowledge on hurdles and barriers for the bio-based economy and brings the earlier study findings up to date according to new developments in legislation, with a focus on understanding why legislative barriers came to be. Since the bio-based economy is a sector that cuts through many "classical" sectors, a multitude of policy areas are in the scope of the analysis, such as waste regulation, biofuels and bioenergy, import tariff regimes, chemical regulations, the Common Agricultural Policy, etc. The focus is put on a selection of EU legislations, which are individually discussed and analysed in so-called factsheets. This approach leads to an overview of the most important EU-wide regulatory barriers that hinder the production and market uptake of bio-based chemicals and materials in Europe.

The results of this report furthermore help to understand the contextual framework of the regulatory barriers in order to better derive suggestions and recommendations for developing a strategic approach of how to overcome these barriers. In the final chapter, the report connects the results to general instruments for innovation implementation, mentions some approaches targeted towards specific legislations and embeds the results in a more systemic approach for future research and development.

The results of this report will be used as one of the key inputs to develop the final roadmap of the RoadToBio project.

2 Introduction

The goal of this task is to assess existing regulatory barriers that hinder the production and material uptake of bio-based chemicals and materials. Since the bio-based economy is a sector that cuts through many “classical” sectors, a multitude of policy areas will be in the scope of the analysis, such as waste regulation, biofuels and bioenergy, construction, import tariff regimes, chemicals regulations, the Common Agricultural Policy, taxes, etc.

This report seeks to collect existing knowledge on hurdles and barriers for the bio-based economy from previous studies. These are for example the BIO-TIC project, the KBBPPS project, the STAR4BBI project and other, smaller studies. From here, the findings will be brought up to date according to new developments in legislation, with a focus on understanding why legislative barriers came to be in order to develop a strategic approach of how to overcome these barriers.

The results of this task will be compiled in a mapping of non-technical hurdles stemming from regulation and will be complemented by a strategic approach of how to overcome these barriers that will feed into the roadmap.

2.1 Brief history of the bioeconomy in the European Union

Around the middle of the 2000s the term bioeconomy first appeared in political discussions within the European sphere. In 2005, the European Commission (EC) held a conference about “New Perspectives on the Knowledge-Based Bio-Economy” (EC, 2015), which effectively launched the bioeconomy into policy circles in the European Union (EU). With the creation of the Lead Market Initiative (LMI) in 2008, which included bio-based products as one of six key sectors for market uptake, Europe acknowledged the importance of developing a strong bioeconomy (McCormick & Kautto, 2013). After extensive public consultation, the EU Bioeconomy Strategy and its Action Plan were published in 2012, based on the "Innovation Union" and "Resource-efficient Europe" flagship initiatives of the EU 2020 strategy. This strategy is a crucial document, recognising the important role the bioeconomy plays in addressing a number of interlinked key challenges (EC, 2017a).

The 2012 EU Bioeconomy Strategy included a number of recommendations from the Lead Market Initiative, with the goal to unlock the potential of the bio-based economy. A review in 2017 reported that progress was made on some issues but that further improvements were necessary for monitoring and assessment, policy coherence and mobilisation of investments, which require a stable regulatory environment. However, the strategy has supported the development of bio-inspired solutions, innovations and technologies that can replace fossil raw materials. Important milestones include national and regional bioeconomy strategies, the launch of the public private partnership (PPP) Bio-based Industries (BBI) Joint Undertaking (BBI-JU), and the European Bioeconomy Alliance, a cross-sectoral coalition working on realising the potential of the bioeconomy in Europe (EC, 2017b).

On 2 December 2015, the European Commission put forward a package to support the EU's transition to a circular economy. In a circular economy the value of products and materials is maintained for as long as possible. Waste and resource use are minimised, and when a product reaches the end of its life, it should be used again to create further value. It is envisaged that the development towards a circular economy will bring major economic benefits, contributing to innovation, growth and job creation. In a circular economy, a strong bio-based economy based on renewable feedstock is of vital importance.
Bio-based production is widely viewed as a central element of the future economy. For this to become a reality, innovative product value chains need to be developed that replace existing fossil-based alternatives or offer completely new functionalities. Although this

broader goal has been identified nearly a decade ago, progress towards a strong market position and commercial success is behind of what was envisaged (OECD, 2014). Shifting the established, fossil-based industry towards sustainability is a huge and complex task, encompassing largely different industries, enterprises and policies. Thus, it is not surprising that a multitude of factors and reasons can be linked to the (lack of) development. It is this complexity which makes it so difficult to come up with clear, straightforward answers and strategies how to realize a largely bio-based economy. While in many areas visible progress was achieved, policy making and resulting regulatory barriers remain a field of concern that lead to a number of identified hurdles, which in turn impede the development of bio-based production economies in the EU. With this report, we intend to summarize the most important barriers created by regulation, how they came to be and how they could be strategically targeted in the future.

2.2 Regulatory hurdles and barriers for bio-based chemicals and materials

Compared to the established field of bioenergy, the materials and chemicals sectors need to consider a much wider range of policies and regulations. Already back in 2010, Carus et al. (2010) noted:

> A small number of simple policy instruments, developed against a background of a broad political consensus, were used to great effect. They mobilised a very large quantity of biomass for transport fuels. This showed that highly regulated markets such as the market for transport fuels provide more opportunities for policy intervention compared with the more diverse and less regulated markets relevant to the material use of renewable resources. The more diverse markets for material uses not only offer fewer points where policy levers can be applied to significant effect, they are also global markets subject to intense global competition.

The number of relevant legislative acts for bioeconomy is high, but usually designed with focus on a different topic. There is currently no specific EU legislation for bio-based chemicals and materials. (Ronzon et al., 2016). Many existing policies actually hamper market uptake of bio-based chemicals and materials either because they were designed with a different goal in mind or because the bio-based economy, as a new market field, simply was not considered when the legislative was originally drafted. As a result, even though the bioeconomy strategy of the EU exists, a coherent and harmonized policy concept is still missing.

In recent years, there has been ongoing discussion and evaluation of regulatory barriers and hurdles caused by this lack of coherence, but even though many issues were highlighted by different studies, actual progress is still lacking. Just recently, the European Commission Directorate-General for Research and Innovation stated in its 2017 review of the bioeconomy strategy (EC, 2017a), that progress on the issue of regulatory framework for the development of new markets for the bioeconomy has remained limited. And in the recently published “stakeholder manifesto”, the European Bioeconomy Stakeholders Panel notes that „for the bioeconomy to continue to develop in a sustainable way in Europe, a coherent, transparent and predictable policy making process is essential. Removing regulatory uncertainty will encourage innovators and entrepreneurs to invest in the development of new or improved bio-based products.“ (European Bioeconomy Stakeholders Panel, 2017).

Lack of Policy Attention

Back in 2014, the Organisation for Economic Co-operation and Development (OECD) noted that "Whilst progress in bioelectricity and biofuels production is palpable, decades of research efforts into bio-based chemicals and plastics production have not led to similar commercial progress. This is not a constraint due to lack of technical know-how. Rather, bio-based production of chemicals and materials has not received the policy attention necessary for biochemicals to start substituting for petrochemicals (and therefore potentially to bring about GHG emissions and help governments meet their climate change obligations)" (OECD, 2014). Several studies in the last years have identified and addressed that the above-mentioned variety of regulatory barriers can largely be attributed to the lack of policy attention and a so-called non-level playing field between the usage of biomass for energy or for material purposes (e.g. OECD, 2014). More precisely, Carus et al. (2015a) noted:

> While a multitude of policy documents already acknowledge the potential of the bioeconomy and also that there is currently no level playing field between the different uses of biomass, concrete implementation of any measures that would change this situation is sorely lacking.

Non-level Playing Field

A prominent explanation for this discrepancy in the bioeconomy can be found in the political focus on bioenergy and biofuels production over the last decade, which led to the creation of policies favouring the acquisition of large quantities of biomass for energy use. Carus et al. (2011) pointed out:

> The political and economic framework in the EU does not support the industrial material use of biomass – this is in contrast to bioenergy and especially biofuels, which has expanded rapidly In the EU over the last ten years. The European „Innovation Union" needs to establish a level playing field for bio-based chemistry and materials in order for the EU to realize the potential of greening its process industries.

In turn, a situation has been established where biomass is systematically allocated to these sectors and drawn away from the production of bio-based chemicals and materials. Or, to put it another way, due to the supportive policies for bioenergy, increased interest in biomass leads to higher biomass prices. While the bio-based production of chemicals becomes less profitable, the subsidies for bioenergy application enable biofuel producers to purchase large amounts of the available biomass. As a result, "the current framework creates a non-level playing field between bio-based materials and energy, triggers never-ending discussions about a variety of issues such as land-use change and multiple counting of different biomass sources in quotas, and ultimately hinders Europe's bio-based economy from tapping into its full potential of innovation, investment and jobs" (Carus M. et al., 2014)."

The market today is not necessarily driven by demand, but rather limited by the supply of sustainable biomass. Even though valid reasons for the support of bioenergy exist, in times where the EU strongly pushes towards a circular economy, this non-level playing field opposes the idea of cascading use of biomass: Bio-based chemicals and materials can be utilized to create higher value-added products before they get burned for energy purpose as a final act of value generation. Carus et al. (2015) provide comprehensive background information on the cascading issue, but in general, cascading use of biomass increases the resource efficiency, the sustainable use and the generation of value added from biomass and is part of the circular economy. The direct allocation to bioenergy purposes undermines these ideas and thus the cascading concept (OECD, 2014).

Discrepancy between established and new industries

Besides this non-level playing field, a more general issue is that innovative industries regularly struggle against competition from long established industry branches. For bio-based chemicals and materials this is true when they compete in a competitive environment with highly optimized fossil-based, petrochemical products. The established companies are usually larger in size and capital and had decades to not only adapt to regulatory processes in their respective fields, but also influence them towards their own interests. Of course, there are also long-established bio-based fields like the oleochemistry but also here new biotechnological processes emerge and need comprehensive testing and evaluation. And in less traditional fields, bio-based companies often start as small enterprises or start-ups to market a new idea. Complex, expensive and time-consuming regulations and compliance with legislations are naturally more damaging to these companies than they are to the established players. Therefore, regulatory regimes usually impact the bio-based chemicals sector stronger than they impact the competing petrochemicals sector (OECD, 2014). While this in principle is also true for the bioenergy sector, very strong political support has created an artificial competitiveness that enabled market certainty and development.

The complex situation for bio-based chemicals and materials can be summarized in a competition triangle as shown in Fig. 1: The chemical and material use is competing with bioenergy for biomass not used for food or feed, but due to the support system the prices for biomass and land have greatly increased. This makes access to biomass for chemical and material use more expensive, which is not compensated for by support measures. When looking at competition with fossil resources, the petrochemistry is subject to heavy taxes for energy application but there are neither taxes nor import duties for fossil-based chemical or material applications. Consequently, the chemical or material use of biomass is in direct competition with the petrochemical industry without any supporting measures. And quite the contrary, the increased biomass prices are not counterbalanced by taxes on fossil carbon sources. New bio-based industries must therefore develop in the face of well-established and long-optimized mass production industries.

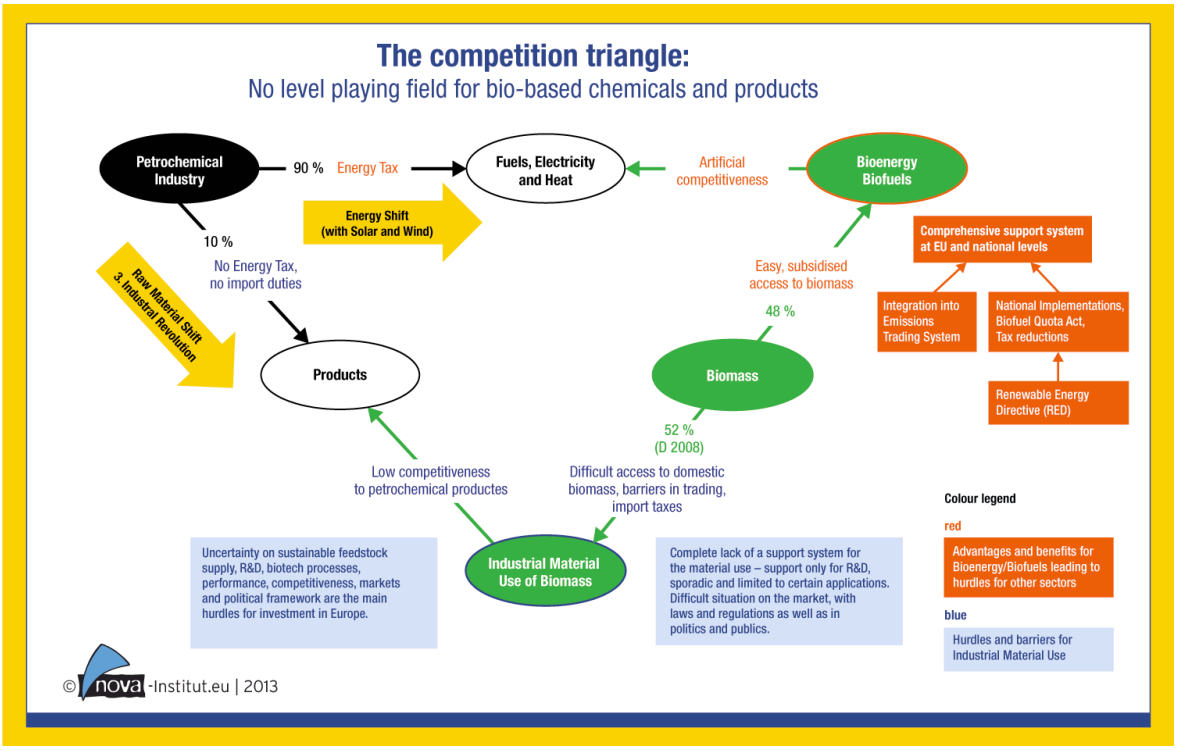

Figure 1 - The competition triangle (nova-institute, 2013)

Outside of Europe

Outside of Europe, other regions in the world have made their own progress towards developing a bioeconomy. Strategies have emerged worldwide, from South America (e.g. Brazil, Paraguay) over Africa (e.g. Kenya, South Africa) to Asia. Quoting the OECD, "In the United States, however, greater support for bio-based products has started to emerge." For example, in the Farm Bill of 2014, the United States Department of Agriculture (USDA) "Biorefinery Assistance Program" was renamed into the "Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program". The crucial point is that the same policy mechanism is now being used to support both biofuels and bio-based products and materials because the Farm Bill 2014 expands the Biorefinery Assistance Program to also include bio-based product, renewable chemical manufacturing and forestry products into their so-called BioPreferred® program.

In South-East Asia, Malaysia was the first country in Asia to introduce a bioeconomy strategy already back in 2005, which was at that time mostly focused on biotechnology. In 2011, the country released its first version of the "National Biomass Strategy 2020", focusing on agricultural biomass valorisation (mainly palm oil). The second edition from 2013 now also explores the development of higher added value opportunities from the country's biological resources in general, with special considerations for residues (German Bioeconomy Council, 2015).

Towards a Circular Economy

The EU Commission Expert Group on Bio-based Products, whose main task is assisting the Commission in the preparation of legislative proposals and policy initiatives, believes that focus should be put on the contribution of renewable and sustainable bio-based products to the development of a resource efficient circular economy. "Supportive policy signals, measures and incentives are needed in order to stimulate innovation and bio-based product commercialisation in this promising sector, particularly, in an ongoing era of heavily subsidised markets for fossil carbon product development. Coherent, holistic, supportive frameworks, emphasising the link between the circular economy, the Bioeconomy and the role of bio-based products, need to be developed across all relevant areas including agriculture, industry, regions, environment, climate, trade, energy and innovation policies." (CEG, 2017).

A recent paper discussing the bioeconomy and circular economy concludes that neither of the two concepts is complete without the other (Carus and Dammer, 2018). For example, the bioeconomy will benefit from increased circularity, and large volumes of organic waste streams can only be integrated into the circular economy by bioeconomy processes. But it is also pointed out that the two concepts cannot be simply thrown together:

> The concepts of bioeconomy and circular economy have similar targets and they are overlapping to a degree, but neither is fully part of the other nor embedded in the other. It would be a great loss for the bioeconomy to be misunderstood as merely a part of the circular economy, which does not include certain crucial aspects of the bioeconomy. The bioeconomy research agenda, strategy, and policy will overlap with a circular economy strategy (for example in eco-efficiency of processes), but will always need additional and specific topics.

Where possible, this report will therefore briefly consider implications on and synergies with the circular economy concept, and this topic will be explored in further detail in a following deliverable.

Regional approaches

It is often emphasized that regional focus and solutions are important for the development of the bio-based economy, e.g. because biomass resources can often not be easily or cheaply transported over longer distances (e.g. Luoma et al., 2011). Furthermore, under RIS3, the „Research and innovation strategies for smart specialisation" the concept of regional research and innovation strategies is encouraged in order to build on a region's strength and create competitive advantages. Many countries and regions within the EU have indeed developed their own national or regional bioeconomy strategies, either fully dedicated or at least related to the topic, to build on the advantages of regional approaches (EC, 2012).

A comprehensive evaluation on regional level would require intensive research and stakeholder engagement for multiple, comparable regions, which is out of the scope of this study. Furthermore, the RIS3 report also highlights that regional strategies often lack a wider national or transnational perspective. In order to tackle regulatory barriers and hurdles from a wider perspective, this report will therefore focus on EU-wide legislation. Because European legislation strongly impacts national and regional implementation, we believe that this approach will offer valuable insights that enable the development of strategic approaches on all levels nonetheless.

3 Factsheets about relevant EU legislations

Today, there are several EU-wide pieces of legislation in place that affect the bio-based industry. In the following, we describe those that have been identified constituting regulatory hurdles and barriers. The report summarizes results of previous studies and intends to draw connections to respective EU legislation in a number of factsheets, each specific to one directive. More specifically, research started by considering results from the KBBPPS project, from the BIO-TIC project, from the JRC (Joint Research Centre) Science for Policy Report – Bioeconomy report (Ronzon et al., 2016), first insights from the STAR4BBI project and a study by Luit et al (2016) focussing on REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) and the bioeconomy. Starting with these projects and documents, they were investigated for already identified barriers for the increase of bio-based chemicals and materials. Often, a direct connection to specific regulation was already mentioned, which offered starting points for identifying relevant EU legislations. Based on these findings, further research, mostly literature research, was done in order to update and complement the findings of the mentioned studies and to develop factsheets for those legislations that are considered as critical in terms of creating regulatory barriers for bio-based chemicals and materials. In order to deliver a holistic picture and offer perspectives for strategic approaches towards solutions, we will briefly establish why the respective legislations came to be, what their main intentions are, what barriers and hurdles for the bio-based economy they create and how they developed in recent years.

The factsheets intend to present brief information on selected EU legislations or regulations in order to collect ensuing barriers for the bioeconomy and especially the bio-based chemistry. For this purpose, the factsheets will be split in three parts: “History & Reason” will give a short overview about the creation of the legislation and explain what the main goals are. “Barriers for bio-based chemistry” will highlight which barriers are caused by the respective legislation, largely summarizing results and insights from previous studies. “Recent developments & strategic approaches” intends to present current discussions and recent changes of the specific legislations in order to identify whether some barriers have been acknowledged in political discussions or if adaptations either aggravate or moderate some of the barriers. Additionally, some considerations about potential avenues that might be pursued to tackle the identified barriers were given, where such considerations were possible.

3.1 Factsheet Renewable Energy Directive (RED)

History & reason

The Renewable Energy Directive (RED) came into force as part of the so called "climate and energy package" of the European Union. The directive required the EU to supply at least 20% of its total energy needs from renewable sources by 2020 with the sub-target of a 10% share of renewable energy for transport fuels. Its main purpose was to **reduce greenhouse gas emissions** through the use of energy from renewable sources, together with energy savings and increased energy efficiency. Additional reasons for implementation were "**security of energy supply**, **promoting technological development** and **innovation** and providing opportunities for **employment** and **regional development**, especially in rural and isolated areas" (Directive 2009/28/EC).

A following, strong debate on indirect land use change (iLUC) caused by the RED led to an amendment of the directive. With the directive (EU) 2015/1513 of 9 September 2015, a limit for the share of energy from biofuels produced from cereal and other starch-rich crops, sugars and oil crops and from crops grown as main crops primarily for energy purposes on agricultural land was introduced which shall be no more than 7 % of the final consumption of energy in transport in the Member States in 2020. Moreover, in order to support the development of advanced biofuels, fuels made from certain feedstocks (listed in Annex IX of the directive) count twice their energy content towards the 10% goal and do additionally not fall under the 7% cap.

Barriers for bio-based chemistry

The principle goal of the directive is to promote the use of renewable energy, including bioenergy. This leads to a **higher demand and higher prices for biomass** in general. Based on a detailed analysis of the RED and its influence on biomass, the following market distortions have been identified to result from the Directive: Land prices are increased, biomass prices are increased, residues and wastes are strongly incentivized for biofuel use and biorefineries are almost only focusing on the production of biofuels (Piotrowski et al., 2014).

Contested feedstocks: With the iLUC amendment, an even stronger competition for certain types of biomass was created – more specifically those that are included in Annex IX. Some of those materials are actually used by high-value chemical industries, who faced fierce competition for their raw materials once they were added to Annex IX. Examples for feedstocks that are contested by both the chemical and the fuels industry are crude tall oil (CTO), glycerol or animal fats. Interestingly, the Commission is empowered to adopt delegated acts in accordance with Article 32 to amend the list of feedstocks in parts A and B of Annex IX in order to add feedstocks, but not to remove them.

Non-level playing field: In summary, the RED results in a non-level playing field with scarcity and higher prices for biomass that also serves as feedstock for the bio-based industry. As a consequence, the limited biomass supply is favoured to be used for energy purposes, which directly contradicts the circular economy idea because it reduces the cascading use of biomass and instead promotes direct, final use for energy generation. The issues caused by the RED are so impactful that in a previous stakeholder study about bio-based products, „more than half of the answers revolved around the subsidy system for bioenergy and biofuels, embodied in the Renewable Energy Directive on the European level. Respondents indicated that the support for the energy use of biomass makes feedstocks too expensive, thus creating market distortions since the support is not counter-balanced by any incentives for the material use of biomass." (KBBPPS, 2015).

Ambiguous incentives: As a final issue, the RED and its differential counting of various fuels in the quota incentivize the use of lignocellulosic feedstocks, albeit it is doubtful that the often-heard claim of their advantages over the first generation hold up to close investigation (Brack, 2017). To elaborate, food crops are often more land efficient than non-food counterparts, meaning that less land is required for the production of a certain amount of biomass. This holds especially true for fermentable sugar, essential to biotechnology processes, where the food crop produces the same amount of sugar on less land than the supposedly "unproblematic" second generation lignocellulosic non-food crop (Carus et al., 2014).

Recent developments & strategic approaches

As already mentioned, in 2015, the European Parliament (EP) voted to endorse a compromise agreed with the EC to reform the RED and the Fuel Quality Directive (FQD) due to the discussion around iLUC. Dammer and Carus (2015) analysed:

> Since the new provisions of the Directive are only valid until the end of 2020, this does not constitute a long-term framework that could give security to investors – neither from the energy sector, nor from the material sector. The existing competition for biomass between the sectors is not mentioned, still ignoring highly value-adding and employment-creating bio-based industries. That means that the material sector needs to take the opportunity to influence the framework that will be created for the time up until 2030 in the next few years by actively participating in the political debates in Brussels and the Member States to finally establish a level playing field.

On 30 November 2016, the Commission published a proposal for a revised Renewable Energy Directive (COM(2016) 767 final/2) for the 2021-2030 period, also called RED II, which sets the target of at least 27% renewables in the final energy consumption in the EU by 2030 and therefore further increases pressure on biomass availability for the bioeconomy. On 28 November 2017, the EP voted for an increase in the targets proposed by the Commission.

Main points of discussion are the renewable energy target for 2030 (27-35%), a binding sub-target for renewable energy in the transport sector (12%) and a quota for blending obligation to include a certain number of advanced biofuels, including CO_2-based fuels in purchasable petrol (between 6.8% and 10% in 2030). The intention is to freeze the contribution from biofuels and bioliquids from food or feed (main crops) at 2017 consumption levels and to cap their share at no more than 7% of final consumption in transport in 2030, in order to minimize iLUC emissions. This reduction of main crop availability is important because yields and conversion efficacy of non-food crops can be lower than for first generation feedstocks/fuels and thus rather aggravate than mitigate land demand and iLUC risks.

There is still ongoing and controversial discussion about the newest RED II proposal. A critical issue is that the proposal incentivizes the felling and burning of additional trees beyond their wastes and residues. But large inefficiencies in harvesting trees and the "energy generated/carbon released"-balance have raised concerns about the increased renewable share the RED II calls for. In January 2018, a letter from a large group of scientists was sent to the EP, pointing out the high impact expected on forests due to the increasing wood demand for bioenergy. The letter actively encourages the parliament to restrict the forest biomass eligible under the directive to residues and wastes (Letter from Scientists, 2018). This is in particular a concern for forests in the United States, as pointed out by Carus et al. (2016):

> However, forestry is strictly regulated in Europe, so European countries have turned to the southeastern U.S. to supply their rapidly-growing demand for biofuel. [...] The demand just keeps growing. Some estimates predict that in five years' time from now, Europe will be importing as much as 70 million tonnes of wood to burn.

As a whole, the revision proposal appears to assemble a wide range of support mechanisms for a multitude of energy forms under one roof. The first-ever inclusion of CO_2-based fuels means that available support will be spread between more forms of energy supply than before, which are less dependent on biomass. From a bio-based materials point of view, this gives hope for improved and fairer access to biomass. But, especially for feedstocks that are accepted for "advanced biofuels", the situation has potentially worsened (Dammer et al., 2017).

For bio-based chemicals and materials, this can be potentially negative depending on the feedstock classification by Member States. As already stated, some feedstocks in part A of Annex IX, are also utilized in the chemical and material industries. The RED II quota can here lead to increased demand and higher prices for these feedstocks.

The decreasing demand for biomass by first-generation biofuels will likely allow an increase of biomass demand by bio-based materials, especially if prices go down accordingly. This is expected to contribute to an upswing of the bio-based materials sector, provided that the industry will not be frightened off by the bad image of first generation feedstocks. The proposal could lead to the fact that in the future less biodiesel might be allowed from e.g. rapeseed as a main food crop. In this example, a huge increase in protein demand for feed could be expected, because this is usually a co-product of biodiesel production.

Aviation fuels are another field of interest. Global aviation is responsible for roughly 5% of man-made global warming and is one of the fastest growing emission sources. While road transport works towards electrification in order to decarbonize, similar breakthrough technologies are not on the horizon for air transport. But advanced biofuels and power-to-liquid (PtL) or CO_2-based fuels alternatives might provide options to reduce aviation emissions. The RED II can here play a part to stimulate a fuel shift in the aviation sector, but it needs to ensure sustainability criteria like feedstock availability and also consider higher costs of alternative aviation fuels in comparison to fossil kerosene (T&E, 2017).

3.2 Factsheet Waste Framework Directive (WFD)

History & reason

Dating back to 1975, the Waste Framework Directive (WFD) was created with the main purpose of turning the EU into a recycling society. The 2008 Revised Waste Framework Directive intended to clarify, simplify and integrate several existing EU laws.

The revised directive sets basic concepts and definitions related to waste management, such as definitions of waste, recycling, recovery, explains end-of-waste criteria and how to distinguish between waste and by-products. It requires that waste has to be managed **without endangering human health** and **harming the environment**. Waste legislation and policy of the EU Member States shall apply the following waste management hierarchy: prevention, preparing for re-use, recycling, recovery, disposal (Fig. 2).

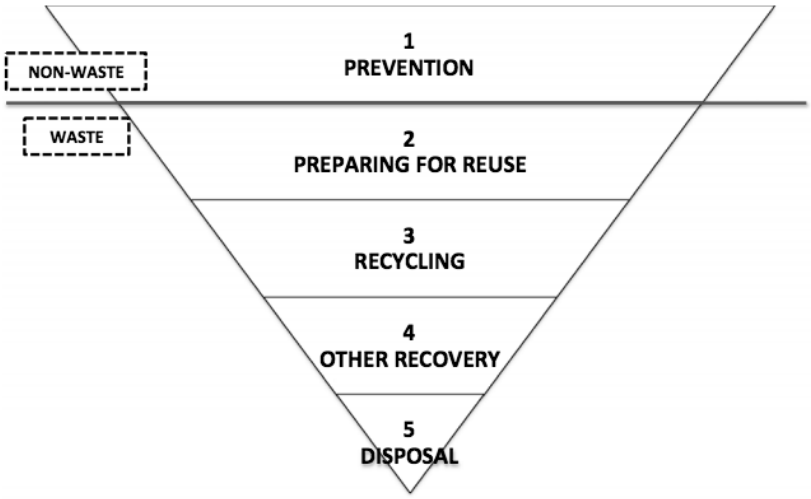

Figure 2 - Waste hierarchy as in the WFD 2008 (from Gharfalkar et al., 2015).

Two central components of the revised WFD have been the introduction of life-cycle thinking and the above-mentioned end-of-waste criteria. Life-cycle thinking looks at environmental impacts throughout the entire life cycle of a product, from extraction of resources to their disposal phase. End-of-waste criteria define at which point of treatment a waste can be regarded as (secondary) product again. The directive also introduced the "polluter pays principle" and the "extended producer responsibility", putting more responsibility on producers. Finally, the directive demands Member States to recycle 50% of their municipal waste by 2020. For 2014, statistics suggest that 44% of all municipal waste in the EU was recycled or composted (EP, 2014).

Barriers for bio-based chemistry

The main barrier for waste streams is the **non-uniform classification of materials as waste, residue or coproduct,** leading loopholes that cannot be addressed by national legislation alone. Several Member States have defined their terms of waste classification in accordance with already existing environmental legislation (such as the WFD), while others created definitions believed to be suitable for other purposes, e.g. renewable energy and the RED. This has resulted in feedstocks classified differently in the Member States, so that a feedstock can be a co-product in one country while it is a residue in another. Since for many waste streams neither European harmonised nor nationally established end-of-waste criteria are available, there is no sharp border between a waste and a chemical/product.

This difference in classification of a material as being a “product” or “waste” can furthermore result in situations where a material has to comply with both product and waste legislations, depending on the regions it is marketed in. This has implications on the material, e.g. whether and where it can be processed and how it can be used at its end-of-life stage. It also is critical for life-cycle assessments, where waste is often treated as a new material that carries zero burden. For companies manufacturing bio-based chemicals from waste streams it is therefore hard to establish and accomplish legal obligations because of uncertainty when waste becomes a product and if it then needs to be registered under REACH.

The fact that a material or industrial stream is classified as a waste does not necessarily mean that such an item has no potential application or (hidden) added value. In some cases, wastes may have valuable applications. The already mentioned tall oil from wood processing, often considered a waste, is a valuable chemical feedstock and can be used to produce adhesives, rubbers, inks and emulsifiers. As a consequence, these materials are used in sub-optimal ways in terms of environmental benefit/cascading use (BIO-TIC, 2015).

Under the current waste hierarchy, usage of wastes for higher value applications is not facilitated, which is in direct contrast to the circular economy idea. **The use of gasification, pyrolysis and other processes to produce new chemical materials from waste is not counted as recycling**. Instead, these technologies are counted as energy from waste applications and do not reflect the higher value applications that chemical production brings (BIO-TIC, 2015).

A rather broad issue is that the **usage of waste for chemical application requires intensive regulatory work**. While this is an important step in order to protect human health and the environment from harmful fractions of waste, it is nonetheless a factor that increases both the work load and overall costs for using waste streams as a raw material for chemical production. This is a disadvantage when competing with chemical products that are not derived from waste streams.

Recent developments & strategic approaches

The 2015 adopted Circular Economy Package includes revised legislative proposals on waste to stimulate Europe's transition towards a circular economy. As part of its package, the EC also submitted a proposal amending the 2008 Waste Framework Directive, which responds to a legal obligation to review the waste management targets set in the legislation (EC, 2015).

This amendment process is still on-going. In March 2017, the European Parliament gave its opinion on the 1st reading, from where the discussion is now continued within the European Council and its preparatory bodies. Main points of discussion are targets for recycling of municipal waste, recycling of packaging waste and a binding landfill target of municipal waste, all by 2030 (EP, 2014). The EP proposed stricter targets for 2030 than the original proposal included, suggesting 70% municipal waste recycling (compared to 65% in the proposal), 80% packaging material recycling (compared to 75%) and a maximum of 5% of municipal waste being landfilled (compared to 10%). Additionally, the EP proposed to implement food waste reduction targets.

The KBBPPS project concluded that the Waste Framework Directive “should set up end-of-waste criteria for compost and digestate, so that they are not defined as waste and could therefore be marketed as bio-based products (e.g. as fertilizer and soil improver) or as precursors to even more high-value bio-based products. This would also serve to strengthen the declared EU goal of a circular economy and cascading use of resources.” (KBBPPS, 2015). Building on this, the current proposal for a revision to the EU Fertiliser

Regulation suggest EU level end-of-waste criteria for bio-waste and digestate, which would allow them to circulate freely in the EU internal market. Proposed amendments to the EU waste legislation also envisage specific measures targeting quality bio-waste for recycling and targeting industrial symbiosis for feed materials.

For bioplastics and against the background of the on-going revision of the EU waste legislation, panellists on the 12th European Bioplastics Conference in November 2017 agreed that greater investments in the waste sorting infrastructures are key to improving the quality and volumes of recycling in Europe. At the same time, increased efforts in the harmonisation of standards, certification, and labelling of bio-based and biodegradable plastics are necessary in order to communicate the benefits of bioplastics in a transparent manner (European Bioplastics Conference, 2017).

A report about regulatory barriers for the circular economy by a consortium of scientists and consultants (technopolis, 2016) suggested to support „a harmonized approach to the implementation of the waste framework directive across the Member States“ and „to better consider by-products, in particular also in the definition of standards.“ The report further proposes to better align the directives for waste and products and recommends to include scientifically validated information, highlighting the possibility to take data from the REACH classification process.

It seems these recommendations are taken into consideration: In January 2018, in order to continue with the implementation of the Circular Economy Action Plan, the European Commission adopted a new set of measures. These include an EU-wide strategy for plastics, aiming for all plastics to be recyclable by 2030. Furthermore, the Commission acknowledged issues with the interface between chemical, product and waste legislation. Here, the Commission wants to facilitate closer cooperation between existing chemical and waste management expert networks and prepare an on-line EU repository for all adopted national and EU end-of-waste and by-product criteria. It also aims to launch a study to gain a better understanding of Member States' practices in regards to implementation and verification of provisions on end-of-waste as a basis for possible future guidelines (EC, 2018a).

3.3 Factsheet Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)

History & reason

The REACH regulation entered into force on 1 June 2007 and is considered one of the most comprehensive chemical regulations in the world (Ronzon et al., 2016). REACH places the burden of proof on companies and puts the responsibility for understanding and managing risks on manufacturers and importers. REACH also addresses the continued use of chemical substances of very high concern (SVHC) because of their potential negative impacts on human health or the environment.

There is currently no specific EU legislation or regulation for bio-based chemicals. However, they have to comply with general requirements for chemicals and materials, where the manufacture, supply and use of chemicals is governed by REACH. The regulation aims to achieve a **high level of protection for human beings and the environment** and contributes to sustainable development by **increasing chemical safety** and providing guidance for **adequate control of risks during use and production** of substances.

Barriers for bio-based chemistry

If a substance is intended to be used in the EU and it has not been registered before via REACH, the procedure of regulation needs to be followed. Bio-based chemicals and materials face a number of hurdles caused by this regulation, which are not necessarily related to the bio-based attribute itself. Often, the barriers are rather created by the overall character of the relatively new bio-based chemicals industry, which is driven to some parts by small enterprises and the use of new/different applications, chemicals or materials. These characteristics and the strict framework of REACH lead to barriers that have been identified in previous studies and are summed up in the following. It should be noted that these barriers do not necessarily apply to the significant number of large chemical companies also involved in bio-based innovation as part of their portfolio.

Difficult & expensive procedure of admitting new chemicals to the European market. As mentioned, the REACH regulation is a strict and detailed process requiring knowledge and labour. Bio-based chemicals are often new products that have not been registered under REACH yet and thus require the producer to comply with this regulation. Preparing such a registration is not trivial, and the majority of small and medium-sized enterprises (SMEs) has insufficient internal know-how to be totally independent from external service providers. These enterprises then often lack the necessary funds to go through the registration process and therefore encounter severe market disadvantages (KBBPPS, 2015). The EU assessed the affordability for SMEs and noted that between 2013 and 2016 only 18% of all applications were from SMEs. Main factors for this development are the mentioned financial constraints, but it is also noted that SMEs typically rely on their upstream suppliers for Authorisation (EC, 2017c).

Lack of awareness about REACH: Where traditional chemical companies are generally aware that they need to comply with REACH, other companies (especially new and smaller players on the market – both often applies to bio-based industries) are not always well accustomed to REACH since they may not consider themselves as part of a chemicals supply chain, while in fact they are. Here a direct link to the WFD can be identified: Especially when waste streams are recovered and cease to be waste, but instead become a product, difficulties arise because these recovered substances are falling under the scope of REACH and need to be registered (Luit et al., 2017).

Lack of homogenous definition which materials are exempt from REACH. To some extent, chemicals can be exempt from the REACH regulation, but the rules for these exemptions appear confusing. For example, digestate is not exempt from REACH whereas compost and biogas are, even though all three are remains of biodegradable feedstocks (EC, 2016). In addition, REACH imposes costs for products from manure, because recovered materials such as struvite need to be registered under REACH, which incurs additional costs on manure processors (technopolis, 2016). This lack of clarity amplifies the aforementioned lack of awareness.

Finally, there is a general **lack of guidance and support for SMEs** how to successfully manage the REACH process, as the available aid (also financially) often does not correspond to the specific needs of the SME.

Recent developments & strategic approaches

Since its official implementation, the REACH regulation has been subject to review every five years. The first evaluation in 2012 concluded that some needs for adjustments have been identified but overall REACH functions well. In the final report of the evaluation, the European Commission noted that "SMEs have been more acutely affected than large enterprises by the compliance costs and other issues related to the legislation, while few benefits have been perceived. […] Given the innovativeness of small and micro-firms, this could have longer term consequences for the EU chemicals industry." (EC, 2015b)

In May 2018, the so called 2018 registration will be enforced. From this point on, companies that manufacture chemical substances or import them from outside the EU above one tonne per year may have registration obligations under REACH. Additionally, if a company manufactures or imports a product (mixture, article), it may contain substances that need to be registered individually. For many SMEs in the bio-based chemical sector, the 2018 registration deadline is the first time where they need to deliver all the different requirements of the REACH registration process, which could lead to financial & regulatory issues for many of these companies.

The REACH REFIT evaluation occurred in 2017, again following the obligation for review every 5 years to monitor progress. For this review, stakeholder consultation was noted as an important part of the evaluation and included a specific consultation on SME relevant issues. The results were published on March 5th, 2018 and the general conclusion is that REACH continues to develop and deliver on its initial target. Support measures for SMEs regarding their obligations have been effective but they still remain vulnerable to REACH effects. Other remaining issues are: Lack of updates of registration dossiers, need for further simplification of the authorisation process, need to ensure a level-playing field with non-EU companies and need to further align REACH with other EU legislation like waste, industrial policy strategy and the circular economy (EC, 2018b).

3.4 Factsheet Common Agricultural Policy (CAP)

History & reason

The EU agriculture is one of the world's leading producers of food and provides food supply and security for European citizens. Rural areas in the EU are still home to 55% of its citizens and serve for employment, recreation and tourism (EC, 2017b). The introduction of the Common Agricultural Policy (CAP) back in 1962 enabled the development of an integrated single market for the whole European market. Major reforms shaped the CAP in 1992, 2003 and 2013, adapting the policy to changing demands in a globalized world.

Today, the main objective of the CAP is to provide a **stable, sustainably produced supply of safe food** at affordable prices for Europeans, while also ensuring a **decent standard of living** for farmers and agricultural workers.

Helping farmers with income support and market measures, the common agricultural policy also ensures **sustainable rural development** according to the specific needs in each EU country.

Barriers for bio-based chemistry

The CAP is the EU's main regulation instrument for agriculture and has therefore large influence on availability and pricing of bio-based feedstocks. For bio-based chemistry, the following barriers have been identified in the past:

Unfavourable agricultural policy through quotas and tariffs, which in turn increase the price of biomass. Since the 2000s, the EU has gradually removed the quotas in order to prepare for and adapt to an increasingly globalized world. With milk in 2015 and sugar in 2017, the last two quotas have been **finally removed.** This means for the sugar sector, that 2018 will be a year of adaptation to the new circumstances with more competitive prices per resource, and no further production limitations.

Costs of feedstock produced in Europe are generally **high** compared to other regions. In addition, demonstration of the necessary environmental sustainability standards requires complex and time-consuming procedures to demonstrate the biomass' sustainability. There are a multitude of different schemes which biomass producers (especially in the agricultural and forestry sectors) must comply with. In order to qualify for support payments as part of cross compliance measures under the CAP, farmers need to ensure environmentally sound production. Not directly related to the CAP but adding to this problem are a number of schemes to certify sustainable production chain, for example the International Sustainability and Carbon Certification+ (ISSC+) and Round Table on Sustainable Biomaterials (RSB).

Recent developments & strategic approaches

On 2 February 2017, the European Commission launched a consultation on the future of the CAP in order to better understand where the current policy can be simplified and modernised. The results recommend to focus on:

- keeping a strong common agricultural policy at European Union level
- the value added of having a common agricultural policy
- challenges ahead (fair standard of living, environment and climate change)
- a need for a simpler and more effective policy.

The consultation “confirmed a widespread consensus that the current CAP tools successfully address current challenges to some extent only. This covers also environmental and climate challenges, where a majority of farmers and other stakeholders consider that the CAP should do more. At the same time, the excess of bureaucracy has been highlighted as a key obstacle preventing the current policy from successfully delivering on its objectives“. The Commission acknowledges in their report that “it is necessary to reduce the regulatory burden of the CAP and improve its value for money while ensuring the achievement of the objectives and increase its integration with other policy areas.” (EC, 2017a).

To increase availability of biomass for material applications, Europe’s rural development policy could facilitate access to renewable feedstocks, encourage farmers to invest time in ‘harvesting’ residues and build up the required infrastructure necessary to bring these residues to manufacturing processes (Nielsen, 2014). The CAP in general would be a viable instrument to push certain biomasses of interest, e. g. hemp or flax, by the reintroduction of quotas (De Mey et al., 2015).

The sugar reforms in 2017 present an opportunity for reinstating this capacity at least in some areas of Europe, but landowners need to be assured that a market exists and that they will receive fair prices. Sugar beet is an excellent and sustainable feedstock for industrial biotechnology, with abundant and easily accessible fermentable sugars. In order to support European growers and processors, the sugar sector was originally subject to production quotas and a minimum price. Even though the quota drop allows the import of alternatives (especially isoglucose), it is expected that sugar beet production and availability will increase as a result, with prices dropping closer to the world-wide level, turning sugar beet into a potentially highly interesting feedstock for the bio-based industry. For 2018, Europe expects 2-3 million tons of sugar surplus, but increased demand from chemical industry seems to be hesitant, mainly because fear of a renewed food discussion is persistent.

The current CAP delivery system relies on detailed requirements at EU level, and features tight controls, penalties and audit arrangements. These rules are often very prescriptive, down to farm level. In the Union's highly diversified farming and climatic environment, however, neither top-down nor one-size-fits-all approaches are suitable to delivering the desired results. In the delivery model of the future CAP, the Union should set the basic policy parameters (objectives of the CAP, broad types of intervention, basic requirements), while Member States should bear greater responsibility and be more accountable as to how they meet the objectives and achieve agreed targets (EC, 2017b).

The European Commission, in their review of the European Bioeconomy Strategy, noted that “Decoupling of CAP helps to ensure flexibility for farmers to adapt to market demand, thus ensuring agriculture and forest biomass provision. In addition, in the context of the Rural Development Policy there are significant opportunities for supporting the development of the bioeconomy. Particular opportunities for innovation in this domain arise through in-built linkages between the CAP, the EIP-AGRI and Horizon 2020 (SC2) – these altogether providing a comprehensive innovation framework. Such a framework could be improved and strengthened in the possible context of a revised Bioeconomy Strategy. In acknowledging that the CAP must be part of the solution to deliver food and nutrition security and address major public health and natural resources challenges, the Bioeconomy Strategy offers a unique opportunity to develop a more ambitious research and innovation strategy. This applies also in the context of the Common Fisheries Policy (CFP), as seafood makes up an increasing part of our food supply“ (EC, 2017b).

The EU spends a part of its budget on direct payments to farmers, forming up to 46% of the European farmer income (EC, 2017b). Some these funds could be directed towards helping

farmers carve out new revenue streams and to start the transformation towards a competitive bio-based economy. European agriculture is in principle under-utilised, which means that farmers could earn more from their land by turning agricultural residues (principally wheat and rye straw, maize stover and sugar beet leaves) into a profitable resource. In Europe, there are over 1 billion tonnes of agricultural residues available that could be sustainably harvested without altering land-use patterns. These residues could be turned into a new set of bio-products and help to provide raw materials to the chemical sector (Nielsen, 2014). Furthermore, similar side streams from the food & feed industry, fishery, forestry, and so on could be utilized in similar fashion to produce new chemicals and materials (Carus & Dammer, 2018).

3.5 Factsheet Council Regulation (EEC) No 2658/87 (CCT)

History & reason

The “Council Regulation (EEC) No 2658/87” on the tariff and statistical nomenclature and on the Common Customs Tariff came into force on 23 July 1987. Since the creation of the internal EU market, goods can circulate freely between the Member States. The EU import tariff, called “Common Customs Tariff” (CCT), therefore applies to the import of goods across the external borders of the EU. It sets up the legal basis for the TARIC (integrated Tariff of the European Union) database, the integrated tariff of the EU, and introduces a common system for coding and classifying goods, known as the Combined Nomenclature (CN), essential for processing and publishing EU trade statistics.

The tariff is common to all EU Member States, but the rates differ from one kind of import to another depending on what good is imported and where it comes from. The tariff is therefore the name given to the combination of the nomenclature (or classification of goods) and the duty rates which apply to each class of goods. In addition, the tariff contains all other Community legislation that has an effect on the level of customs duty payable on a particular import, for example country of origin.

Through the tariff, the Community applies the principle that **domestic producers** should be **able to compete fairly** and equally on the internal market **with manufacturers exporting from other countries**.

Barriers for bio-based chemistry

Although the CCT is based on a specific piece of legislation due to its individual application to goods it is usually more feasible to target a specific duty rate for a good than the overall piece of legislation.

The general barrier created by an import tariff is an **increased price** of a good compared to the globally available price. This is naturally true for all countries and areas in the world that work with import tariffs to protect their native markets and producers. But Europe as a highly developed region with high average income has to implement comparatively high import tariffs to level prices between external and internal suppliers. In scope of the RoadToBio project, this is especially true for feedstocks and here, three resulting main issues can be pointed out:

1) **Global price disadvantage**: When compared to producers outside of the EU, the higher than global feedstock price lead to increased operation costs. While the products might themselves be protected by another import tariff in Europe, on a global level the higher operation costs are a disadvantage and decrease competitiveness of producers in the EU. As a consequence, this is also an incentive for producers to look for site locations outside of Europe.

2) **Competitive disadvantage vs petrochemicals**: Many petrochemicals are exempt from import tariffs or fall under specific agreements that lower the import tariff rate. As a general trend, petrochemicals often have import tax advantages over bio-based feedstock, resulting in competitive disadvantages for bio-based chemicals and materials.

3) **Uncertainty for long-term investments:** The current EU customs regime schemes can result in short term and thus rather unpredictable options and opportunities, which increase uncertainty and hamper the willingness for investments, which are necessary to advance the bio-based economy.

The higher-than-global price also means that producers can purchase less feedstock in Europe for the same amount of money than in other areas of the world. In combination with the RED support for bioenergy application of biomass, the material application of the feedstock is at a clear disadvantage in the EU.

Recent developments & strategic approaches

In respect to ongoing trade negotiations between the EU and Mercosur, the European Chemical Industry Council (Cefic) and the Brazilian Sugarcane Industry Association (UNICA) proposed the idea for full tariff elimination on bio-ethanol, only for use as feedstock in the chemical industry. Currently, import duties on bio-ethanol of 40-60% are in place and the EU production of bio-ethanol mostly follows the demand from the biofuel sector.

Cefic argues that the tariff elimination would be a “win-win-win” situation for all stakeholders involved: The European chemical industry could develop their bio-based segment and increase renewable feedstock share. European bio-ethanol producers could gain new market opportunities due to the development in the bio-based chemistry. Finally, for the trading partners that produce bio-ethanol but have no similar production industries as the EU, new market segments would be opened without harming existing markets.

3.6 Factsheet genetically modified organisms directive 2001/18/EC GMO

History & reason

In 2001, the directive 2001/18/EC on the deliberate release into the environment of genetically modified organisms (GMOs) came into force. Based on this directive, the EU put in place the probably strictest regulation in the world for the presence of GMOs in food and feed (Davison, 2010). The main goals of the strict guidelines are to ensure the **protection of human and environment** in accordance with the precautionary principle and have to be enforced both for the deliberate release of GMO into the environment and when GMOs are placed on the market.

Editing of genes is a rapidly evolving field, where especially new and precise editing techniques like CRISPR/Cas9 have become a strong tool to change and improve crops or pharmaceuticals. In contrast to older GMO techniques, these new technologies only change or delete parts of the DNA (Deoxyribonucleic acid) very specifically and are therefore often considered a more controlled, safer and much cheaper approach.

The CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) method originally protects bacteria against attacking viruses. The enzyme Cas9 recognises the pathogenic viruses and cuts them up in a targeted manner.

Adapting the process, the CRISPR/Cas system is a highly important recent discovery for gene editing. With the help of CRISPR/Cas, building blocks (DNA) of our lives can be changed simply, specifically and quickly. Genes and regulatory sequences can thus be switched off or exchanged to remove or add properties.

Since the CRISPR sequences occur in almost all living beings, CRISPR/Cas can be widely applied, e.g. in the health and plants sciences.

Barriers for bio-based chemistry

Under the existing legislations, GMO **require labelling for food and feed** where the level of approved GMO exceeds 0.9% and for non-approved GMOs the threshold is ‘zero’. While a few mutagenesis techniques that have a proven track record over longer time periods are considered “safe” and exempt from the directive, many genome editing techniques are subject to the strict regulation. There is in fact a long and ongoing discussion and lack of clarification about the regulatory status of products that have been developed under the latest biotechnological tools and applications.

Slow and expensive approval: The process of gaining safety approval for a new GMO is a slow process and subject to extensive political interference. According to a report from Ernst & Young published in 2014, it takes on average around 4 years for a GMO import to be approved in Europe and for GMO cultivation applications it tends to take even longer. Costs for the applicants are estimated at between €7m and €15m, mostly due to the necessity of many studies (E&Y, 2014). New and improved crops therefore face long periods of insecurity before they become accessible as feedstock for the chemical industry and their products.

Recent developments & strategic approaches

The EU is very cautious in deciding the regulatory status of crops resulting from genome editing techniques. Currently, a European decision whether regulations for GMO apply to plants is lacking. For the specific case of CRISPR techniques, there is ongoing and

controversial discussion whether it should be regulated as a genome modification technique or as new kind of breeding mechanic:

Some groups that have opposed GMOs and transgenics have also issued cautions about CRISPR and argue that this new technology still should be regulated while we learn more about it. Furthermore, scientists are still hesitant because of high off-target effects, which means mutations in parts of the genome that were not intended to change. The technique, while precise, can make cuts in the wrong parts of the genome sometimes, although there are promising leads for increased control. This is to a larger extent an issue for health applications and only to a lesser extent for agriculture and biomass production. Plant genomes have many redundant genes, so many genes must be knocked out to shut down a particular trait-producing pathway (Schaefer et al., 2017).

Previous studies have concluded that the directive is not narrow enough in its definition of what GMO exactly refers to. The Directive refers to “insertion of nucleic acid molecule […] capable of continued propagation” without any further specification. In conclusion, every technology that inserts nucleic acid molecules leads to an application of the regime (Spranger, 2015), which means that CRISPR/Cas9 would have to follow the Directive guidelines.

On the other side, a risk assessment by the German government determined that a gene-edited form of canola was not genetically modified under federal laws, and Sweden’s Board of Agriculture ruled that any gene-edited plant did not qualify as a GMO under European Union regulations. In January 2018, the European Court of Justice (ECJ) has indicated that crops and chemicals developed using precise gene-editing techniques, like CRISPR/Cas may not necessarily have to be regulated as strictly as less precise genetically modified organisms (GMOs). The European Court’s advocate general has come out in support of applying the new and more precise genome editing tools and a final judgement is expected by the end 2018. Member States might still regulate individually, if they decide to, but this indicates a shift towards a more liberal approach towards the newer genome editing technologies.

Should the CRISPR/Cas9 system not be classified as GMO, improved and adapted plant variations could lead to a higher efficiency and increased land availability for biomass production in the future, increasing biomass availability in general. Additionally, specific plant breeds could be developed that offer favourable properties or other advantages for usage in the organic chemistry.

3.7 Factsheet EU Emissions Trading Scheme EU ETS

History & reason

The European Union Emissions Trading Scheme (EU ETS) is the world's first and so far the largest installation-level 'cap and trade' system for cutting greenhouse gas (GHG) emissions. The system is intended to assist the EU in **reaching** both **its immediate as well as longer-term emissions reduction objectives** by "promoting reductions of emissions in a cost-effective and economically efficient manner". The scheme was mostly a result of discussions of how to reach the Kyoto GHG emission reduction targets.

The main features of the EU ETS are the emission cap (a ceiling on the maximum amount) and the trading of EU emission allowances (EUAs). The cap guarantees that total emissions are kept to a pre-defined level (and do not rise above it – in the period for which the cap applies). Covered installations have to submit an EUA for each tonne of carbon dioxide equivalent they emitted during a year. In total, the EU ETS organised four trading periods (2005-2007, 2008-2012, 2013-2020, and 2021-2028), with a full review and the option of further periods afterwards (Chandreyee & Velten, 2014).

Barriers for bio-based chemistry

The EU ETS focuses on the capture of CO_2, which promises to become an important building block for applications in the chemical industry and which can be bio-based if the source for the CO_2 emission came from green carbon. Captured CO_2 can either be buried and thus stored (Carbon Capture and Storage, CCS) or it can be used for further processes and products (Carbon Capture and Utilisation, CCU). Currently well-established technologies in the organic industry are, for example, urea synthesis, Fischer-Tropsch technology for synthetic naphtha and kerosene (PtL) production or methanol production and further processing. Additionally, fine chemicals like carbamates, polyols and polycarbonates or biotechnological pathways to produce ethanol can be explored.

The main barrier in this case is the fact that under the current third trade period, **only CCS processes are eligible** for credits under the ETS system, while the application of CCU is not. This also effects the chemical utilisation of CO_2 emitted from green carbon sources.

Recent developments & strategic approaches

Prior to the fourth trading period, a revision process will be enacted to adapt the ETS to recent developments. In that regard, a recent court decision acknowledged the eligibility of precipitated calcium carbonate (PCC) production by Schaefer-Kalk for the EU ETS. While the CO_2 gets mineralized in the production process, it is nonetheless a CCU technology, which has opened the door to further discussions about the general eligibility of CCU processes and how a solid framework to credit CCU processes might be designed without endangering the basic idea of the ETS, the emission reduction.

The BIO-TIC project suggests that „CO_2 based products could be promoted through the EU ETS scheme. Products made from CO_2 are currently not eligible for credits under EU ETS, however CO_2 sequestered through CCS is." The EU ETS enters its fourth stage in 2021-2028, so the inclusion of CCU technologies within any possible following scheme would be an opportunity to promote the usage of captured CO_2, which also includes organic/green carbon sources (BIO-TIC, 2015). On the other side, there are also arguments against including CCU: A policy brief by the zero emissions platform (ZEP, 2016) disputes that the climatic values of different types of CCU should be better understood before including CCU processes in the ETS system.

Looking at the topic from another perspective, CCS processes store carbon while CCU processes substitute the usage of carbon from other sources. Both can therefore achieve the same effect of avoiding additional carbon emissions. CCU has been gaining momentum in recent years, most visibly by creation of various initiatives and projects focussing on the utilization of CO_2 emissions. In the end, it is to some extent also a political decision whether increased incentives for CCU applications should be encouraged and developed. While more discussions, decisions and perhaps more certain frameworks are for the future, we wanted to raise awareness that CCU could become an option for further bio-based resources for the chemical industry. In this regard, there are possibilities to align well with the idea of a circular economy.

3.8 Factsheet Energy Efficiency Directive (EED) and Energy Performance of Buildings Directive (EPBD)

History & reason

Inspired by the Kyoto Protocol, the EU defined binding targets to decrease energy consumption across all sectors. The building sector contributes to 35 % of total GHG emissions, 40% of final energy consumption, utilizes 50% of extracted materials, and 30% of the water consumption in the EU. Developed from the first version, Directive 2002/91/EC, the 2010 Energy Performance of Buildings Directive (EPBD) and the 2012 Energy Efficiency Directive (EED) are the current EU's main legislation covering the reduction of the energy consumption of buildings.

Main target of the EPBD is to **promote improvement of the energy performance of buildings**. The EED mandates energy efficiency improvements in order to encourage efforts to **use energy more efficiently** in all stages and sectors of the supply chain. From 2020 on, new constructions will have to consume nearly zero energy.

Barriers to bio-based chemistry

Both the EPBD and EED are translated into national laws by the Member States. Because challenges and demands differ between countries (e.g. high sun intensity in Southern Europe, strong wooden-based industries in the Nordics), actual implementations are encouraged to be adapted according to the respective circumstances. In other words, both the EPBD and the EED intend to give Member States their freedom to facilitate energy transition in a way that fits with the wide diversity of national developments (CA EPBD, 2016). In this regard, for better understanding of regulatory barriers caused by both legislations, a look on the national level becomes necessary. Studies suggest that surprisingly little data is available on the actual impact of policy instruments in the construction sector, with a serious lack of quantitative data on policy effects (Meijer et al., 2009). Therefore, we highlight here some more explicit barriers identified by the KBBPPS project to point out rather specific problems for bio-based products as insulation material, in the hopes this can be instrumental for bio-based chemicals as well (KBBPPS, 2015).

Insulation performance / thermal conductivity of natural fibre materials Producers claim that the insulation performance of natural fibre insulation is not evaluated fairly. Natural fibre insulation materials are vapour active and can buffer and release moisture up to a higher degree without degrading their functionality, but the standard evaluation method adds a correction factor if a material collects moisture, leading to worse results for the bio-based materials.

Moisture permeable materials are not allowed as insulation in some Member States. Bio-based insulation is perfectly happy to become moist temporarily and still perform thermally. It even provides advantages compared to moisture tight insulation, since it serves to better regulate moisture content in a room and to minimize the risk of condensation and mould growth.

Good properties such as high heat transfer (decrement) delay and good acoustic performance are not included in standards. Apart from the absolute insulation effect, the residual heat reaches the room later than with convention insulation. This can have positive effects for example in work environments but is not reflected in any testing in order to comply with norms. Producers of these materials cannot obtain any advantage in marketing for their more expensive materials.

Lack of regulation, standard specification and protection. The above mentioned issues for insulation materials lead to the conclusion that for many bio-based insulation materials,

there is a general lack of fair standardisation and regulation. This might partly be due to the novel character of these materials, so that they have not been considered as a standard option for regulation yet. The KBBPPS project determined such issues also for mulch films in agriculture.

Recent developments & strategic approaches

On 30 November 2016 and as part of the "Clear Energy for all Europeans" package, the Commission proposed an update to the Energy Performance of Buildings Directive to help promote the use of smart technology in buildings and to streamline the existing rules. The Commission also published a new buildings database – the EU Building Stock Observatory – to track the energy performance of buildings across Europe.

On 19 December 2017 a political agreement was reached by negotiators from the Council of the EU, the EP, and the EC on the proposed update. Based on the Commission's proposals, the co-legislators agreed to add targeted amendments to the current Directive aimed at accelerating the cost-effective renovation of existing buildings, with the vision of decarbonising building stock by 2050 and mobilising investment. The legal text of this political agreement must now be finalised and formally adopted by both the Council and the European Parliament in the coming months.

The construction sector causes a large part of the EUs GHG emissions and environmental impacts. It is therefore envisioned to develop environmentally friendly materials and chemicals that lessen the impact of construction in terms of its use of non-renewable resources and energy consumption. Bio-based products are thus becoming increasingly important in the building materials market. Natural and bio-based construction materials represent a promising solution for optimizing buildings' environmental sustainability, thanks to several advantages: They often offer low mass densities, low thermal conductivity, high acoustic absorption properties, less harmful effects on health and local availability. As pointed out, often more specific regulations have negative effects on new bio-based options, so it might be worthwhile to investigate how the EED and EBPD could be utilized to improve this situation.

To create incentives for higher bio-based shares in the construction sector, investment subsidies for wood-based buildings would be another option to increase the share of wood construction, although this could lead to a distorted wood demand and funnel innovation efforts into wood-based materials. Purkus et al. (2017) propose a combination of niche support and indirect demand pull measures: using sustainably sourced wood in public construction projects could promote learning and skill development, provide impulses for entrepreneurs to specialize on wood-based building, and raise awareness among private project planners. Meanwhile increasing the costs of cement through carbon pricing or the costs of non-cascading waste through waste and recycling regulation would incentivize search processes for alternative construction options on a broader scale.

3.9 Further legislation impacting the bioeconomy

In order to provide a more complete picture about regulations affecting biomass supply, a few remaining policies and topics shall be briefly covered. Similar to the EED and EPBD, these topics do have larger implications on the bioeconomy in general but are very wide in their perspectives and in their national implementations.

Fishery – Common Fisheries Policy

The main target of the Common Fisheries Policy (with its current version from 2014) is to manage fish stocks sustainably, according to the principle of maximum long-term yield. Through replenishment plans and management plans spanning many years, as well as restrictions on catch quantities and also on resources committed to catch operations, activities are directed to attaining the maximum long-term yield from all stocks. By-catches reduce the productive fish stocks, make it harder to estimate the stock situation, damage the marine ecosystems and threaten seabirds, marine mammals and other marine organisms. Therefore by-catches need to be reduced. Industrial biotechnology processes that use aquatic micro-organisms and algae for their diverse ingredients (as a source of raw materials) are of growing interest as a resource-efficient use of biomass (BMEL, 2014).

The CFP manages fishing activities through a range of measures (such as total allowable catches, restrictions on gear and number of vessels) with a view to ensuring sustainable exploitation of fish stocks. The EU promotes the development of sustainable aquaculture, in particular through the European Maritime and Fisheries Fund.

Forestry

Although forestry is a national matter, the EU Forest Strategy (adopted in 2013) provides a common framework based on a series of general principles: sustainable forest management; resource efficiency, rural development and economic growth; sustainable production and consumption of forest products.

Forests cover more than 40 percent of the EU's land area. Sustainably managed forests and wood use deliver a triple carbon effect in mitigating climate change. They provide emission removal, carbon storage, and carbon displacement if wood is used to substitute for non- renewable and highly energy-intensive materials.

They provide the bioeconomy with renewable materials as well as other ecosystem services to create the much-needed shift to a sustainable circular economy. The use of domestically available raw materials has a positive impact on securing the supply of energy and goods. At the same time, the diversity in terms of needs and capacities between the different European regions must be acknowledged. Fostering sustainable forest management throughout Europe will safeguard and avoid the risk of over-exploitation resulting from higher demands on forests (Eustafor, 2017).

Water Framework Directive

The Water Framework Directive 2000/60/EC commits the EU Member States to achieve good qualitative and quantitative status of all water bodies from 2015 on, including marine waters up to one nautical mile from shore.

Aquatic biomass, whether it stems from oceans, rivers or lakes, has huge potential to not only increase food and nutrition security but also to supply raw materials for other high added value chains and products that can be part of organic chemistry. Especially in depths between 200 and 1000 meter, a large unexploited biomass has been identified, including

micro-organisms, copepods, krill and plankton feeding fish, as well as squids and other higher trophic level fish. In their Horizon 2020 work programme 2018-2020, the EC notes:

> These so-called provisioning ecosystem services could ensure private and public benefits, while demonstrating synergies or trade-offs with a broader range of ecosystem services. However, this potential is currently underutilized due to a lack of synergies between sectors and of adequate investments. Consequently, EU intervention is needed to create the conditions to mobilize investments by aligning national and regional innovation research agendas across different blue bioeconomy sectors.

If exploited at sustainable levels, this biomass could be used to produce more high-quality ingredients for the human food chain to decrease the pressure on overexploited fish species and also to potentially discover and develop new bio-based products, for example pharmaceuticals, nutraceuticals or cosmetics (EC, 2017d).

3.10 Barriers unrelated to specific legislations

Albeit the focus of this report is put on the regulatory barriers caused by EU legislation, for a complete picture it is necessary to discuss a remaining regulatory barrier that cannot be directly assigned to a respective legislation: The funding of research & development (R&D) and for upscaling of processes.

Funding of research & development

In the EU, funding for research and development (or innovation) is provided through a number of interlinked programmes. For the ongoing period from 2014-2020, most of the funding stems from Horizon2020, and the European Structural and Investment Funds (ESIF). The JRC estimates that within Horizon 2020 €4.2 billion, or roughly 5.6% of the total budget, is allocated to the priority SC2 (Societal Challenge 2: Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy). Furthermore, the BBI-JU is a public private partnership with a combined budget of €3.7 billion with the objective to develop a sustainable and competitive bio-based industry in Europe with a focus on advanced biorefineries.

Although the EU budget dedicates severe funding to BBI and the bioeconomy through various EU programmes, for example Horizon 2020 or respective national budgets, the results of a study by the European Investment Bank (EIB) suggests that a large number of BBI and SC2 projects and companies in the EU appear to face difficulties raising finance (EIB, 2017). The review of the European Bioeconomy Strategy (EC, 2017b) agrees with and supports this assessment:

> Funding of **high risk investments** is not well supported by current EU instruments: whilst the Strategy and Action Plan called for investments to support integrated activities (e.g. biorefineries), current EC funding instruments do not provide sufficient funding for this type of high risk activities. Some funding has been made available through Horizon 2020, ESIF and the BBI JU, but this remains insufficient given the scale of the investments needed. A recent study [Author's note: The EIB study] has shown that insufficient support to the scaling up from pilot to demonstration and subsequent flagship/first-of-a-kind and industrial-scale projects, as well as regulatory uncertainty, is holding back private investments in the bio-based sector.

A majority of BBI and BE projects face these access-to-finance issues, with most projects reporting that these issues indicate a lack of interest from private financial market

participants, mostly related to the specificities and associated lack of understanding of BBI and BE industries. The EIB study found no correlation between investment size and Technology Readiness Levels (TRL) of projects and the existence of access-to-finance issues, suggesting that systemic barriers are the main culprit (EIB, 2017).

The identified main barriers in that regard are market and demand risks (in relation to a lack of developed markets and insufficient market demand for bio-based products) and regulatory risks (primarily related to the lack of an effective, stable and supportive EU regulatory framework). In turn, both factors are also seen as the most important drivers for a growing bioeconomy (EIB, 2017).

Private investors perceive that investments are of high risk, due to a lack of information, undeveloped technology, instability of markets and challenges due to regulations. Additionally, there are discussions about ownership of biorefineries because the chemical sector sees itself as a customer for basic chemicals from such a refinery but the agricultural sector ends right at the doorstep. To move projects from demonstration phase to an industrial-phase scale (TRL 8 or 9), large investments are necessary. Under consideration of the mentioned risks, many private investors shy away.

In order to facilitate increase private investment in bioeconomy projects, two key recommendations of the EIB study are to a) establish an effective, stable and supportive regulatory framework at EU level and b) develop a new EU risk-sharing financial instrument that can meet the needs of BBI and BE projects to mobilise private capital.

On a more general note, private investment in the EU has overall fallen, especially in countries that were subject to market and financial pressure in recent years, and might in part explain why the willingness to invest in projects that are perceived as risky and with a high uncertainty. An article published in the European Central Bank (ECB) Economic Bulletin in 2016 discussed the decline in public investment and the consequent and ongoing call to stimulate public investment again. As one of its key conclusions, it states that an increase in public investment has positive demand effects and can contribute to the economy's potential output (ECB, 2016).

It might also be worthwhile to take a closer look to the private investment atmosphere in other areas of the world, for example in the US, where the average willingness of private investment, especially for larger investments, seems to be higher.

3.11 Overview of identified regulatory barriers

In the table below (Table 1), the identified regulatory barriers caused by the investigated EU legislations have been summarized. Although the table simply lists all barriers, they actually differ largely in impact – For example, the non-level playing field caused by the RED has a greater influence on the bio-based chemistry and material sector than mandatory labelling of GMO products.

Table 1 - Summary of identified regulatory barriers

Key legislative	Identified barrier
RED	Higher demand and higher prices for biomass
RED	Contested feedstocks
RED	Result: Non-level playing field
RED	Ambiguous incentives
WFD	Non-uniform classification of materials as waste, residue or coproduct.
WFD	Use of gasification, pyrolysis, etc. to produce materials from waste not counted as recycling
WFD	Usage of waste for chemicals requires regulatory work
REACH	Difficult & expensive procedure of admitting new chemicals
REACH	Lack of awareness about REACH
REACH	Lack of homogenous definition which chemicals are exempt from REACH
REACH	Lack of guidance for SMEs
CAP	High costs of bio-based feedstock
CCT	Global price disadvantage
CCT	Competitive disadvantage vs. petrochemicals
CCT	Uncertainty for long-term investments
GMO	Mandatory labelling of GMO products
GMO	Slow and expensive approval procedure
EU ETS	CCU processes not eligible for ETS credits
EED & EBPD	General lack of fair regulation & standardisation for new bio-based options, but barriers in construction are often rather specific, as indicated for insulation materials.

4 Conclusions & strategic outlook

It is not a recent discovery that material use of biomass usually leads to 4 to 9 times higher value products when compared to energy use and also support 5 to 10 times as much employment (Carus et al., 2010). In terms of resource protection, innovation, jobs and added value, material uses regularly demonstrate stronger benefits. Furthermore, these views and considerations are not exclusive to scientists, but are widely accepted to the point that material use has been given political priority and extensive funding for research & development for many years. It is therefore on first glance quite baffling that biomass use for energy has grown heavily in recent years, while biomass use for materials has stagnated on similar levels for the last 20 years. But it is also evident that, for the high importance material biomass use has been ascribed to, a promising and promoting political scenery has never been developed (Carus et al., 2014b).

Considering the range of regulations that were considered in this report alone, it becomes evident that the bioeconomy is a large and highly diverse field, with many different barriers stemming from a variety of regulations. For the European perspective, this is even further complicated by national and regional perspectives and the flexibility the EU grants for the implementation of directives. What is considered a product in country A might be seen as waste in neighbouring country B. The treatment of a waste might differ greatly between two countries, resulting in entirely different remains that can or cannot be recycled or reused.

It is in large parts due to this complexity that the material use of biomass has not significantly developed, that simple solutions are not available and that the sector has not grown despite the political priority it has received. The bioeconomy as a whole is difficult to tackle and legislative changes in favour of it may cause issues elsewhere or contradict original targets of other regulations. The review of the bioeconomy strategy in 2017 (EC, 2017b) states:

> Achieving a good level of policy coherence is crucial for the implementation of the 2012 Bioeconomy Strategy and Action Plan, since the achievement of the interlinked bioeconomy objectives requires an integrated (i.e. cross-sectoral and cross-policy) approach within the EC and beyond. This is needed in order to adequately address the issue of multiple trade-offs but also of synergies and interconnected objectives related to bioeconomy policy (e.g. sustainability and protection of natural capital, mitigating climate change, food security).

This report intends to give an overview of important legislations on EU level that affect the bio-based economy, describing barriers that arise because of the regulation while also highlighting the original intention and target. While some barriers are specific for certain fields or situations (e.g. insulation materials) and others affect more topics than just the bioeconomy, they all add some burden for the bio-based economy that inhibits growth in the material and chemical sector. A full discussion of every single barrier, potential solutions and estimated consequences would be out of scope, but some strategic thoughts and ideas can be found for each of the factsheets and respective regulations. This report furthermore wants to highlight some barriers that are considered critical in terms of holding back the material use of biomass and that are based on different regulations. Additionally, it offers some strategic approaches on how to overcome these barriers.

4.1 Instruments to strengthen innovation implementation

Uncertainty is the central obstacle in preventing investment, market introduction and establishment of innovations (Carus et al., 2014b). This is true for bio-based chemicals and materials as well. Uncertainty can occur with regard to the political framework, political and social acceptance, ecological evaluation, secure access to an affordable raw material base,

the maturity and competitiveness of technologies and processes as well as competitiveness at the raw material (compared to bioenergy and biofuels) and product level (compared to tax-exempt petrochemicals). The review of the bioeconomy strategy (EC, 2017b) also states that uncertainty is an inhibitor for investments:

> […] there are currently no dedicated policy tools at European level to support the development of bio-based products markets, contrary to other countries such as the United States. This regulatory situation, which has been deemed "uncertain" by some stakeholders, has potential negative impacts with the bio-based private sector being reluctant to take risks investing into new areas; […]

In an article by Hodgson et al. in 2016, over 300 stakeholders from science, industry and policy were interviewed about barriers for the European bio-based economy and two key activities wished for were “ensuring continuity of policy” and “building investor confidence in the bio-based economy”, both factors that directly affect overall uncertainty for the investment and marketing of bio-based products.

The number of ways to reform the existing political framework is limited: In terms of market policy measures, the main distinction is usually made between “Technology push” (or “Feedstock push”) and “Market pull” measures. (Fig. 3). A technology push implies that a new invention (or feedstock in case of a feedstock push) is pushed onto the market through R&D, production and sales functions without proper consideration of whether or not it satisfies a need. In contrast, an innovation based upon a specific market pull has been developed by R&D due to an identified market need. “Standards and norms” are a mixed category of both push and pull, since they simplify production but also create more market demand due to greater consumer confidence. For developing strategic approaches, this distinction should be considered (Carus et al., 2014c).

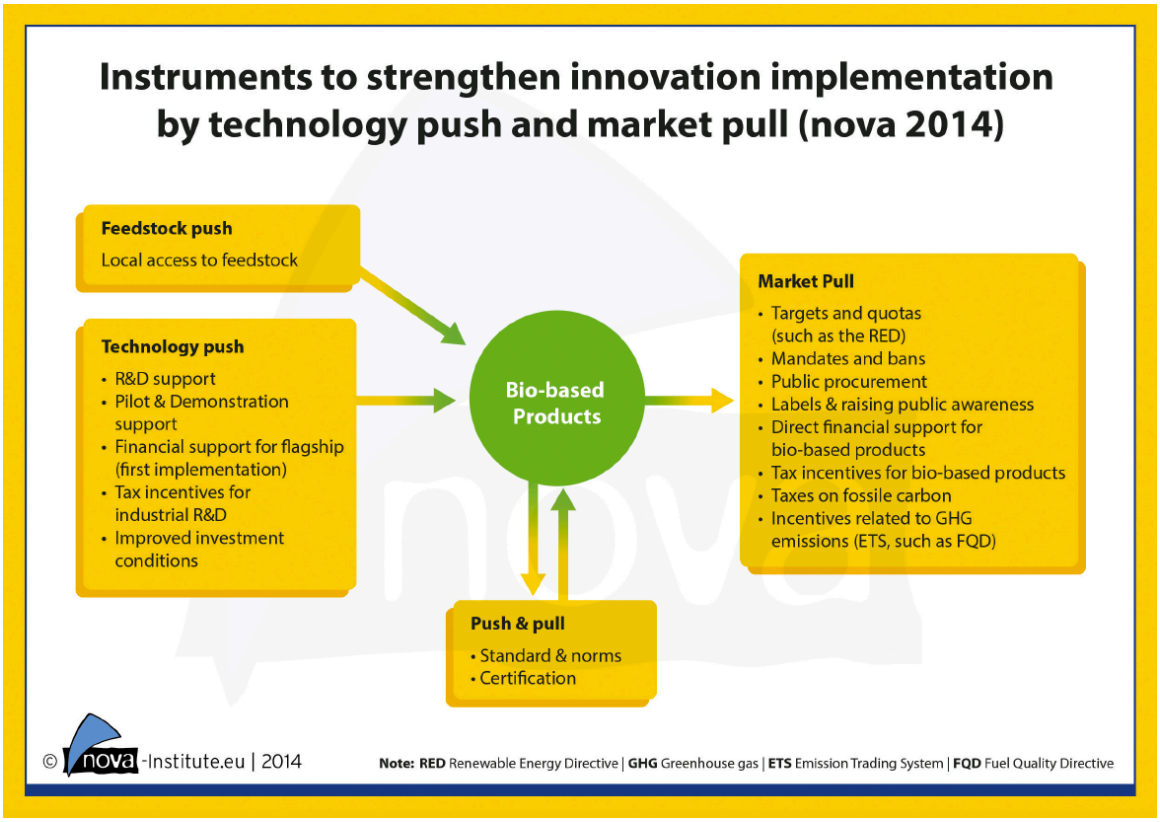

Figure 3 - Instruments to strengthen Innovation implementation by technology push and market pull (nova-institute, 2014)

A currently favoured idea is to make public procurement of bio-based products preferable. The EU but also several countries are currently looking into the possibility of using public procurement as a market pull for bio-based products, but in many cases the legal situation and specifics still need to be worked out. (KBBPPS, 2015). The nearly completed InnProBio project is further investigating the public procurement of bio-based products.

Nearly all of the instruments can be targeted with well-developed policy frameworks. With the development of the bioeconomy strategy in 2012 and the circular economy package in 2015, the EU is certainly working on ensuring a continuity of policy. Additionally, in its communication on a European Industrial Renaissance, the EC stressed the importance of raising the contribution of industry to gross domestic product to 20% by 2020. In this context, the bioeconomy is mentioned as an important factor for the long-term competitiveness of the EU, underlining the following important policy aims:

> The Commission will ensure policy neutrality in access to biomass for different purposes to enable efficient application of the cascade principle in the use of the biomass to ensure an efficient and sustainable use of natural resources. Also if deemed necessary, it will consider measures to enable industry to have access at global market prices to key inputs such as bio-ethanol or starch for bio-based industrial activities emerging from traditional sectors such as chemicals, paper and other forest-based industries." (EC, 2014).

If these goals were to be translated into concrete measures, the bio-based materials industry could profit considerably (Carrez et al., 2017). The RED with its large influence would be one possible target for such measures.

4.2 The Renewable Energy Directive

The RED has been discussed extensively in many reports and papers, but the effects on the material use of biomass are immense and need to be explicitly stated. The described non-level playing field between biomass use for energy and for materials leads, based on the higher value-added properties of material use, to an economic misallocation of resources. Furthermore, as material usage could be included into Circular Economy and cascading use thinking, there is also an ecological misallocation when the end usage for energy is incentivized and thus directly prioritized. Hermann et al. reported in 2011:

> Finally, many policies supporting the use of bioenergy explicitly restrict any (financial) benefits to the use of biomass for energy purposes. As energy and materials compete for the same biomass or agricultural land, this puts bio-based materials at a disadvantage. Altogether, these existing policies act as significant barriers to the market penetration of bio-based materials. This may be because they date from a time when bio-based materials were not on the political agenda at all, or may be the result of simply forgetting this area when drafting the policy. Either way, these policies unintentionally but irrefutably penalize the use of biomass for material production. Irrespective of the cause of such disadvantages, it would be crucial to adapt such policies to also encompass material use of biomass.

Additionally, in its existing form, the RED might even be counterproductive for implementing a circular economy in the EU, as indicated by Carus et al. (2016):

> The existing RED framework does not take resource efficiency, cascading use and circular economy into account and an even contradict those concepts through incentives for the energetic use of biomass and especially through

classification of certain biomass types as being waste, when they can in fact be used for other material purposes.

The prospect of allowing material applications into the framework of the RED has been discussed in further detail in a paper by the nova-institute (Carus et al., 2014a). In short, it is argued that changing the RED, either by including material use or by moving the support towards the level of intermediary products, would be a viable solution to remove one of or even the most critical barrier for increased material use of bio-based resources. Underlying the same conditions as energy usage, biomass would no longer be subject to unequal treatment between applications, enabling the material bioeconomy to work and develop under the same certainty that empowered the biofuel sector to grow and flourish in recent years. That said, the ongoing discussions about the RED II revision on European level imply that the focus of the directive will strictly remain on energy applications also from 2020 on.

4.3 Alternatives to improve biomass availability for bio-based products

What alternatives might be available to improve biomass availability for chemical and material use if the RED retains its energy use focus? How can uncertainty in terms of a constant bio-based resource supply be reduced? Based on the developed factsheets, some alternative options will be briefly discussed here:

The removal of quotas in the European agriculture, most recently of the sugar cap within the CAP, has opened the market to global feedstock availability and its prizes. Here, EU producers profit from reduced feedstock costs and for the example sugar beet, likely from an increased availability of sugar. But whether this translates to increased certainty for bio-based products remains to be seen because the additional raw materials could also end up in the bioenergy sector, could be exported overseas or, because of reduced price margins, could lead to sugar companies encountering profitability issues and the overall production might drop after some delay.

Waste streams and residues have a high potential to not only contribute to a reliable biomass supply for bio-based products, but additionally deliver on the Circular Economy targets. The EU intends to actively improve the interface of waste, product and chemical legislation in order to provide more clarity and certainty when and how wastes can be reused to create new products and chemicals. Improvements here can lead to new and formerly untapped resources, but with the introduction of renewable fuels of non-biological origin and a phase out of food and feed biofuels in the RED II, the EU has also introduced incentives for waste-based fuels, which might compete for the same waste streams.

An alternative approach could be taken when considering import tariffs. Following the idea of Cefic as mentioned in chapter 2.7, specific import tax exemptions could be applied to feedstocks exclusively applied to chemical or material utilization. This requires thorough analysis of European and global markets of the specific feedstock and the consequences that might arise due to promoting the use of these feedstocks for chemical or material use in the EU. But, as briefly touched upon in the case of sugarcane, if the EU internal production of a feedstock is in competition with other industries (like bioenergy), such a tax exemption could indeed provide opportunities for both the feedstock producers in the world and the bio-based chemical and material sectors in Europe. The concept seems especially interesting with regards to the petrochemical industry not paying import tariffs in the EU. Here, the implementation of import tariffs fails because of the resistance of the chemical industry, which fears for its international competitiveness and can only imagine taxation of its fossil raw materials under globally accepted rules. In order to increase the amount of bio-based resources in the European organic chemistry, this approach might indeed offer some interesting perspectives and opportunities.

4.4 Systemic approaches to deploy the bioeconomy

While this report has focused on regulatory barriers in relation to specific legislations, for a strategic approach towards future solutions it is important to also consider a more systemic approach. In ensuring that the transition to bioeconomy not only changes the resource base, but also leads to sustainability and a transition towards the circular economy, innovation in a broader sense is of central importance to the bioeconomy (Carus et al., 2014b; Hellsmark et al., 2016).

To achieve this, the current framework needs to be adapted in order to decrease uncertainty, not only from a regulatory point of view, but also when considering public acceptance of bio-based chemicals and materials. A paper by nova-institute (Carus et al., 2015) concluded:

> […] cross-functional cooperation between policy makers is needed in order to obtain a holistic perspective and policy neutrality. The ideal framework would ensure a balance of push and pull mechanisms that are based on long-term goals and allow for the best technology and application to flourish. This would also create a positive image of the bioeconomy, since end consumers and society would be able to benefit from the shift.

In recent years, the importance of the innovation system perspective has been highlighted as a viable approach to understand processes of diffusion and adoption of new technologies. Hekkert et al. (2011) define an innovation system as follows:

> The most important insight that has dominated the field of innovation studies in recent decades is the fact that innovation is a collective activity. It takes place within the context of a wider system. This wider system is coined 'the innovation system' or 'the innovation ecosystem'. The success of innovations is to a large extent determined by how the innovation system is build up and how it functions

It aims to describe actors, institutions, their interactions and their networks involved in developing, adopting and using new technologies and solutions, including companies, universities, government bodies, associations, NGOs and entrepreneurs (Bauer et al., 2017). Many innovation systems are subject to certain flaws that hamper the development and diffusion of innovations. These flaws are often labelled as system failures or system problems. Well-planned innovation policy therefore should evaluate how innovation systems are functioning, try to create insight in the problems of the system and include the results in their policy making. For designing appropriate policies that allow to address regulatory barriers, the innovation systems literature offers deep insights and emphasizes that a comprehensive and well-coordinated policy mix is required to create an innovation system, which is in turn supportive of a socio-technical path change (Gallagher et al., 2012). Even further, the policy mix should not only support innovative technologies but also increase pressure on the existing status quo in order to promote a regime change. Gallagher et al. wrote in their review 2012:

> It [Author's note: Innovation system perspectives] allows one to assess […] systems in a holistic manner, including supply, demand, the stages of the development cycle, feedbacks, processes, actors, institutions, and networks. This systemic approach facilitates new insights that complement and improve upon traditional views and fragmented policy approaches.

Innovation system analysis can be focused on a spatial scale (e.g. national), or alternatively focus on a specific technological change. The purpose of analysing a Technological Innovation System (TIS) is to analyse and evaluate the development of a particular

technological field in terms of the structures and processes that support or hamper it (Hekkert et al., 2011).

A functional innovation system for the bioeconomy should enable emerging bio-based technologies to learn, adapt and eventually reach competitiveness with fossil resource substitutes. Innovation efforts need to be steered towards bioeconomy pathways with favourable environmental characteristics and the innovations need to achieve social acceptance. In this regard, regulations and norms play an important part that control and guide the behaviour of stakeholders on the market and their interactions and thus can directly impact both market push (strengthening supply site) and market pull (strengthening demand site) factors.

Existing research on the relationship between innovation systems, sustainability transitions and policies has been largely focused on energy system transitions, likely due to the political focus on biofuel and bioenergy. But the experiences gained in this fields and in innovations systems research and general can be applied to the bioeconomy as well: Often, innovation systems are suffering under "transformative failure, which means that strategies, technology pushing policies, network support and demand-pull measures are not sufficient for inducing a change, if clear policies towards a phase-out of the dominant regime are missing. Purkus et al. (2017) determined the following policy design implications to address such systemic weaknesses:

- Strategic commitment to a path transition as a prerequisite for credible long-term policies
- Consistent policy mix to support technology-push and demand-pull and create selection environment
- Gradual strengthening of advocacy coalition, to improve political feasibility of transition policies.

While these recommendations were focused on the wood-based bioeconomy in Germany, the implications could be applied in similar fashion to the bioeconomy. Thus, further research and the application of TIS to subparts of the bioeconomy, like the organic chemistry, or the bioeconomy as a whole could help to foster the transition for material applications of biomass as well. The Commission Expert Group on Bio-based Products identified that progress in the development of bio-refineries has been particularly slow, which might hamper the overall development of a bio-based economy within the EU. They state that "whilst actions have been taken at EU level to address the issue of food waste and encourage the cascading use of biomass where appropriate, investment opportunities related to integrated and diversified bio-refineries remain largely untapped. In order to strengthen the regulatory framework for bio-based products and its contribution to an industrial transformation, the strategic approach may need to be adjusted, with more focused and ambitious actions." (EC, 2017b).

The already mentioned literature review by Bauer et al. (2017) focussed on innovation systems research on biorefineries in particular and determined three key conclusions that will be highlighted in the following. First of all, above mentioned funding of R&D alone is not sufficient to facilitate the development of a future sustainable bioeconomy:

> […] it is nonetheless important to stress that there is a consensus in the reviewed literature that research and knowledge are necessary but certainly not sufficient to further biorefining. That is, simply investing more resources in R&D will not help to enable biorefineries to cross the "valley of death" towards greater commercial investments.

Instead, the review highlights the influence that regulation and policy-making played for the adoption of new biofuel and bioenergy technologies and indicates similar possibilities for the bio-based products:

> Visions for biorefinery technologies and products have focused very much on biofuels and bioenergy, which can be seen of course in light of current attention for climate change mitigation. Similarly, legislation and regulation has been instrumental in creating a market for these products. Here we find a very illustrative example of how policy-making has made a substantial contribution in providing conducive conditions for the adoption and diffusion of biorefineries, albeit with a relatively limited scope in terms of products. Whether and how, (climate) regulation and legislation could also provide a similar role for non-energy related products from biorefineries remains to be seen but would provide a highly relevant and important area of future research.

Finally, there is agreement that regulatory issues and barriers are connected to public perception and it is therefore critical to take a combined look at these topics in order to develop solutions:

> […], it should be noted that issues related to regulation for biorefinery products are heavily intertwined with wider discussions around legitimacy and social acceptance. This has already been documented in the case of biofuels and bioenergy. Questions around legitimacy and social acceptance are deeply political and, some would say, politicized and would require greater attention for how societal discourses around biorefineries are shaped by and shaping its further development. Further research on how these visions and discourses are formed and negotiated by different interests and actors to shape the material outcome of biorefinery innovation processes would be valuable to provide insights on the very different futures that biorefineries may shape.

The current document (D2.1) as well as other results of WP2 within the RoadToBio project (more particularly D2.2 – Public perception of bio-based products and D2.3 – Views of societal stakeholders[1]) aim to assess existing regulatory and acceptance barriers that hinder production and market uptake of bio-based chemicals and materials as well as the public perception of bio-based products. Consequently, the results should be helpful not only for developing a roadmap and giving direct recommendations of how to overcome regulatory and acceptance hurdles, but they could also be further input for (also already existing) systemic approaches towards implementing bioeconomy innovation systems and a wider transition strategy.

[1] Deliverable 2.2 and Deliverable 2.3 can be found on www.roadtobio.eu

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